DISSERTATION

PROMOTING THE CONSUMPTION OF BEANS AND OTHER PULSES FOR PUBLIC HEALTH: A TRANSLATIONAL APPROACH TO ADDRESS CONSUMER BARRIERS TO INTAKE

Submitted by

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ABSTRACT

PROMOTING THE CONSUMPTION OF BEANS AND OTHER PULSES FOR PUBLIC HEALTH: A TRANSLATIONAL APPROACH TO ADDRESS CONSUMER BARRIERS TO INTAKE

Beans and other pulses (i.e., the dry, edible seeds of non-oilseed legumes like chickpeas, cowpeas, dry beans, dry peas, and lentils) are linked to a myriad of positive impacts on human and environmental health, including promotion of gut health and healthy weight management, reduction of chronic disease risk, mitigation of greenhouse gas emissions, improvements in soil health, conservation of water resources, and more. Moreover, pulses are highly nutrient-dense, have a long shelf-life, demonstrate wide culinary versatility, and are relatively affordable compared to other foods. Accordingly, pulses offer the chance to consume a healthful diet based on sustainable food choices, all at an economical price point.

Although this combination of positive assets may make pulses seem like a natural choice for consumers to include as a dietary staple, global consumption of pulses has stagnated at around 21 g/day/capita. This research focuses on United States consumers, who eat less than 1 cup of cooked pulses per week, which is below the recommendation. According to the Dietary Guidelines for Americans (DGA), there are only four dietary components of public health concern (i.e., nutrients or other dietary components – like fiber – for which low intakes are associated with health concerns) in the United States. Among these four dietary components of public health concern are dietary fiber and potassium. Pulses are rich in both, thus increasing intake across the population could contribute to raising levels of these critical dietary

components. Although it depends on age group and gender, the levels of pulse intake recommended by the DGA are around 1 – 3 cups per week. Increasing intake to meet this recommendation would help provide adequate levels of dietary components of public health concern. Raising it even further, to around 1 cup per day, has been associated with numerous human health benefits, as discussed in the Introduction.

Reversing the current trend of dramatically low consumption would allow the public to better capitalize on all the benefits that pulses have to offer. To achieve this, it is vital to address the potential barriers to pulse intake that consumers face, paramount among them being unfamiliarity with how to cook and prepare pulses, long cooking times, and concerns over flatulence. Simultaneously, it is key to highlight the many motivating factors to eat pulses, including taste and culinary versatility, nutrition and health, and environmental benefits. Through engaging in a translational approach that addresses barriers and emphasizes motivators, not only is knowledge disseminated, but consumers can be motivated to engage in behavior change and increase their pulse consumption.

This research is comprised of three primary efforts designed to directly target motivators and mitigate barriers to pulse consumption in the United States: 1.) creation of an Extension Bean Toolkit, which includes various consumer resources and an online 1-hour class; 2.) development of the Bean Cuisine and engagement with citizen scientists to improve the cuisine and monitor impacts of participation; and 3.) testing of the effects of elevation and soaking conditions on bean cooking time to address the concern over long cooking times and provide consumers with accessible cooking tips.

Before designing the Extension Bean Toolkit, a Food Habits Survey was conducted to better understand preparation and consumption habits, barriers, motivators, and potential points of consumer interest related to pulses. Based on results and in conjunction with review of the literature, resources were developed for the toolkit, as well as the 1-hour class, titled Beans: Good for You, Good for the Planet. Participation in the class resulted in significant gains in knowledge about pulses, an increase in the importance of motivators, a decrease in how much barriers discourage consumers, and consumption frequency also appeared to increase. See Chapter 2 for details.

The Bean Cuisine is a 2-week cuisine (i.e., meal plan) with 56 pulse-centric recipes that correspond to 14 unique breakfast, lunch, snack, and dinner ideas. The Bean Cuisine was designed to have 35% of dietary protein from pulses, due to recent preclinical findings that suggest this level of consumption is when benefits for gut health and weight maintenance are attained. The main barrier addressed was lack of awareness of how to cook and prepare pulses, and culinary versatility was a main motivator. Fifty-six citizen scientists were recruited and provided feedback on one day (i.e., four recipes) of the Bean Cuisine, and impacts of participation were monitored. The Bean Cuisine was modified based on their feedback to improve the recipes to ensure they were clearly written and the taste would appeal to a wider audience. Participation in the project resulted in significant gains in knowledge about pulse health benefits, versatility, and how to cook dry pulses. Moreover, common themes in free response data demonstrated that citizen scientists had increased awareness of pulse variety and versatility, they changed the frequency of and ways in which they ate pulses, they had a positive experience and thus a good perception of citizen science, and that some became pulse advocates, sharing the benefits of pulses with their communities. More details can be found in Chapter 3.

Not knowing how to cook dry pulses and the long cooking times pose barriers to regular pulse intake. Therefore, to be able to provide consumers with better information regarding the effects of cooking conditions and elevation on cooking time, a Mattson cooker was used to assess the cooking time of pinto beans at four locations, ranging from around sea level to over 3,000 meters. Seven different cooking conditions were evaluated in replicate at each location: an overnight soak or a quick soak in only water or in a 1% solution of sodium chloride or sodium bicarbonate, with a no soak and no salt added comparison. Cooking time increased with elevation, and both the soaking of beans and the addition of salt shortened cooking time. A handout was created to equip consumers with information and practical, accessible tips to facilitate faster, better experiences when cooking dry pulses. Refer to Chapter 4 for details.

Through the Extension Bean Toolkit and Bean Cuisine citizen science work, a translational approach was adopted to reach the public with current research findings that aligned with areas in which they expressed interest. The mitigation of potential barriers to pulse intake and the highlighting of the numerous benefits of pulses was a primary focus in this work. After participating in the Extension class or citizen science project, participants demonstrated greater knowledge about pulses. More importantly, they expressed a greater intention to eat pulses, indicating that participation in these translational projects helped motivate them to change their behavior and regularly integrate more pulses into their diets.

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How do I write an Acknowledgements section that even comes close to doing justice to recognizing all the support I have received along my PhD journey? I feel incredibly blessed to have a strong network of mentors, colleagues, family, and friends, and I cannot thank you all enough.

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CSU Extension: I could not have accomplished this all without you. My sincere thanks for training me on how the Food Safety and Health team conducts outreach (especially Marisa, Jess, and Elisa), letting me stay at your home to test bean cooking times at higher elevation, for including me as part of the Horticulture team and buying me a lovely bean necklace when I had to step down to focus full-time on beans, for inviting me to the County Fair (Bean Dazzle, Alison!), farmers' market, and other offices and research centers to talk about beans, for welcoming me at Food Systems meetings and events, for helping me spread the word about surveys, classes, and the Bean Cuisine citizen science project, and for all the other things in between, be they big or small.

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If I omitted your name, please know it was not intentional and feel my warm gratitude. Cheers to the next chapter of life, and may it be full of beans!

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CHAPTER 1: BACKGROUND

Summary

Pulses – the dry, edible seeds of non-oilseed legumes, such as chickpeas, dry beans, dry peas, and lentils – are well-known for the many benefits they can offer for human and environmental health. A highly nutrient-dense food, they contain almost no fat and are an excellent source of dietary fiber and rich in protein and various micronutrients, including potassium, iron, and B vitamins like folate. Consumption of pulses is associated with promotion of gut health and healthy weight maintenance, as well as a reduction in the risk of several chronic diseases, such as type 2 diabetes, cardiovascular disease, and certain types of cancer like colorectal cancer. In addition to these benefits for public health, the environmental benefits of pulses are numerous, as they can help reduce greenhouse gas emissions, improve soil health, and conserve land and water resources. Importantly, pulses are relatively affordable, meaning that these benefits are available at an economical price point. Nonetheless, U.S. pulse consumption has declined in recent decades, and this important food crop is dramatically under-consumed in many countries around the world. The question, then, is why? Research demonstrates that although there are many factors that can motivate pulse intake, there are also several key barriers to high consumption. Barriers vary among different groups, but main barriers include unfamiliarity about how to prepare pulses, unawareness of their versatility, concerns over flatulence, and long cooking times. To allow for capitalization upon the many advantages that pulses have to offer, it is important to understand the motivators and barriers that consumers face. A translational approach that emphasizes positive aspects of pulses and integrates evidence-based information to mitigate barriers is one way to empower consumers with the information, motivation, and

behavioral skills to eat pulses more regularly. Helping motivate consumers to routinize pulse consumption is a critical step in reversing the trend of low intake and allowing people to enjoy the many public and environmental health wins associated with eating pulses.

1. What Are Pulses?

The words legume, pulse, and bean are sometimes used interchangeably, but they have distinct meanings. Fabaceae (Leguminosae) is the overarching botanical family and includes crops such as oilseed legumes (i.e., legumes with a high fat content that are often harvested for their oil, like soy and peanut), forage legumes, vegetable legumes, and pulses, i.e., the dry, edible seeds of non-oilseed legumes [1]. The Food and Agriculture Organization of the United Nations (FAO) clarifies that pulses are harvested only for dry grain and therefore do not include crops that are harvested green, which would be considered vegetable crops. Eleven types of pulses are recognized by FAO, including broad beans, chickpeas, cowpeas, dry beans, dry peas, pigeon peas, lentils, and several others [2]. Thus, beans are a type of pulse, and both beans and pulses are legumes. Figure 1.1 shows the major types of legumes that are commonly produced and consumed and delineates the relationship between legumes, pulses, and beans [1].

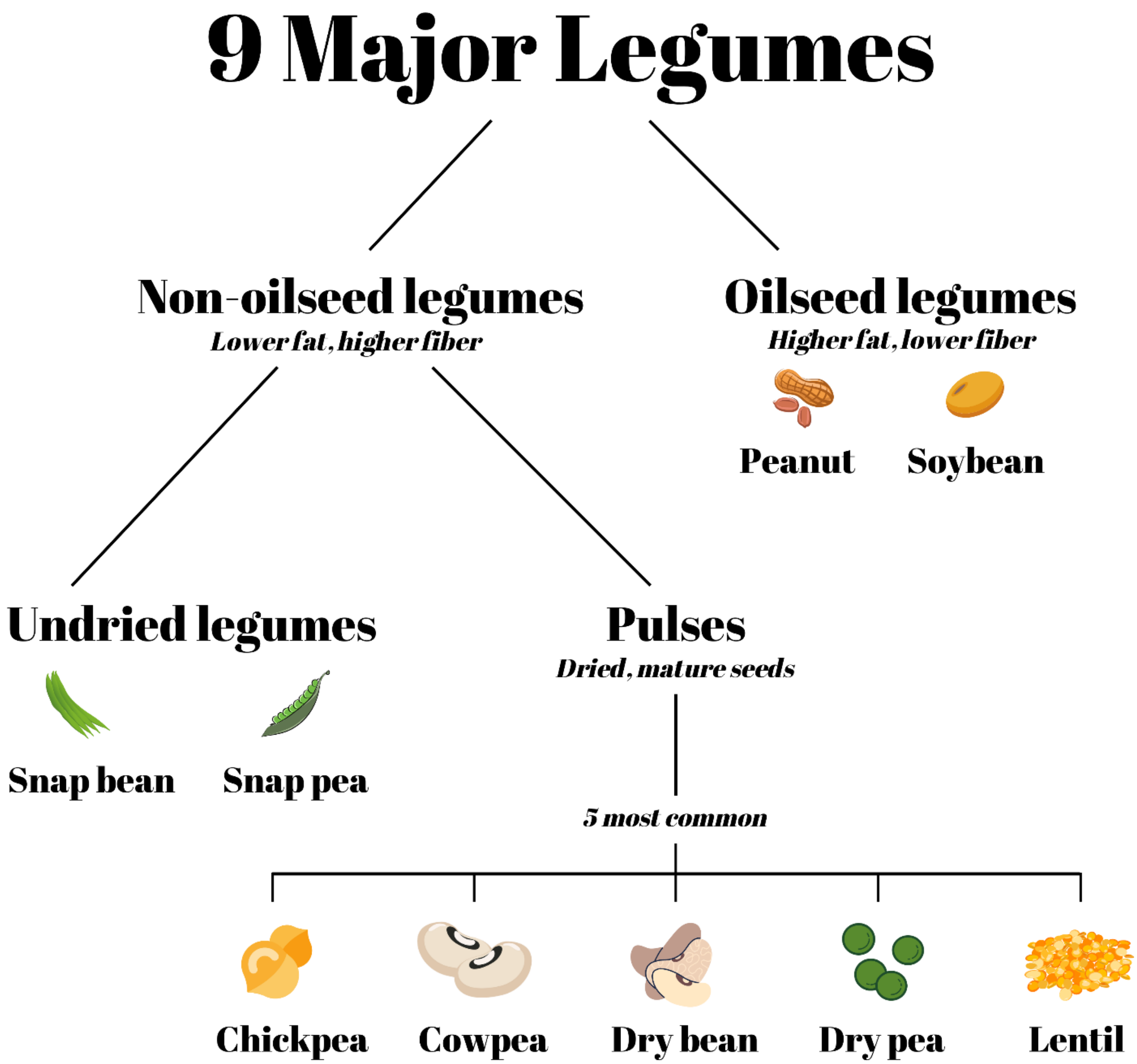

Figure 1.1.[1] Commonly consumed types of legumes. After separating legumes into oilseed and non-oilseed legumes, non-oilseed legumes can be further divided into two categories: undried legumes and pulses. Pulses are the dried, edible seeds of grain legumes that are then cooked before being consumed.

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[1]This figure has already been published with the journal MDPI Nutrients and can be found online at: https://www.mdpi.com/2072-6643/13/4/1100. Citation information is as follows: Didinger, C.; Thompson, H.J. Defining nutritional and functional niches of legumes: A call for clarity to distinguish a future role for pulses in the dietary guidelines for Americans. *Nutrients* **2021**, *13*, 1100.

2. Nutritional and Human Health Benefits of Pulses[2]

Unhealthy diet increases the risk of chronic diseases, which cause nearly three-quarters of all deaths globally [3,4]. Risk factors for chronic disease – like elevated blood pressure, hyperglycemia, overweight, and obesity – can be attenuated through proper nutrition, thus the adoption of a healthy diet is one of the main ways to reduce chronic disease risk [4]. Not only does chronic disease negatively impact human health, but there are serious economic repercussions. For example, the treatment of chronic disease cost the United States $1.1 trillion in 2016, or around 6% of Gross Domestic Product (GDP) [5]. To improve human well-being and minimize the economic costs of chronic disease, primary prevention (i.e., preventing people from becoming sick in the first place) is critical. At the heart of primary prevention are cost-effective, sustainable approaches, such as following a healthy diet based on nutrient-dense foods [6]. Beans and other pulses are exactly such a food, enabling people to meet nutrition recommendations without overconsuming calories.

2.1 Pulse Nutrition

Pulses are very low in fat but high in a wide variety of nutrients, including protein and micronutrients like potassium, iron, and B vitamins like folate [1,7-9]. Moreover, they are one of the richest natural sources of dietary fiber. Fiber is under-consumed in many parts of the world,

[2]For more details on nutritional and human health benefits of pulses, please refer to the following publications: 1.) Didinger, C.; Thompson, H.J. The role of pulses in improving human health: A review. *Legume Sci.* **2022**, *4*, e147.; 2.) Didinger, C.; Thompson, H.J. Defining nutritional and functional niches of legumes: A call for clarity to distinguish a future role for pulses in the dietary guidelines for Americans. *Nutrients* **2021**, *13*, 1100.; and 3.) Didinger, C.; Foster, M.T.; Bunning, M.; Thompson, H.J. Nutrition and human health benefits of dry beans and other pulses. In *Dry Beans and Pulses: Production, Processing, and Nutrition*; Wiley: Hoboken, NJ, USA, 2022; pp. 481–504.

resulting in a "dietary fiber gap," or the stark difference between recommended intake and actual consumption [10]. Over 90% of women and 97% of men in the United States do not meet recommended dietary fiber intakes, according to the most recent Dietary Guidelines for Americans (DGA), where adequate intake is defined as 14 grams of fiber per 1,000 calories consumed [11]. The DGA 2020-2025 further specify four "dietary components of public health concern" because their low intakes are associated with health concerns: calcium, vitamin D, potassium, and dietary fiber [11]. Pulses are high in both potassium and dietary fiber while being nutrient-dense (i.e., helping attain nutritional recommendations without excessive calories) and providing many beneficial nutritional aspects (see Figure 1.2). Thus, increasing the amount of pulses in the diet is one practical approach to address this public health concern.

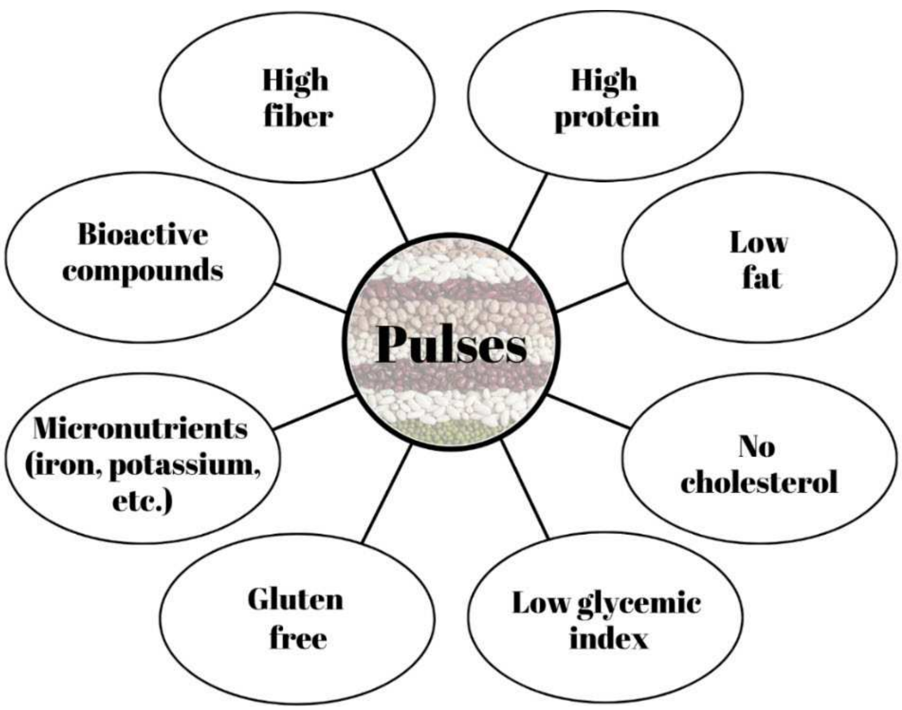


Figure 1.2.[3] Nutritional and health benefits of pulses.

[3]This figure has already been published with the journal Legume Science and can be found online at: https://onlinelibrary.wiley.com/doi/full/10.1002/leg3.147. Citation information is as follows: Didinger, C.; Thompson, H.J. The role of pulses in improving human health: A review. *Legume Sci.* **2022**, *4*, e147.

Comparing 100-kilocalorie portions is one way to compare foods and examine nutrient density, because it shows the amount of nutrition available in the same caloric amount across foods [1]. As demonstrated in Table 1.1, pulses have a unique nutritional profile that is different from other legumes (e.g., oilseed legumes like soy and peanuts) and from grains. When compared to oilseed legumes, pulses have a lower fat content and much more fiber. Whereas dry bean has nearly 7 g of fiber in a 100-kcal portion, the same caloric amount of peanuts has under 2 g and soybean under 4 g. Importantly, pulses are fiber-rich while also being high in protein, providing an approximate one-to-one ratio of fiber and protein. As is evident in the table, pulses contain more fiber than whole grains. In fact, even though a primary recommendation to increase fiber intake is to replace refined grains with whole grains, pulses are about two to three times richer in dietary fiber than are whole grains [12], with this difference being even more pronounced when compared to refined grains. Pulses also contain about double the amount of protein as grains, even when compared to grains that consumers tend to think of as being rich in protein, like quinoa. Fiber and protein are both thought to help improve satiety and weight management [13-15], thus pulses being high in both may help promote a healthy body weight.

Pulses are so nutrient-dense and nutritionally unique that – unlike other foods – they are included in two food groups in the DGA: the protein food group and “beans, peas, lentils” vegetable subgroup [11]. While high in fiber and several vitamins and minerals like vegetables, they are also rich in protein, like other protein foods (e.g., meat, fish, tofu). Yet, when compared to other items in the protein foods group, it is clear that they are also distinct, as shown in Table 1.2. While meat contains no fiber by definition, pulses are high in both protein and fiber. Also, many animal protein-based foods contain fat and cholesterol, but pulses are naturally cholesterol free and contain almost no fat.

Table 1.1.[4] Nutritional analysis of 100-kilocalorie portions of representative pulses, oilseed legumes, and grains.

	Chickpea (~1/3 cup)	**Cowpea** (~1/2 cup)	**Dry bean** (~1/2−1/3 cup)	**Dry pea** (~1/2 cup)	**Lentil** (~1/2 cup)	**Peanut** (~2 Tbs)	**Soybean** (~1/3 cup)	**Rice, brown** (~2/5 cup)	**Rice, white** (~1/2 cup)	**Quinoa** (~1/2 cup)
Protein (g)	5.4	6.7	6.7	7.2	7.8	4.6	10.6	2.2	2.1	3.7
Total lipid (g)	1.6	0.5	0.4	0.3	0.3	8.7	5.2	0.8	0.2	1.6
Carbohydrate (g)	16.7	17.9	18.0	17.7	17.4	2.8	4.9	20.0	21.7	17.8
Dietary fiber (g)	4.6	5.6	6.6	7.2	6.8	1.5	3.5	1.3	0.3	2.3
Folate (µg)	104.9	179.3	112.9	56.0	156.0	42.3	31.4	7.4	45.0	35.0
Iron (mg)	1.8	2.2	1.6	1.1	2.9	0.8	3.0	0.5	0.9	1.2
Potassium (mg)	177.4	239.7	268.9	312.1	318.1	124.3	299.4	70.5	27.1	143.3
FDC[a] ID	173757	175252	173735	175257	172421	1100536	174299	1101631	1101625	168917

[a]FoodData Central, United States Department of Agriculture (USDA) (https://fdc.nal.usda.gov/). The nutrition information for 100-kcal portions are provided and FDC ID numbers are listed in the table. Dietary fiber is classified as a dietary component of public health concern by USDA, and dramatic fiber differences are evident between pulses, oilseed legumes, and grains. All pulses, soybean, and grains were boiled and peanut is unroasted.

[4]This table has already been published with the journal Legume Science and can be found online at: https://onlinelibrary.wiley.com/doi/full/10.1002/leg3.147. Citation information is as follows: Didinger, C.; Thompson, H.J. The role of pulses in improving human health: A review. *Legume Sci.* **2022**, *4*, e147.

Table 1.2.[5] Nutritional analysis of 100 kilocalorie portions of dry bean versus other protein foods.

	Dry Bean	Chicken Breast, Skin not Eaten	80/20 Ground Beef	Hard-Boiled Egg	Salmon	Almonds, Unroasted	Tofu
Approximate Amount	~1/2–1/3 cup	~2–oz.	~1.3–oz.	~1.25 eggs	~2–oz.	~2 Tbs	~3.5–oz.
Protein (g)	6.7	16.8	8.1	8.1	16.1	3.7	10.0
Total Lipid (g)	0.4	3.1	5.6	6.8	3.5	8.6	5.6
Carbohydrate (g)	18.0	0.0	0.0	0.7	0.1	3.7	2.5
Dietary Fiber (g)	6.6	0.0	0.0	0.0	0.0	2.2	2.6
Folate (µg)	112.9	4.0	3.1	28.4	3.1	7.6	MV
Iron (mg)	1.6	0.3	0.8	0.8	0.3	0.6	1.8
Potassium (mg)	268.9	200.0	95.6	81.3	288.8	126.6	156.4
Calcium (mg)	20.5	4.0	7.6	32.3	5.6	46.5	187.2
Choline (mg)	24.7	43.0	25.4	189.7	74.5	9.0	MV
Magnesium (mg)	53.0	15.9	6.3	6.5	21.3	46.6	MV
Vitamin A, RAE (µg)	0.0	5.1	0.9	96.1	25.0	0.0	0.0
Vitamin C (mg)	0.0	0.0	0.0	0.0	0.3	0.0	0.0
Vitamin E (mg)	0.7	0.6	0.0	0.7	0.3	4.4	MV
FDC ID	173735	1098457	171797	173424	1098965	1100508	1219633

All subgroups of protein foods in the DGA are represented: (1) beans, peas, lentils by cooked dry bean; (2) meats, poultry, eggs by chicken breast, ground beef, and hard-boiled eggs; (3) seafood by salmon; and (4) nuts, seeds, soy products by almonds and tofu. No fat (e.g., oil) was added when preparing these foods. Information from USDA FDC [16].

[5]This table has already been published with the journal MDPI Nutrients and can be found online at: https://www.mdpi.com/2072-6643/13/4/1100. Citation information is as follows: Didinger, C.; Thompson, H.J. Defining nutritional and functional niches of legumes: A call for clarity to distinguish a future role for pulses in the dietary guidelines for Americans. *Nutrients* **2021**, *13*, 1100.

Pulses are composed of approximately 16-30% protein content [7,17]. However, some consumers express concerns about lower protein quality in pulses. Although true that pulses may be considered an "incomplete protein," there is a need to re-examine this narrative in much of the world [18]. By definition, a complete protein contains adequate amounts of all nine of the essential or indispensable amino acids, i.e., the amino acids that the body cannot synthesize. Pulses are low in the essential amino acid methionine, and sometimes tryptophan [7,19]. It is important to note that plant foods do contain all amino acids, they simply contain some of them in limiting amounts [18], as is the case for methionine levels in pulses. Hence, eating a well-balanced diet allows for protein complementation, even if animal proteins are not included in the diet. For instance, grains like rice and millet are high in methionine but low in lysine – of which pulses contain adequate amounts [20]. Therefore, eating these foods together ensures that people are provided the necessary amounts of all the amino acids. Notably, these foods do not have to be eaten in the same meal to attain the benefits; rather, people should consume a varied diet throughout the day and week [21]. Especially considering that populations in many countries, like the United States, consume much higher amounts of protein than are necessary, it is important to emphasize nutrient-dense, environmentally friendly sources of protein to better promote more sustainable, health-promoting food systems [18].

2.2 Human Health Benefits of Pulses

Likely due to their unique, nutrient-dense profile and bioactive compounds [1,6], pulses are associated with a wide array of benefits for human health. Studies demonstrate that regular inclusion of pulses in the diet could also result in significant health care cost savings [22,23]. Although it is important to address weaknesses in the scientific literature – such as limited sample sizes and heterogeneity among trials that culminate in low quality of evidence – the overall body of literature supports that including more pulses in the diet could be a practical way to help combat the obesity epidemic and prevent various types of chronic disease [6,24].

2.2.1 Pulses and Healthy Body Weight Management

An elevated body mass index (BMI) is a major risk factor for a host of chronic diseases, including type 2 diabetes, cardiovascular diseases, and several types of cancer [3]. An imbalance of energy, or consumption of more calories than the body expends, can result in overweight (i.e., BMI ≥ 25 kg/m^2) and obesity (i.e., BMI ≥ 30). Despite the risks associated with overweight and obesity, rates are on the rise, with 39% of adults in 2016 overweight and 13% obese [3]. Healthy lifestyle choices – paramount among which is following a healthful dietary pattern – play a key role in maintaining a healthy body weight. Increasing nutrient-dense, fiber-rich foods like pulses has great potential to be a part of the solution to reversing and preventing overweight and obesity.

Pulses are purported to play a role in several factors impacting BMI, such as satiety, moderation of food intake, and healthy body weight management [14,15,25]. For instance, a 2014 meta-analysis (9 studies, $n = 126$ participants) evaluated the effects of pulses on satiety and food intake [26]. The investigators found that pulses resulted in greater satiety but also noted that subsequent meal intake did not appear to be affected [26], although this could be attributed to challenges such as limited sample size. A more recent meta-analysis on randomized controlled trials ($n = 940$ participants, median diet duration = 6 weeks) was published in 2016 and examined the effects of pulses on body weight [27]. Researchers showed a weight reduction of 0.34 kg (95% confidence interval [CI] -0.63 to -0.04 kg; $p = 0.03$) associated with the diets including pulses (median intake of 132 g/day or approximately 1 serving/day) versus the comparator, pulse-free diets [27]. An important point in the study was that weight loss was seen not only in weight loss diets, but also in neutral-energy-balance diets that had been intended for weight maintenance. This highlights the potential for regular pulse intake to promote weight loss even without strict adherence to a calorie-restrictive diet [27]. However, further research is necessary, as the effect size is minimal and longer-term weight loss was not evaluated.

Several attributes of pulses could contribute to healthy weight management. Pulses have a low glycemic index (GI), and the consumption of low-GI diets has been associated with promoting lower body weights, partially through more controlled, consistent levels of glucose and insulin levels over time [28]. Moreover, higher protein and fiber intakes have been associated with greater satiation and less hunger [13], and pulses are rich in both of these dietary components. A pilot study on individuals with metabolic syndrome showed that whole beans as a source of intrinsic fiber resulted in higher postprandial levels of a hormone associated with satiety, cholecystokinin (CCK), than a control meal with no fiber and the added or extrinsic fiber meal [29]. This highlights that fiber in the form of pulses may have stronger effects on satiety than fiber supplements.

The most recent, robust report released by the World Cancer Research Fund/American Institute for Cancer Research (WCRF/AICR) concluded that consumption of fiber-rich foods protects against weight gain, overweight, and obesity, and it recommends consuming at least 30 grams of dietary fiber per day [30]. One way to attain this fiber recommendation and the recommended intake of other key nutrients without overconsuming calories is to choose fiber-rich, nutrient-dense foods like pulses. Thus, regular pulse intake may be a cost-effective, practical approach to achieve a healthy body weight.

2.2.2 Pulses and Chronic Disease Risk Reduction: Type 2 Diabetes

Diabetes incidence is increasing around the globe in both adults and children, with type 2 diabetes accounting for over 95% of diabetes cases [31]. A healthy diet and maintaining a normal body weight are ways to prevent type 2 diabetes (T2D), a condition in which there is insulin resistance [31]. Pulses can play a role in helping achieve this.

One prospective study found that those in the highest quartile of total legume and lentil consumption had a lower risk for diabetes (hazard ratio [HR] = 0.65, 95% CI 0.43-0.96; and HR = 0.67, 95% CI 0.46-0.98, respectively) [32]. Chickpeas also showed an inverse relationship, but it only bordered on significance (HR = 0.68; 95% CI 0.46-1.00) [32]. Furthermore, substituting one half-serving of legumes per day for similar servings of other protein- or carbohydrate-rich foods (i.e., eggs, bread, baked potato, or rice) was associated with a reduced risk of diabetes incidence [32]. However, a subsequent meta-analysis found no association of pulse intake and diabetes incidence, although the overall certainty of the evidence was rated as very low [33]. One potential reason for failing to find significant associations is the tendency to combine all legumes when doing an analysis rather than separating out pulses, as was the case in a recent meta-analysis that failed to find a significant association between total legume intake and T2D [34]. Making the distinction between pulses and non-pulse legumes is important because the different types of legumes could have discrepant impacts on T2D.

The high-fiber and low-GI nature of pulses could also contribute to helping manage or prevent diabetes [35,36]. For example, a dose-response analysis of 17 prospective cohort studies revealed a lower risk for T2D when individuals achieved a total daily dietary fiber intake of 25 grams or more, resulting in a combined relative risk (RR) of 0.81 (95% CI 0.73-0.90) [37]. Furthermore, an umbrella review of 16 meta-analyses found that the highest fiber intake had a reduced risk for T2D compared to the lowest fiber intake (RR = 0.81-0.85) [38]. Moreover, low-GI diets may be useful for improved glycemic control [28]. A study on the effect of legumes as part of a low-GI diet showed that participants with T2D who were randomized to the low-GI legume diet experienced greater reductions in glycated hemoglobin, or HbA_{1C} (i.e., a glycated protein that reflects a person's level of glucose control, where higher test levels can reflect diabetes), than the high wheat fiber diet [39]. Although there is some conflicting evidence on the exact impact of pulse intake on T2D, the overall evidence combined with the fact that pulses are a high-fiber, low-GI food suggests they can play a role in promoting glycemic control, avoiding complications in individuals with insulin resistance or diabetes, and helping prevent T2D.

2.2.3 Pulses and Chronic Disease Risk Reduction: Cardiovascular Disease

Cardiovascular diseases (CVDs) are the number one cause of death globally, with unhealthy diet and obesity being major behavioral risk factors for CVDs [40]. Thus, adopting healthy dietary patterns that also support a healthy body weight is pivotal to remediating CVD incidence and mortality.

Pulse intake appears to lower total and low-density lipoprotein (LDL) cholesterol and other CVD biomarkers [41] and may contribute to the prevention of CVDs [42,43]. Epidemiological and clinical studies support a relationship between high serum total cholesterol and LDL cholesterol levels and CVD, so reductions in these numbers can have a positive effect on reducing the risk for CVDs [6,44,45]. One study found that consuming one serving of beans per day associated with a 38% reduced risk (odds ratio [OR] = 0.62, 95% CI 0.45-0.88; $p < 0.05$) of myocardial infarction versus individuals who rarely ate beans [46]. Another study in hypercholesterolemic individuals found that daily consumption of a half cup of beans over an 8-week dietary intervention resulted in a reduction in serum total cholesterol and LDL cholesterol

[47]. More recently, a randomized crossover study in adults with elevated LDL cholesterol had participants eat either white rice or canned beans (a daily rotation of several varieties: black, navy, pinto, dark red kidney, and white kidney) daily [48]. Results showed that when individuals ate 1 cup of canned beans every day, they experienced decreases in total and LDL cholesterol, but these benefits were not seen when eating white rice [48]. Other studies also support these findings, with bean diets reducing serum total cholesterol and LDL cholesterol in individuals consuming beans versus control study participants [49,50].

Several studies that examined the effects of legume consumption (not only pulse) have also found that legumes are associated with a reduced risk for CVDs. For example, when compared with the lowest quartile of legume intake, the highest quartile had a reduced risk of CVD mortality (RR = 0.72, 95% CI 0.60-0.88) [51]. Also, data from the National Health and Nutrition Examination Survey (NHANES) revealed a strong inverse relationship between legume intake and the risk of CVD, with consuming legumes at least four times a week being associated with an 11% lower risk for CVD (RR = 0.89, 95% CI 0.80-0.98) than when eating legumes less than once per week [52].

A meta-analysis on ten randomized controlled studies evaluating the effects of pulses on blood lipids found a reduction in cholesterol and LDL cholesterol levels [53]. A more recent meta-analysis found that – although the current evidence supports that pulses are associated with lower CVD incidence – the overall certainty of the evidence is low [54]. Again, this underscores the need for more robust clinical studies. However, overall research supports that regularly including pulses may be a smart dietary strategy to help prevent CVDs [55].

2.2.4 Pulses and Chronic Disease Risk Reduction: Cancer

The World Cancer Research Fund and American Institute for Cancer Research (WCRF/AICR) evaluated a range of research on cancer prevention and survival, ultimately distilling a few key recommendations based on what was rated as strong evidence [30]. One of the primary recommendations was to eat a diet rich in whole grains, vegetables, fruit, and pulses, and they recommend getting at least 30 grams of dietary fiber per day. In the outlined dietary goals, the WCRF/AICR specifically recommends pulses, stating, "include foods containing wholegrains, non-starchy vegetables, fruit and pulses (legumes) such as beans and lentils in most meals" and "if you eat starchy roots and tubers as staple foods, eat non-starchy vegetables, fruit and pulses (legumes) regularly too if possible" [56]. Yet, it should be acknowledged that the 2018 WCRF/AICR report classified the impact of legumes on the risk for breast, colorectal, and prostate cancers as "limited – no conclusion" [30].

There is a strong linkage between cancer and aging [57,58]. Interestingly, in a study that examined food intake patterns of people 70 years and older, legume intake was the only statistically significant and consistent indicator of longevity [59]. Each 20-gram per day increase in legume consumption showed a 7 to 8% reduction in the mortality hazard ratio [59]. The risk reduction could partially be due to protection from chronic diseases like cancer. This – combined with the WCRF/AICR report's emphasis on high-fiber foods like pulses – highlights the role that pulses can play in a healthful dietary pattern that may help prevent cancer.

Evidence ties consuming pulses to cancer risk reduction [60], potentially through an ability for compounds in pulses to induce apoptosis in cancerous cells and inhibit pathways that are related to aging and the development of cancer [61]. Indeed, in a recent prospective study, those who consume higher amounts of total legumes and lentils were found to have a reduced risk of cancer mortality [62].

Research has examined the potential effects of pulse intake on several types of cancer, including breast, prostate, and colorectal. Quality of the evidence is sometimes low, which could be due to several key challenges faced in nutritional studies and also on studies specifically relating to the impacts of pulses, such as small sample sizes and a paucity of research that specifically examines pulses instead of combining them with other legumes or food patterns, which could result in confounding factors [6,24]. The WCRF/AICR report found strong evidence that eating fiber-rich foods protects against colorectal cancer [30]. One could naturally expect that one of the richest natural sources of dietary fiber – pulses – would show a similar quality of evidence. Although this reveals that further research is still needed, emerging evidence does suggest that pulses may help reduce cancer risk [6]. A summary of evidence is shown in Table 1.3.

Table 1.3.[6] Legume intake and cancer risk.

Cancer Type	Evidence of Prevention (Human Studies)	No Association (Human Studies)	Preclinical Support
Breast	• 24% reduction in breast cancer risk in women 26- 46 years consuming beans or lentils >2x/week compared to <1x/month [63] • 21% reduction in risk in breast cancer among underweight to normal weight postmenopausal women consuming more beans and legumes [64] • Traditional Mexican dietary patterns high in foods such as legumes were associated with lower risk of breast cancer in the Four-Corners Breast Cancer Study [65]	• No association between overall breast cancer risk and bean/legume intake in postmenopausal women participating in the original Nurses' Health Study [66]	• Bean intake can decrease breast cancer risk [67-69] • Beans in the diet reduced cancer incidence from 95% to 67%, and the number of tumors per animal from 3.23 to 1.46, versus the control [69]
Colorectal	• 65% reduced risk of advanced adenoma recurrence reported in individuals in the highest quartile of dry bean intake versus the lowest quartile in the Polyp Prevention Trial [70] (***but see comment under 'No Association'*) • In the Nurses' Health Study, women consuming ≥4 servings of legumes per week had a 33% lower incidence of colorectal adenomas than those consuming less than one serving per week [71]	• **However, there was no further effect of beans on recurrence of non-advanced adenomas in the Polyp Prevention Trial [70]	• Compared to control-fed animals, the investigators reported lower incidence of colon lesions in mice fed whole bean, bean residue, and bean extract [72] • The incidence of tumors in rats with chemically-indued colon cancer was reduced in animals fed bean-based diets compared to control animals [73,74]

[6]This table has already been published with the journal Legume Science and can be found online at: https://onlinelibrary.wiley.com/doi/full/10.1002/leg3.147. Citation information is as follows: Didinger, C.; Thompson, H.J. The role of pulses in improving human health: A review. *Legume Sci.* **2022**, *4*, e147.

Table 1.3. Legume intake and cancer risk *(cont.)*.

Cancer Type	Evidence of Prevention (Human Studies)	No Association (Human Studies)	Preclinical Support
Colorectal *(cont.)*	• Meta-analyses have found a decreased risk of colorectal adenoma for the highest versus lowest intake of legumes [75], and that dietary legume consumption decreased risk of colorectal cancer [76]		
Prostate	• 10% reduction in risk of prostate cancer in men consuming the highest amount of legumes (excluding soybeans and soybean products) compared with the lowest consumers [77] • High legume intake correlates with lower prostate cancer incidence, and the dose-response meta-analysis indicated that for each 20 g/day increase in legume intake there was a reduction in the risk of prostate cancer by 3.7% [78]	No association between dry bean consumption and prostate cancer risk [79], nor legume intake and mortality from prostate cancer [80]	

The literature is too narrow to focus on only pulses, thus studies in this table address legume intake and cancer risk. They do not include studies that examine associations between cancer and fiber intake, a vegetarian diet, or other factors that are not legume-specific. For more details on the findings of this research, please refer to [6].

2.2.5 Pulses Promote Gut Health

Recent research suggests that diet, obesity, and chronic diseases are linked by the gut microbiome [81] and that changes or disturbances to gut microbiota composition are linked to numerous health concerns, such as diabetes, certain cancers, and obesity [82]. Whereas refined, processed foods can harm gut health, the consumption of whole foods is associated with a healthy gut microbiome and low levels of diet-related disease [83]. Fiber-rich foods provide important energy sources for microbiota residing in the cecum and colon, and low intake of dietary fibers can contribute to depletion of specific gut microbes [84]. Accordingly, pulses – as one of the richest natural sources of fiber – may be highly beneficial for gut health.

Dietary fiber cannot be hydrolyzed by the gastrointestinal enzymes of humans, and most soluble fiber is instead fermented by gut microbes, resulting in the production of metabolites like short-chain fatty acids (SCFAs) [84,85]. In turn, these SCFAs have been associated with numerous health benefits, such as improved glucose homeostasis and strengthened gut barrier function [85,86]. Furthermore, the resistant starch in pulses can act as a prebiotic ingredient and support growth of beneficial bacteria [87]. Other compounds, such as resistant proteins, may also play a role [88].

Several studies in humans suggest a link between pulses and gut health, and research is rapidly emerging. One study found that supplementing the diet with chickpea appeared to modulate the intestinal microbial composition to promote intestinal health, for instance by reducing the number of individuals showing high amounts of bacteria groups that include pathogenic bacteria [89]. Another study ($n = 82$) investigated the relationship between sex, BMI, and fiber on the composition of the gut microbiome and found a strong association for fiber from beans and gut microbiome composition in men, although the relationship was only marginal ($p =$

0.06) when men and women were combined [90]. Moreover, factors such as the type of legume and processing method (e.g., pressure cooking, a combination of germination and cooking) can also result in different impacts on gut microbiota [91]. Taken together, this demonstrates the need to better understand these complex relationships, and more extensive clinical studies linking the effects of pulses on the gut microbiome and the resulting health outcomes for the host are still needed [92].

There is also preclinical support for the effects of pulses on health impacts, such as attenuation of the severity of the obese phenotype (e.g., reduced insulin resistance and improvements in the leptin:adiponectin ratio) [93] and improvements in glucose tolerance [94]. Due to the large number of preclinical studies that suggest positive effects of pulses on gut health [95-97] and the fact that pulses are rich in dietary fibers, it is reasonable that the inclusion of pulses in the diet could support gut health.

3. Environmental Benefits of Pulses

Not only do pulses promote human health benefits, but they can advance sustainable dietary patterns. For example, pulses play a prominent role in the EAT-Lancet Commission's universal healthy reference diet, which was specifically designed to promote both human and environmental health. This diet recommends including 50 grams of dry beans and other pulses (which cooks up into around 100 grams) daily, or the equivalent of about 170 calories [98]. Certainly, pulses are known for providing a myriad of environmental benefits, including being climate-friendly and reducing greenhouse gas (GHG) emissions, improving soil health, conserving water and improving water quality, and helping reduce the amount of land required to produce food [99-101]. With environmentally sustainable food consumption an increasingly pressing topic and many consumers already demonstrating favorable attitudes about sustainable food choices [102], it is important to make sure that consumers are aware of the benefits of pulses to best take advantage of how regularly eating this food can benefit planetary well-being.

3.1 Pulses Can Reduce Greenhouse Gas Emissions

Pulses can play a role in climate change mitigation in several ways, such as requiring less fertilizer, helping reduce food waste and associated GHG emissions, and resulting in lower emissions than many other protein sources [99,101], as shown in Figure 1.3. As clearly demonstrated, production of pulses generates much less GHG emissions than do animal proteins, especially when compared to ruminant (e.g., beef, mutton, lamb) meat [103,104].

As shown in Figure 1.3 and corroborated by other studies, shifting towards more plant-based diets that include pulses could play a role in reducing GHG emissions [98,103,104]. For example, it has been found that substituting beef with beans in the United States could help achieve about 46 to 74% of the reductions needed to meet the country's 2020 GHG target [105]. Of course, location and production practices affect the overall environmental impact, but studies have found that ruminant meat can have about 150 times higher of a carbon footprint than do pulses [106], or even 250 times the emissions per gram of protein than legumes [107].

Food loss and waste at the supply chain and consumer levels contribute around 6% of total global emissions [108]. However, pulses have a long shelf-life and store well in various forms, such as dry, canned, and frozen, helping reduce food waste. Indeed, reductions in food loss and waste have been found to decrease GHG and water usage, in addition to helping fight malnourishment in developing regions [109]. Moreover, the ability of pulses to be stored dry can help minimize the large energy requirements that are associated with cold chain logistics [110].

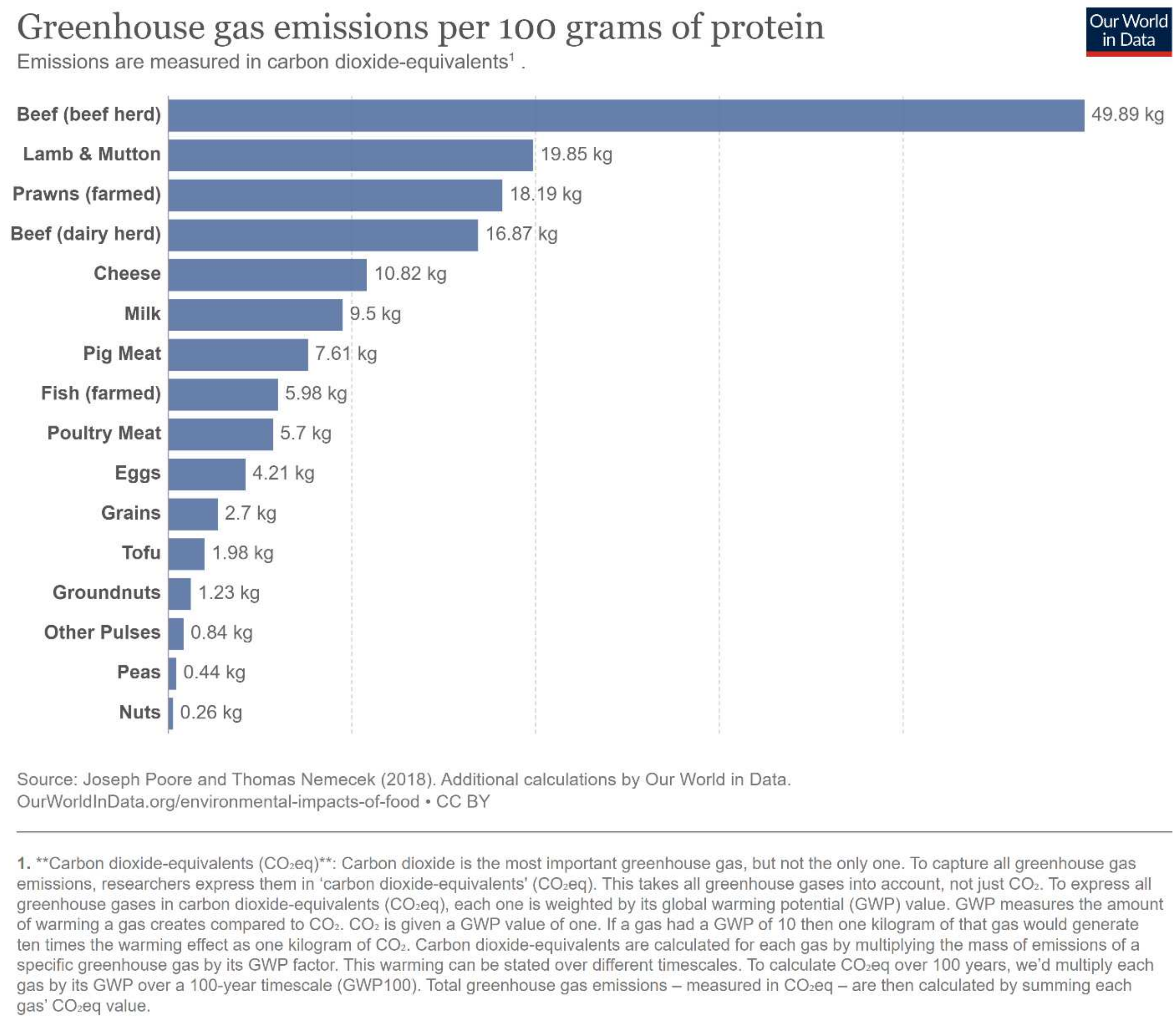


Figure 1.3. Greenhouse gas emissions per 100 grams of protein. Image source: https://ourworldindata.org/grapher/ghg-per-protein-poore [103].

Another way in which pulses help reduce GHG emissions is through their ability to fix nitrogen, thereby decreasing the need for synthetic fertilizers and helping save farmers money on inputs [101]. The production of synthetic nitrogen fertilizers results in emissions, with the nitrogen fertilizer supply chain being found responsible for nearly 11% of agricultural emissions and 2.1% of global GHG emissions [111]. Almost 40% of these impacts from the nitrogen fertilizer supply chain were due to the production of fertilizer and another 59% came from field emissions [111]. Once in the field, nitrogen can be lost through leaching, gaseous emissions, runoff, and erosion, exacerbating not only climate change but also problems such as reduced water quality and loss of biodiversity through eutrophication [112]. However, legumes like beans and other pulses have a unique ability to fix atmospheric nitrogen through a symbiotic relationship with nitrogen-fixing bacteria called rhizobia [99,101], thereby reducing the need for the manufacture and application of synthetic fertilizers. Studies suggest that 1 kilogram of protein provided in the form of beans requires 12 times less fertilizer to produce than the same amount of protein as beef [113]. Agriculture is the primary source of the potent GHG nitrous oxide, and the majority of these emissions are from nitrogen fertilizer application [100], again highlighting the need to reduce reliance on synthetic fertilizers.

Overall, shifting to plant-centric diets can help mitigate the impacts of GHG on climate change, and pulses play an especially critical role in this due to their ability to fix nitrogen and reduce the need for the production and application of synthetic nitrogen fertilizers. Indeed, legume rotation has been found to be one of the most effective ways to reduce nitrogen pollution [114]. Moreover, there are economic benefits associated with inclusion of legumes in agricultural systems, with the amount of nitrogen fixed annually by the legume-rhizobia symbiotic relationship resulting in savings of US $8-12 billion [99].

3.2 Pulses Can Improve Soil Health

In addition to providing a natural source of soil nitrogen as opposed to synthetic fertilizers, pulses help improve soil structure and health [99]. Furthermore, cropping with legumes like pulses can increase soil carbon content, for example through the supply of biomass [100], and improve carbon management, enhancing carbon sequestration in deeper soils [115]. Due to their nitrogen-fixing ability, legumes have been found to store 30% higher soil organic carbon than other species [116]. Moreover, including pulses has a “break crop effect,” with crop diversification helping reduce the pressure of diseases, pests, and weeds that would occur without crop rotation [100,117].

Another important role of pulses is in crop rotation, where their inclusion helps increase profitability and reduce production costs, for instance through lower input costs due to a decreased need for fertilizer [118]. Beans and other pulses can be rotated with crops like wheat, maize, and rice, and there are advantages for crops that follow pulses [119]. Diversifying crop rotations through the addition of pulses appears to benefit system productivity [120] and the production of subsequently planted crops [99], which has economic benefits [101]. There are also nutritional benefits to including pulses in crop rotation. Crops that follow legumes can have higher protein content [99]. The intercropping of legumes with cereal crops is another way to boost cereal protein content [121], demonstrating that pulse production can play a role in improving the nutrition of other crops.

3.3 Pulses Contribute to Water Conservation and Improved Water Quality

The production of pulses requires less water than that of other sources of protein. Thus, transitioning to more pulse-centric diets can play a role in the conservation of water resources. For example, to produce 1 kilogram of protein in the form of beef has been shown to use approximately ten times more water than 1 kilogram of protein in the form of kidney beans [113]. The dramatic difference in water use of different protein foods is shown in Figure 1.4, where pulses require much less freshwater withdrawals than most other sources of protein [122].

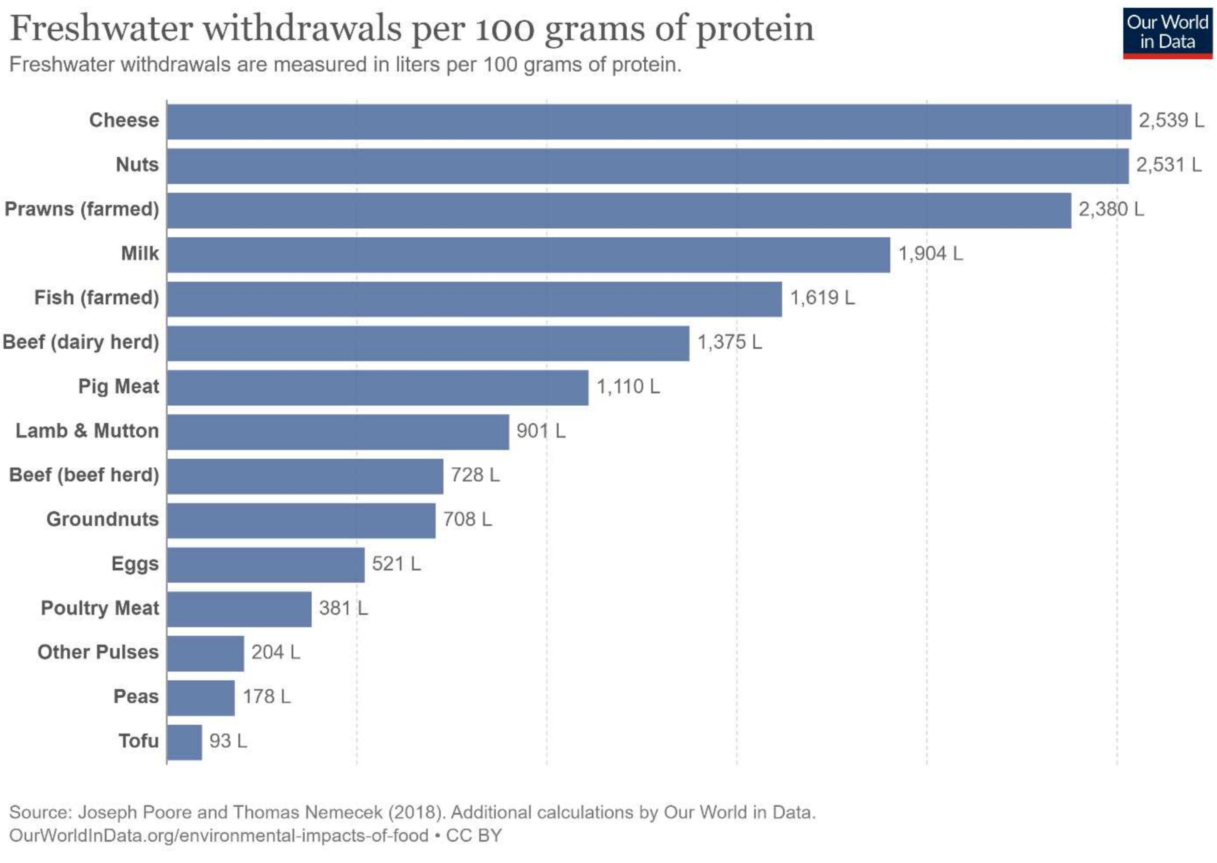


Figure 1.4. Freshwater withdrawals per 100 grams of protein. Image source: https://ourworldindata.org/grapher/water-per-protein-poore [122].

In addition to requiring less water to produce than many other protein sources, pulses can help improve water quality [99,101]. Due to their ability to fix nitrogen, pulses need less fertilizers and thus can minimize fertilizer runoff. Fertilizer runoff is one contributor to eutrophying emissions, which represent excess nutrient runoff into waterways, resulting in nutrient imbalances and ecosystem pollution [123]. Eutrophication has numerous negative environmental impacts, like biodiversity loss and GHG emissions [99].

3.4 Pulses Can Help Reduce Land Use

Compared to many other sources of protein, the production of pulses requires less land. For example, producing 1 kilogram of protein in the form of beef uses about 18 times more land than it takes to produce the same amount of protein in the form of kidney beans [113]. Another study found that a calorie-equivalent substitution of beans for beef could free up over 40% of cropland in the United States [105]. Figure 1.5 highlights the land use of various sources of protein, and pulses are found at the lower end of the spectrum.

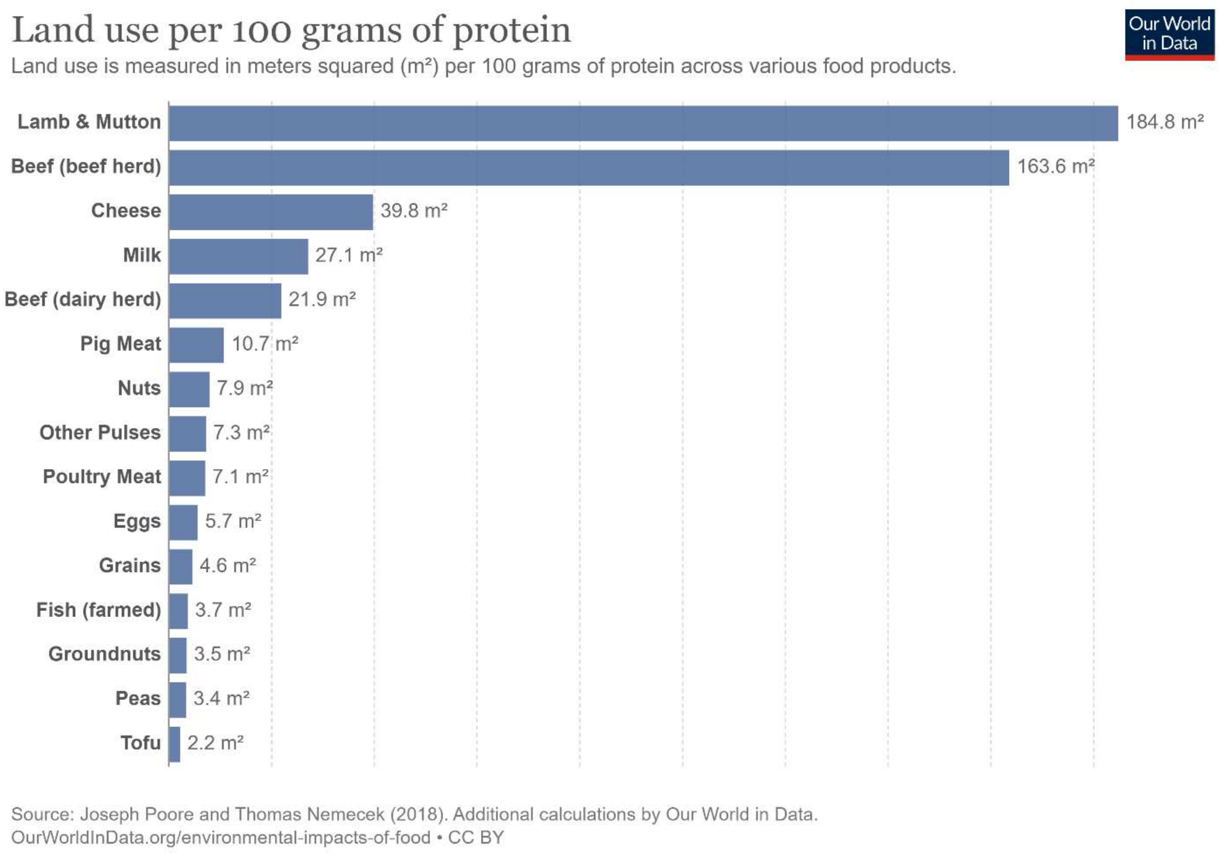


Figure 1.5. Land use per 100 grams of protein. Image source: https://ourworldindata.org/grapher/land-use-protein-poore [124].

One way to further improve land use efficiency in pulses would be to reduce yield gaps, or the actual yields attained versus the genetic yield potential [99,119]. Even though countries like the United States have enjoyed consistent increases in yield over the last several decades, on-farm yields are lower than potential yields [125]. Therefore, improving management and production practices can result in even larger savings in land use.

4. Barriers and Motivators for Pulse Consumption[7]

4.1 Current Pulse Intake Levels

In spite of the myriad of benefits of pulses for human and environmental health, global pulse consumption is low, with levels stagnating at around 21 grams per day [126]. However, consumption varies among countries, as is shown in Table 1.4, which lists the average number of kilocalories of pulses consumed per capita per day [127]. Some countries, like Rwanda, eat much larger amounts of pulses than other countries, like the United States. In fact, the average consumption of pulses in Rwanda appears to be nearly ten times that of the United States, and over ten times greater than in the United Kingdom. Different factors influence these varying levels of intake, including average income levels, culture, and tradition.

Table 1.4. Estimated kilocalories of pulses consumed per capita per day.

Year	World	Kenya	Mexico	Rwanda	UK	USA
2010	63	112	99	331	28	38
2011	63	150	99	332	22	30
2012	65	160	114	333	29	36
2013	65	162	122	331	32	39
2014	66	157	99	342	28	33
2015	66	162	95	339	28	33
2016	66	150	99	347	28	35
2017	70	149	100	340	28	35
2018	68	149	100	336	28	35
2019	68	168	91	333	14	33
2020	69	158	92	309	23	48

Data is from FAOSTAT, using the kilocalorie per capita per day numbers for aggregated pulses [127].

[7]For more details on nutritional and human health benefits of pulses, please refer to the following publication: Didinger, C.; Thompson, H. Motivating pulse-centric eating patterns to benefit human and environmental well-being. *Nutrients* **2020**, *12*, 3500.

As the research herein focuses on the United States, it is important to examine current consumption levels and recommendations in this country. The most recent Dietary Guidelines for Americans (DGA) 2020-2025 lists five vegetable subgroups; one of these is the Beans, Peas, Lentils group, which refers to pulses [11]. The recommendation for consumption varies with age group and sex, but for the "Healthy U.S.-Style Dietary Pattern at the 2,000-Calorie Level," (p. 20) the recommendation is to have 1 and ½ cups of cooked pulses per week [11]. However, over 80% of the US population ages 1 and older eats less than the recommendation, as shown in Figure 1.6 [11]. The shortfall is often dramatic, as demonstrated in Figure 1.7, which shows that for the vast majority of males and females of most age groups, pulse intake is far below the recommendation, and is generally less than 1 cup per week [11].

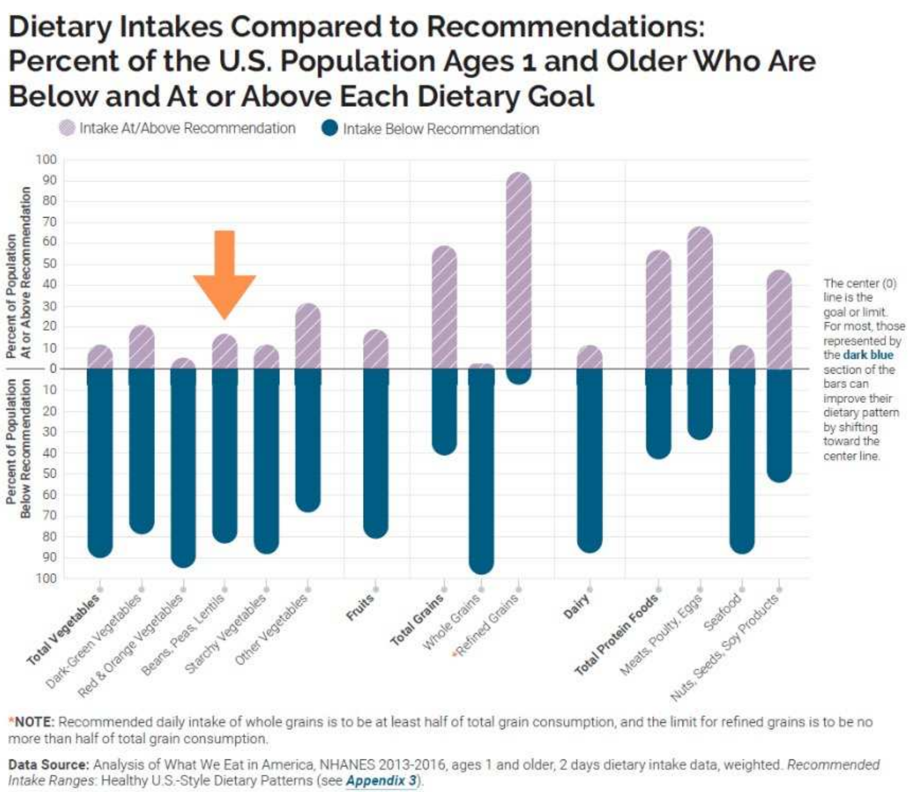
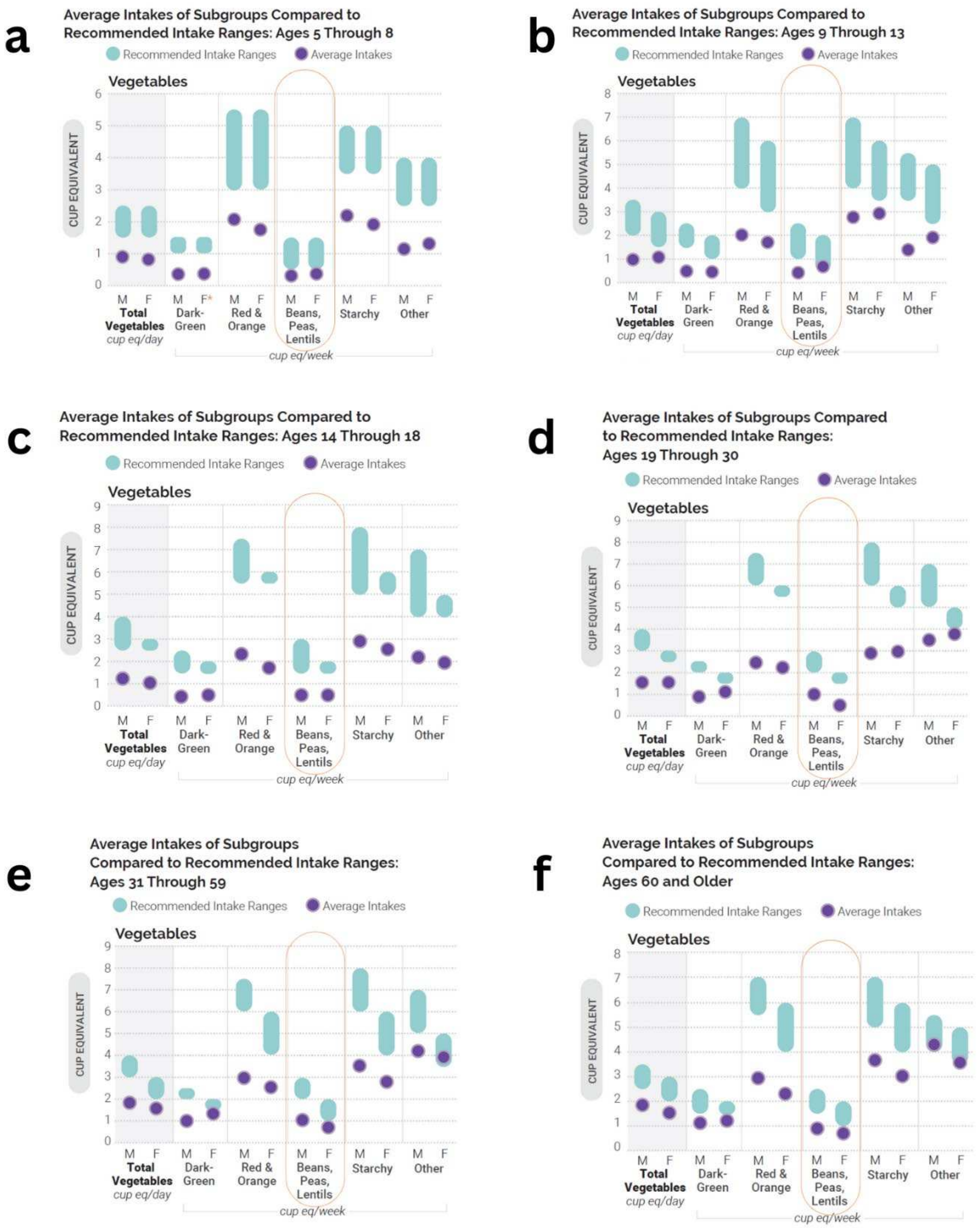


Figure 1.6. Dietary intake of pulses versus the recommendation. The figure is from the DGA (https://www.dietaryguidelines.gov/sites/default/files/2020-12/Dietary_Guidelines_for_Americans_2020-2025.pdf [11]), and an orange arrow has been added to highlight the beans, peas, and lentils (i.e., pulses) vegetable subgroup.



Data Sources: *Average Intakes*: Analysis of What We Eat in America, NHANES 2015-2016, day 1 dietary intake data, weighted. *Recommended Intake Ranges*: Healthy U.S.-Style Dietary Patterns (see ***Appendix 3***).

Figure 1.7. Average pulse intake in the United States by age group. Graphs a through f are from the DGA (https://www.dietaryguidelines.gov/sites/default/files/2020-12/Dietary_Guidelines_for_Americans_2020-2025.pdf [11]) and were compiled into one figure, with an orange circle added to highlight the pulses vegetable subgroup.

4.2 Barriers to Higher Pulse Consumption

One reason for low consumption is potential barriers consumers face, highlighting the importance of understanding these barriers and how to mitigate consumer concerns [128]. Several key barriers have been identified in the literature, including long cooking times of dry pulses, a lack of familiarity of how to cook and prepare pulses, worries regarding flatulence, dislike of the taste and/or texture, concerns about antinutrients, and a negative stigma of pulses as a poor person's food or only for vegetarians or vegans [128]. These barriers and ways to help address them are outlined in Table 1.5.

There is strong evidence-based support to address these barriers, and mitigating consumer concerns could play an important role in increasing pulse intake to a level that better advances both human and environmental health [128]. Another potential barrier is simply not being aware of the many benefits of pulses. Accordingly, it is important not only to address consumer barriers, but also to emphasize motivating factors.

Table 1.5. Potential barriers to higher pulse intake.

Barrier	Points to Address
Long cooking times [129-132]	• Consumer-accessible tips for faster cooking • Increasing awareness of faster cooking options (e.g., lentils) and convenient, healthful pulse-based products (e.g., canned pre-cooked beans, pastas made with pulse flours) • Can cook large batches and freeze
Lack of familiarity of how to cook and prepare pulses [130,131,133]	• Preparation tips • Versatile forms of pulses (e.g., canned, dry, frozen) and pulse products (e.g., pasta, snacks) • Creative and simple recipe ideas
Worries regarding flatulence [131,133,134]	• Share evidence that concerns about flatulence are often overexaggerated [134] • Provide tips on how to reduce flatulence • Emphasize the importance of fiber and healthy foods for gut health
Dislike of the taste and/or texture [130,131,135]	• Highlight different ways to prepare pulses that can change texture (e.g., mash and add to a dish, panfry or roast for a crispy texture) • Emphasize versatility of pulses and pulse products and their different tastes
Concerns about antinutrients [128,135]	• Emphasize that this can be a misnomer and some so-called antinutrients can offer health benefits [136,137] • Share tips to eliminate or reduce antinutrients, such as soaking and then fully cooking [138,139]
Negative stigma [118,140,141]	• Provide examples of pulse dishes and products and groups using them that demonstrate versatile uses and category differentiation to help break the stigma (e.g., athletes eating pulses, dishes that combine pulses and meat, dishes with special heirloom beans served by chefs)

4.3 Motivators for Pulse Consumption

Just as there are established barriers to greater pulse intake, there are also key motivators for consumption. These include taste, culinary versatility, excellent nutritional quality, human health benefits, affordability, environmental benefits, and culture and tradition [128,131]. In conjunction with addressing consumer concerns related to potential barriers, it is critical to emphasize the numerous motivators to eat pulses more regularly. These motivators and potential ways to highlight them are detailed in Table 1.6.

Among the motivators, taste is of particular importance because it is often considered the most important factor when consumers make food choices [142-144]. This has been confirmed in research on pulses, for instance when taste was ranked as the top reason that Canadian pulse consumers ate pulses [131]. Their economical price point allows pulses to also more equitably advance food and nutrition security [126,145]. Even though consumers may recognize pulses as environmentally friendly, this knowledge has not always been found to impact their pulse intake [130-132]. Accordingly, although this is an important part of the overall narrative of the benefits of pulses, it is essential to showcase multiple motivators rather than just focusing on one. Ultimately, consumers are looking for delicious, convenient, affordable, and nutritious foods that ideally are also good for the planet.

Table 1.6. Motivators for higher pulse intake.

Motivator	Points to Address
Taste [130,131,146]	• Versatile flavors and textures of pulses, ranging from sweet to earthy to neutral • Ability of pulses to absorb other flavors
Culinary versatility [131,141]	• Highlight the diverse types of pulses, as well as the many uses for pulses and healthful products with pulse ingredients • Emphasize that pulses are not just for the dinner meal but can be eaten at any time of day • Share creative, tasty recipes
Nutrition [130,131,133,147]	• High in protein • Rich in fiber • Packed with important vitamins and minerals, such as potassium, iron, and B vitamins like folate • Can share comparisons with other foods to showcase high nutrient density of pulses
Human health benefits [130-133]	• Gut health • Help promote healthy weight management • Chronic disease prevention
Affordability [126,131]	• Share average costs of both dry and canned pulses • Can compare price with other protein foods or other nutrient-dense foods
Environmental benefits and sustainability [131,133]	• Highlight numerous benefits for sustainability, including helping reduce greenhouse gas emissions, improve soil health, and save water • The role of pulses in the P's of sustainability: people, planet, prosperity [148,149]
Culture and tradition [126,131,133,150]	• Emphasize the rich global culinary history of pulses in cuisines around the world

Although knowledge is important, in and of itself, it is often insufficient to drive behavior change and influence food choices [128]. This has been observed in studies on pulses, where even when consumers have some knowledge about the nutrition and health benefits of pulses, they may not be regular consumers [141,146]. To promote health behaviors, integration of a behavior change model can provide structure and insights. One such model that can be used to promote regular pulse intake is the Information-Motivation-Behavioral Skills (IMB) model, which delineates three core determinants of health behaviors: information that can be translated into behavior, motivation, and behavioral skills to facilitate the behavior [128,151,152]. There are two major components of motivation – personal and social motivation – and they are influenced by personal attitudes, cultural norms, and social support [151]. To best promote consumption, a multi-pronged approach is more likely to effectively help shift behavior, through providing a combination of information about the benefits of pulses, motivation to regularly eat them, and behavioral preparation skills [128]. An example of how three main benefits of pulses – viewed through the lens of the IMB model – can be used to help motivate consumers to routinize regular consumption is shown in Figure 1.8.

Another example of how increasing pulse intake could be accomplished would be through a project that engages the public, such as citizen science [153]. In this instance, information would be provided during the project to bolster participant knowledge about the benefits of pulses and how to prepare them. Both personal and social motivation would be appealed to, as shown in Figure 1.9. Also, participants would engage in behavioral skills as part of the project, familiarizing them with the actual preparation of pulses and boosting their confidence in their ability to use pulses. The IMB model suggests that this combination of information, motivation, and behavioral skills would then help encourage the adoption of the desired health behavior: increasing pulse intake.

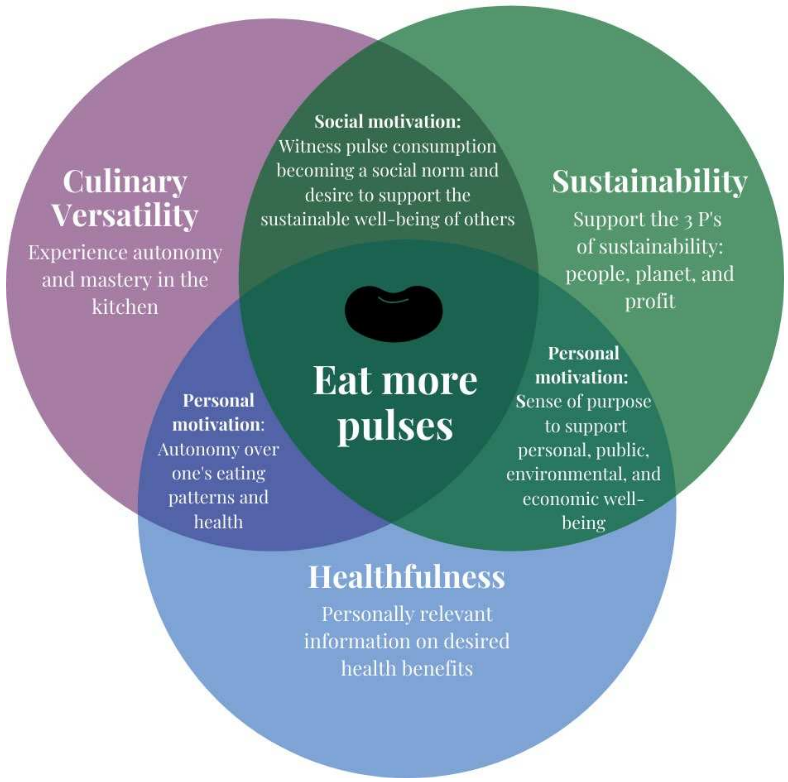


Figure 1.8.[8] Emphasizing the culinary versatility, sustainability, and healthfulness of pulses to drive social and personal motivation to increase consumption.

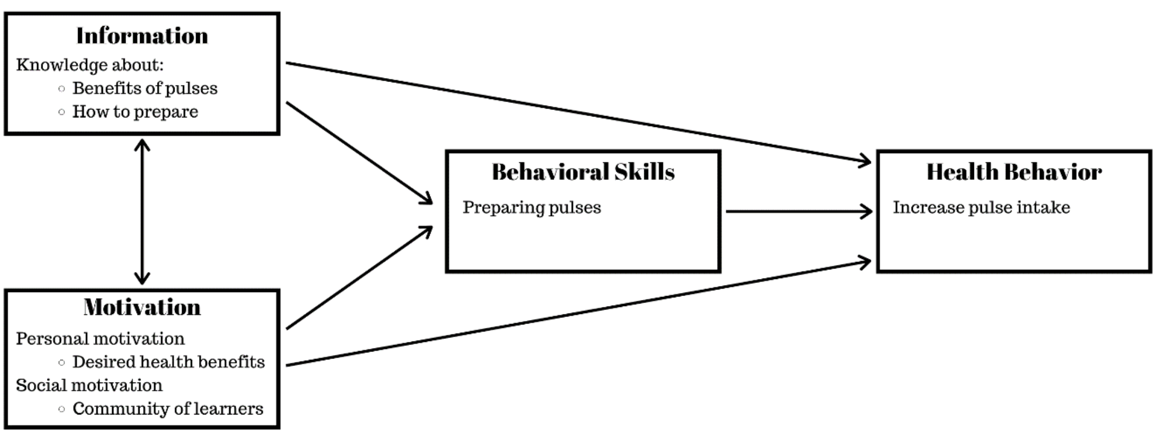


Figure 1.9. Increasing pulse intake with a citizen science project, guided by the IMB model.

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[8]This figure has already been published with the journal MDPI Nutrients and can be found online at: https://www.mdpi.com/2072-6643/12/11/3500. Citation information is as follows: Didinger, C.; Thompson, H. Motivating pulse-centric eating patterns to benefit human and environmental well-being. *Nutrients* **2020**, *12*, 3500.

4.4 A Translational Approach

To encourage increased consumption, it is key to address established consumer barriers and motivators for pulse consumption. One attractive approach is translational research, which is viewed as essential in improving health [154,155]. For many, translational science has traditionally been considered a "bench-to-bedside" enterprise where research was harnessed to produce new drugs and treatment options, acting as an interface between basic science and the clinic [154]. However, the meaning of translational science also encompasses ensuring that research knowledge reaches the public such that they can benefit [154]. For this type of translational science, helping individuals change behaviors and make more informed choices that advance public health is the goal, and it is not the clinic that is the research setting, but rather the community [154,155]. Adoption of a behavioral change model like the IMB model can provide key insights and guidelines when conducting translational research [128].

Extension is an excellent platform through which to accomplish translational research. The very mission of Extension is to translate research into action by bringing evidence-based discoveries and information to communities to benefit well-being, and Extension has the ability to quickly disseminate resources and information through its networks [156]. For the research described herein, a translational approach to promote higher intake of beans and other pulses was adopted to emphasize motivators for pulse intake and mitigate potential barriers.

CHAPTER 2: A TRANSLATIONAL APPROACH TO INCREASE PULSE INTAKE AND PROMOTE PUBLIC HEALTH THROUGH DEVELOPING AN EXTENSION BEAN TOOLKIT[9]

Summary

Practical, affordable solutions need to be implemented to address global challenges confronting human and environmental health. Despite a myriad of benefits for people and the planet, beans and other pulses (e.g., chickpeas, cowpeas, dry peas, lentils) are under-consumed. To better understand consumer concerns and interests, a Food Habits Survey was conducted and the findings were incorporated into the Colorado State University Extension Bean Toolkit. Guided by the Information-Motivation-Behavioral Skills model, the toolkit included informational social media posts, cooking guidance, and an online class. A convenience sample of participants was recruited through Extension and university networks. After class participation, significant gains in knowledge of pulse nutrition, versatility, and cooking were observed, with an average increase of 1.5 points on a 5-point Likert scale ($p < 0.001$). Moreover, participants ($n = 86$) perceived a greater importance of motivators (e.g., nutrition, versatility, environmental benefits) and found barriers (e.g., flatulence, long cooking times, unfamiliarity) to be less discouraging. Most

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[9]This research has already been published with the journal MDPI Nutrients. To stay true to how the paper was published but adhere to CSU Graduate School dissertation formatting: 1.) the numbers of figures, tables, and supplementary materials referenced have a “2.” appended to them to reflect being in chapter 2; 2.) keywords and journal ending statements (e.g., funding, data availability statement) are not displayed; 3.) spacing has been adjusted to match CSU formatting; and 4.) the supplementary materials mentioned in this paper can be found online at https://www.mdpi.com/2072-6643/15/19/4121. Citation information is as follows: Didinger, C.; Bunning, M.; & Thompson, H.J. A translational approach to increase pulse intake and promote public health through developing an Extension Bean Toolkit. *Nutrients* **2023**, *15*, 4121.

participants reported an intention to eat more pulses, and among those who completed the 1-month follow-up survey, pulse intake frequency increased ($p = 0.004$). Emphasizing motivating factors while simultaneously mitigating barriers to consumption can help reverse insufficient intake and promote healthy behavior change. Leveraging Extension or similar networks is one way to adopt a translational approach to better reach the public with this information.

1. Introduction

The world is facing severe challenges for human and environmental well-being, including a cost-of-living crisis, rising rates of obesity and chronic disease, and climate change [3,99,157]. Accordingly, there is dire need for affordable, accessible solutions. Beans and other pulses (i.e., the edible, dry seeds of non-oilseed legumes like chickpeas, cowpeas, dry peas, and lentils) have a relatively economical price and the ability to simultaneously promote public and planetary health [6,99,100,145]. Thus, pulses can play a key role in addressing many global challenges.

Despite the myriad of benefits they offer, consumption of pulses is low in many countries around the world. Average global consumption appears to be stagnating around only 21 grams per day per capita [126]. Yet, there is evidence that consumption can be higher. For example, several countries in Eastern Africa eat around 150 grams per day [158]. Indeed, an improved nutritional status appears to go hand-in-hand with higher consumption of pulses. Individuals who regularly eat more beans and other pulses have higher intake of several key dietary components (e.g., dietary fiber, folate, potassium) and also consume lower levels of fat [159,160].

The adoption of more pulse-centric eating habits can allow people to capitalize on the benefits of beans and other pulses for human and planetary health. A key approach to encourage higher pulse intake is to emphasize the motivating factors of pulses while simultaneously addressing any barriers, i.e., consumer concerns that may prevent higher pulse intake [128]. Motivators include their versatility, affordable price point, nutrient-dense profile, and contributions to healthy and sustainable eating patterns [130,133]. Detailed information about the benefits of pulses for gut health, healthy weight maintenance, and chronic disease (e.g., diabetes, cardiovascular disease, certain types of cancer) prevention is beyond the scope of this paper but can be found in the recent literature [6,15,24,27,32].

Despite numerous benefits, there are several primary barriers to higher pulse intake that are well-established in the literature, including long cooking times and concerns over flatulence [128,129,133]. Another key barrier is unfamiliarity, or a lack of understanding of how to prepare pulses and regularly include them in a variety of meals [128,161]. For example, Doma and colleagues found that consumers tend to prefer to eat beans at certain times and in particular dishes [133]. Most consumers they surveyed ate beans in the winter, for dinner, and mainly in dishes like chili and soup [133]. This presents a challenge because lack of awareness of the versatile ways to eat pulses for different meals of the day and in a wide variety of dishes can reduce the likelihood that consumers will regularly choose to include them. Thinking beyond more traditional meals like chilis and soups to varied, diverse options can provide a wider array of choices to incorporate pulses into daily diets. This could include dishes like smoothies, salads, sheet-pan bakes, and other ways to include pulses in breakfasts, lunches, snacks, dinners, and desserts.

Our research team recently conducted a citizen science project to inspire people with the culinary versatility of pulses and received participant feedback on the Bean Cuisine (i.e., a 2-week cuisine that incorporated beans and other pulses into 14 unique breakfasts, lunches, snacks, and dinners for a total of 56 recipes) [161]. Participants significantly increased their knowledge about the health benefits of pulses, pulse versatility, and how to prepare dry pulses. They also reported feedback such as, "I'm more aware of ways to incorporate beans into every meal, and I'm paying more attention and trying to eat them more" [161] (p. 12). Citizen science can be a powerful approach to engage the public [153], but it is also important to reach a broad audience that may not have the ability to participate in a citizen science project. One way to accomplish this is to leverage Extension to quickly disseminate information throughout its network. Extension, which is part of the land-grant university system, is well-connected in rural and urban areas throughout the United States, and staff lead programs and initiatives within their respective counties to improve the well-being of communities [162].

The mission of Extension is to translate research into action by bringing evidence-based discoveries and information to local communities to support public health [156]. Thus, Extension is perfectly suited to accomplish translational research. Traditional science often considered translational research as "bench-to-bedside" work that served as an interface between basic science and the clinic [154]. Yet, translational science also encompasses ensuring that research knowledge reaches the public such that they can reap the benefits of scientific findings [154]. For this type of translational science, helping individuals change behaviors and make more informed choices that promote public health is the goal. Moreover, it is not the clinic that is the research setting, but rather the community [154,155].

To conduct translational research through Extension, we developed a toolkit, or a collection of educational program resources targeting an issue [163]. This paper addresses increasing consumption of a variety of pulses – beans as well as chickpeas, cowpeas, dry peas, and lentils. However, the toolkit was called a "Bean Toolkit" instead of a "Pulse Toolkit" due to higher familiarity with the word "bean." Nonetheless, due to including several pulses in addition to beans, the toolkit is attractive and relevant to a broad population. As it is called the Bean Toolkit, the words "pulse" and "bean" may be used interchangeably in this paper.

The Colorado State University (CSU) Extension Bean Toolkit is intended to reach a wider audience via multiple outlets of the Extension network, such as a 1-hour online class, handouts, social media posts, and other creative outreach tools with information about beans. Before creating the toolkit, a Food Habits Survey was designed and conducted. Survey findings were combined with results from the scientific literature to ensure consumers' interests and concerns would be addressed. The CSU Extension Bean Toolkit was designed to mitigate established consumer barriers and emphasize motivators. Doing so promotes increased intake of beans and other pulses, which has the potential to advance the health of both people and the planet.

2. Materials and Methods

2.1. Food Habits Survey Development

To inform the development of the Extension toolkit and class, an online survey was developed in Qualtrics. The survey was conducted to better understand consumer viewpoints, behavior, and preferences. The lead author developed the survey questions based on consultation with experts and a literature search of barriers and motivators for pulse consumption. Similar question topics and format to other surveys assessing pulse intake-related information amongst consumers were adopted, such as those by Doma [133], Heer [146], Palmer [140], and Winham [164]. Questions were refined with the other authors, who are experts in pulses and/or Extension program development and evaluation. To establish content validity, experts were asked to provide feedback on question and response option wording, content, and clarity [165-167]. Their areas of expertise included pulse nutrition and health benefits, consumer behavior as it relates to pulses, outreach work, survey design, and program evaluation.

After modifying the survey per expert feedback, a pilot was conducted to measure reliability, or the ability of the survey to produce consistent results [167]. To assess test-retest reliability, the survey was administered at two time points approximately 2 weeks apart (average time between responses = 14.2 days), with no intervention in between. A convenience sample of the following two groups completed the survey pilot: university students and Extension volunteers. Overall, 33 individuals completed the survey at two separate time points ($n = 27$ indicated female, $n = 27$ White, $n = 19$ were between 18-39 years of age, and $n = 12$ were between 50 and 79 years of age). Although 33 is not a large number for a test-retest approach, questions were designed to be like other Extension surveys and previous research on motivators and barriers to bean consumption. Thus, the main purpose was to ensure participant understanding of question wording and determine via free response feedback if appropriate response options had been provided. The Food Habits Survey was designed to inform toolkit and class development and was not intended to be a standalone study on consumer behavior and preferences.

For non-free response questions, Spearman correlations measured correlations between the test and retest scores for ordinal and/or Likert-type data [167]. Generally, survey items are considered reliable when they have a correlation coefficient of at least 0.7 and *p*-value of less than 0.05 [165,167]. Percent agreement was also calculated because, for small sample sizes, correlations can be misleading and agreement values are another way to assess consistency, especially for categorical variables [167,168]. Moreover, agreement is one way to examine Likert scales and determine if people are choosing similar responses (e.g., “strongly agree” at the first time point and “somewhat agree” at the second time point). Percent agreement values greater than 66% are considered fair [168].

Based on Spearman and agreement values, as well as any feedback received, questions were either removed or modified as needed, with decisions reached via researcher corroboration. The wording of all questions and response options was reviewed. Modifications or removal occurred for questions with a *p*-value greater than 0.05, for which Spearman correlation scores were below 0.7, and/or with low agreement scores. Examples of modifications include:

- **Question removal**. For example, one of the original questions asked about the elevation at which participants live, which can influence cooking time of dry pulses [169-171]. Participants were directed to a site to tell them their elevation. This question was removed because participants said that being redirected to another site sometimes exited them from the survey. Another question that was removed was one that asked about the importance of the barrier “concern about antinutrients like lectins,” due to low Spearman correlation and agreement scores ($\rho = 0.47$, $p = 0.007$, agreement = 0.56).
- **Response option removal**. For several questions, the option of “other” was removed because no one filled in this response, indicating the provided response options were sufficient. The consulted experts also did not suggest other response options.
- **Question and/or response option wording clarification**. For several questions, statements that clarified that more than one option could be selected were added.

This survey was an integral part of the formative evaluation and development of the Extension Bean Toolkit and class. The final Food Habits Survey can be found in Supplementary Materials S2.1. A link that provided access to the survey was distributed via multiple platforms, including emails, newsletters, and social media posts. It was advertised as a Food Habits Survey to reduce bias with regards to bean preferences and consumption. This was similar to the approach taken by Doma and colleagues, wherein the survey was called the Food Survey Study [133]. Those who completed the Food Habits Survey could choose to receive materials developed as a result of the survey, a summary of survey findings, and to be entered into a drawing to win one of multiple $20 Amazon gift cards. This survey work was approved by the Colorado State University Institutional Review Board, protocol #2016. Survey findings informed development of the Extension Bean Toolkit components and online class.

2.2. Development of Toolkit Components

The components of the CSU Extension Bean Toolkit were developed based on the findings from the Food Habits Survey, a review of the literature, and input from experts and Extension colleagues. For instance, our recent study on how elevation and cooking conditions impact cooking times provides a summary of tips to shorten cooking times [171]. The tips and handout that were developed as part of that research were provided to consumers via the Extension Bean Toolkit. Ways to reduce cooking time include soaking, adding salts to the soaking water, and utilizing fast-cooking pulses (e.g., lentils) [171-174]. Regarding flatulence, the literature shows that this concern is overexaggerated [134], a point that is important to relay to consumers. Practical suggestions to reduce flatulence include slowly increasing consumption of pulses [134] and discarding the soaking water if preparing dry pulses in the home [175]. Unfamiliarity is another key barrier to address. The literature suggests that recipes are one way to accomplish this [131]. Therefore, unfamiliarity was mitigated through providing a range of simple, creative, and tasty recipes. Information to equip consumers to overcome these barriers was provided in the Extension class and toolkit.

The purpose of the toolkit was to educate consumers on the benefits and versatile uses of pulses and provide accessible cooking tips, thereby helping to increase knowledge and awareness of pulses. The Information-Motivation-Behavioral Skills (IMB) model guided toolkit development. The IMB model states that there are three core determinants of the performance of health behaviors: 1.) information that can be translated into behavior; 2.) social and personal motivation; and 3.) behavioral skills that facilitate the behavior [128,151,152]. The Extension Bean Toolkit appealed to all three constructs of the IMB model. Information was provided about the many benefits of pulses and how to prepare them. Personal motivation was appealed to through explaining the desired health benefits that can be obtained through regular pulse consumption. Social motivation occurred through creating a community of learners in the online class and encouraging them to engage with one another via the chat feature. Improved behavioral skills were promoted via in-depth explanations of how to prepare pulses and the various ways of using them, and through providing handouts and recipes. The main toolkit components included:

- **A bean calendar.** The bean calendar, Bean Appetit, had an introduction with background about pulses and practical cooking information. Each month contained a photo, a short caption, and a QR code that linked to a recipe and/or other related page with helpful pulse information. The web pages are available on Food Smart Colorado, an affiliate website of CSU Extension that provides nutrition, health, and food safety information. As part of the calendar, 13 pulse-centric recipes were developed, and they can be found on the website: https://foodsmartcolorado.colostate.edu/food/2022-bean-calendar-recipes/
- **Social media**. Monthly social media posts were designed and posted from January 2022 to October 2023. The first year of posts were associated with the months of the

bean calendar. The second year of posts addressed other topics of consumer interest, such as human and environmental health benefits, information about how to cook beans, and creative recipe ideas. Regular posting allowed followers of Food Smart Colorado to be exposed to various types of information that addressed potential barriers to pulse intake and emphasized motivators. Analytics such as viewer reach were assessed through Food Smart Colorado's Facebook Professional Dashboard.

- **Handouts**. Two main CSU Extension handouts were developed, one titled "Cooking Dry Beans" and the other "Tips for Cooking with Dry Beans and Other Pulses." The handouts were distributed as part of the Extension class, as well as being made available online at Food Smart Colorado and linked to in social media posts.
- **Blog posts**. The lead author wrote several pulse-related blogs on Live Smart Colorado, a CSU Extension blog run by Family & Consumer Science Extension Agents and Specialists at CSU.

2.3. Designing and Conducting the Extension Class

Class topics were informed by areas of consumer interest and motivators and barriers for pulse consumption, as determined by the Food Habits Survey and a review of the literature [128,130,133]. To structure the class, a farm-to-table approach was decided upon. The class began with discussions of bean crops in the field and their sustainability benefits, followed by nutrition and health information, practical cooking tips, and creative and delicious ways to regularly incorporate beans into the diet. For all topics, motivating factors were emphasized, and potential areas of misinformation and barriers were addressed.

The 1-hour online class was offered through Zoom and was promoted through the Extension network, colleagues, CSU emails and newsletters, and social media. All surveys were designed in Qualtrics. Questions came from previous Extension class surveys and the questions that had been piloted and assessed for validity and reliability during development of the Food Habits Survey. This Extension work was approved by the Colorado State University Institutional Review Board, protocol #3589.

2.3.1. Validation Class

After the design of the class, an initial testing of impact was conducted, herein called the validation class. The lead author worked with CSU Extension agents throughout the state to promote the class, holding six different class sessions in partnership with six different counties in Colorado. For the validation class, survey data was collected at three time points. This provided the chance to: 1.) gather more complete feedback from participants about the class to see if any changes should be made before the final class implementation; and 2.) better understand the potential impact on short-term behavior. Before the class, participants completed the pre-survey (Supplementary Materials S2.2), followed by the post-survey immediately after the class (Supplementary Materials S2.3). After the class, participants were emailed the CSU Extension bean handouts developed as part of the toolkit, as well as links to recipe resources on Food Smart Colorado and Colorado Dry Beans. This was part of a Colorado Department of Agriculture funded project, so this helped direct people to an organization that can provide local bean information. To assess impacts on short-term behavior, participants were also contacted to complete a 1-month follow-up survey (Supplementary Materials S2.4), with the chance to receive a $10 Amazon gift card as an incentive upon completion of all three surveys.

Participant feedback was positive, and no modifications to the slides were necessary. However, a couple of points were incorporated into the final class. One, people requested more recipe information. However, there was not adequate time in the class to discuss recipes in-depth and still address other topics. Thus, it was emphasized that recipes would be shared in the follow-up email, and links were immediately sent to participants after completion of the class. Also, there appeared to be confusion about the wording of the question asking about the importance of barriers, as is discussed in the results. Therefore, the wording and response options on the final class survey were adjusted as follows:

- Original wording: “How important are the following in discouraging you from eating pulses? 'Important' reflects a factor that discourages you. 'Unimportant' represents a factor that does not discourage you.” Response options ranged from “very important” to “very unimportant.”
- Modified wording (asked twice, to assess importance before and after): “BEFORE/AFTER the class, how important were the following in discouraging you from eating pulses?” Response options ranged from “highly discourages” to “does not discourage.”

2.3.2. Final Extension Class

For the final class, only one survey was administered, immediately following the class. This reduced respondent burden and increased the likelihood of gathering complete data from participants, as opposed to an incomplete set of responses to a multi-survey set like in the validation class. Retrospective pre-post design has been found to afford many benefits, including requiring less time to administer, establishing a common metric, and reducing the response-shift bias that can occur with program participation [176,177]. See Supplementary Materials S2.5 for the final class survey. Questions were a compilation of those on the validation class surveys. Instead of asking about knowledge level and the importance of barriers and motivators at multiple time points, participants were provided two matrices. One asked about knowledge, motivators, and barriers before the class and the second about after completion of the class. For example, participants rated their knowledge of three different topic areas (nutrition and health benefits, versatility, and how to cook dry pulses) by responding to the following two questions:

1. On a scale of 1 (low) to 5 (high), how would you rate your knowledge of the following BEFORE the class?
2. On a scale of 1 (low) to 5 (high), how would you rate your knowledge of the following AFTER the class?

In addition to CSU Extension, outside venues also hosted the class, such as the Denver Botanic Gardens. As with the validation class, participants were sent a follow-up email with the CSU Extension bean handouts and links to recipe resources on Food Smart Colorado.

2.4. Statistical Analyses

All statistical analyses were conducted in IBM SPSS Statistics version 28 (IBM Corp. Released 2021. IBM SPSS Statistics for Windows, Version 28.0. Armonk, NY: IBM Corp.). Statistical analysis to assess test-retest reliability of the Food Habits Survey questions is detailed in the above Food Habits Survey section. When analyzing the final data set for the Food Habits Survey and the Extension class, the statistical analysis was conducted similarly to that of our recent Bean Cuisine citizen science research [161]. Briefly, descriptive statistics were used for categorical variables like demographics. For Likert scale questions about knowledge and the importance of barriers and motivators, Wilcoxon signed rank test was used to assess if significant changes occurred.

For free response data, the lead author utilized an inductive approach, beginning with opening coding [178,179]. All free response data was reviewed to create categories and subcategories, which were updated as the analysis progressed [133,180,181]. Via comparative analysis, related codes were categorized and themes were extracted. The constructs of the IMB model [151] informed theme extraction, with focus on key information, motivational aspects, and behavior changes that could influence pulse intake [128]. These codes were grouped into themes that were fully supported by the data and corroborated with the other researchers on the project. Quotes were then selected to illustrate the themes that emerged and arranged into tables.

3. Results

3.1. Food Habits Survey

A total of 940 individuals completed the Food Habits Survey (see Supplementary Materials S2.1 for the survey questions). There was higher participation by White, educated females: 82.8% of participates selected White as their ethnicity, nearly 33% had a master's degree, and about 80% were female. A relative lack of socioeconomic diversity is a challenge faced in other outreach work [161]. Although this could limit generalizability to a larger audience [153,182], it may be representative of the population likely to utilize the resulting Extension Bean Toolkit resources and take the Extension class. This is because the recruitment methods were similar for both, thus a comparable group is likely to be reached when these resources are promoted. For more details about respondent demographics, see Supplementary Materials S2.6.

3.1.1. Pulse Intake Frequency and Preparation Habits

When asked about frequency of pulse intake, the most frequent response was "1-3 days per week" (n = 438, or 46.6%), as shown in Table 2.1. When "never" was coded as 1 and "every day" as 6 (i.e., higher numbers corresponded to more frequent intake), average consumption was 4.1, with a standard deviation of 0.94. Notably, this survey question only provided data on a range of frequency of consumption, not the exact number of days on which pulses were consumed, nor the intake volume. Thus, the average consumption score of 4.1 represents a range of days per week that the average survey respondent eats pulses, but it does not provide more detailed information on average intake. This is a limitation of the survey tool, as will be discussed later in more detail.

Table 2.1. Frequency of pulse intake of Food Habits Survey respondents.

How often eat pulses	Number (out of *n* = 940)	Percentage of respondents
Every day	63	6.7
4-6 days per week	229	24.4
1-3 days per week	438	46.6
1-3 times per month	166	17.7
Less than 1 day per month*	40	4.3
Never	4	0.4

*On the survey, this response option was phrased as "several days per year, but less than 1 day per month."

Most participants reported that they were omnivores (*n* = 680, 72.3%), followed by pescatarians (*n* = 106, 11.3%), vegetarians (*n* = 84, 8.9%), and vegans (*n* = 69, 7.3%). When examining frequency of pulse intake by dietary pattern, it is evident that those respondents who follow pescatarian, vegetarian, and vegan dietary patterns eat pulses more often than the omnivore group. As shown in Table 2.2, vegans were the group with the highest frequency of pulse intake. Whereas some omnivores (*n* = 4) selected never for pulse intake frequency, the least frequent option selected by pescatarians was "several days per year, but less than 1 day per month." For both the vegetarian and vegans surveyed, the least frequent option selected was "1-3 days per month." This suggests that these groups demonstrate more frequent pulse consumption than omnivores.

Participants provided information about their pulse cooking and consumption habits. The majority of individuals (*n* = 882, ~94%) had cooked with dry pulses at least once before. This is a high percentage and may represent a bias or limitation. However, the question only asked whether participants had cooked dry pulses at least once. Thus, it is not clear what percentage of these 882 respondents regularly cook dry pulses versus how many have only cooked dry pulses once or a few times.When asked “Which cooking method(s) do you regularly use when preparing beans? You can select more than one,” the highest number of respondents selected stovetop (*n* = 594 of the 882 that have cooked dry pulses before), followed by slow cooker (*n* = 350) and electric cooker (*n* = 330). Traditional pressure was the least common response (*n* = 93), with more people regularly using their ovens (*n* = 155) than a traditional pressure cooker.

Table 2.2. Average frequency of pulse intake, by dietary pattern.

Dietary pattern (*n* out of 940)	**Average* ± SD**	**Mode**
Vegan (*n* = 69)	5.04 ± 0.74	5 (= 4-6 days per week)
Vegetarian (*n* = 84)	4.70 ± 0.77	5 (= 4-6 days per week)
Pescatarian (*n* = 106)	4.37 ± 0.88	4 (= 1-3 days per week)
Omnivore (*n* = 680)	3.89 ± 0.89	4 (= 1-3 days per week)

*A larger number represents more frequent pulse intake, where 1 = never, 2 = several days per year, but less than 1 day per month, 3 = 1-3 days per month, 4 = 1-3 times per week, 5 = 4-6 days per week, and 6 = every day.

Soaking dry pulses was a common practice among those who cook dry pulses. Only 63 of the 882 people who cook dry pulses indicated that they never soak before cooking. The most common response option when asked “How likely are you to soak dry beans and other pulses before cooking?” was “Very often (81-100% of the time)” (*n* = 230). Of the respondents who soak dry pulses at least some of the time before cooking, most people discard the soaking water (*n* = 625), with a much smaller number that chooses to cook in the soaking water (*n* = 188). Additionally, *n* = 374 individuals (about 46% of those who indicate they soak dry pulses) have tried the quick soak method. This method entails boiling for about 3 minutes and then letting stand for 1 hour before cooking, instead of a longer overnight soak [171,183].

Respondents were also asked about what influenced their decision to use salt when cooking with dry pulses. This question was asked to the 882 individuals who indicated they have cooked dry pulses before. It was evident that there is confusion about this topic, because almost the same number of people indicated that salt can help pulses soften (*n* = 139) as did the number that thought salt prevents pulses from softening (*n* = 137). Therefore, addressing this potential area of confusion could be a helpful topic to cover in the consumer resources and class. Overall, the most common factor that influenced the decision to use salt or not was recipe instructions (*n* = 237), indicating the importance of clear, well-written recipes.

3.1.2. Pulse Preference and Form in Which Pulses Are Eaten

Respondents were asked about how much they liked five main types of pulses, with results shown in Table 2.3. Dry beans were the favorite type of pulse (*n* = 803 like dry beans), followed by chickpeas (*n* = 766). Cowpeas (also called black-eyed peas) and dry peas were the least favorite type of pulses, with *n* = 139 and *n* = 132, respectively, indicating they do not like these pulses. Cowpeas also appeared to be the least familiar pulse to respondents, with the highest number of individuals (*n* = 89) indicating they have not tried them before.

Table 2.3. Respondent liking of five main types of pulses.

Pulse Type*	**Mode** Score**	**Total Likes*** (*n*)**	**Total Dislikes**** (*n*)**	**Have Not Tried (*n*)**
Dry beans	Strongly like	803	60	4
Chickpeas	Strongly like	766	71	12
Lentils	Strongly like	707	79	18
Dry peas	Somewhat like	612	132	30
Cowpeas	Somewhat like	510	139	89

*Pulses were clarified with the following wording in the survey: chickpeas (also called garbanzo beans); cowpeas (also called black-eyed peas); dry beans (pinto, black, kidney, etc.); dry peas (split peas). **To calculate the mode, "have not tried" was considered one step further than strongly dislike, as individuals had not been interested enough to even try this type of pulse before. ***This shows the sum of participants who indicated they either strongly or somewhat like this type of pulse. ****This shows the sum of participants who indicated they either strongly or somewhat dislike this type of pulse. Note that the number of neutral responses is not shown in the table.

Participants also indicated how they have eaten pulses in the last year. They were provided with a list of types of pulse dishes and could select multiple options. Table 2.4 indicates the breakdown of how respondents reported eating pulses. Pulses mixed with grains, dips, and soups all had over 700 respondents indicate that they have eaten pulses this way within the last year, with nearly 700 selecting chili. Dishes made using pulse flour were less common ways to consume pulses. Dessert was by far the least common way that people ate pulses, with only 192 individuals indicating they have eaten desserts with pulses within the last year.

Table 2.4. How respondents ate pulses within the last year.

Type of dish	***n* (out of 940)***
Beans or other pulses with rice or other grains	772
Dips	731
Soups	705
Chili	697
Plain beans or other pulses	658
Refried beans	655
Salads	623
Pastas (pulses mixed in with pasta, not pulse flour pastas)	452
Breads, crackers, or pastas made with pulse flour	407
Desserts	192

*This is the number of individuals who selected yes when asked if they ate this type of pulse dish within the last year.

3.1.3. Motivators and Barriers to Pulse Intake

Respondents also indicated the relative importance of various motivating factors to eat beans. Table 2.5 shows how respondents rated the importance of nutritional factors of beans. As shown in the table, protein and fiber were deemed the most important nutritional factors by respondents. The total number of important responses (i.e., the sum of “very important” and "somewhat important") was similar for fiber and protein, *n* = 809 and *n* = 812, respectively. The average importance score of protein was slightly higher than that of fiber though, also with a smaller standard deviation. Although the low-calorie nature of beans and other pulses was still important to respondents, it ranked as the least important of the nutritional motivators.

Table 2.5. Importance of nutritional motivators to Food Habits Survey respondents.

Motivator	Average* ± SD	Mode	Total Important** [*n* (%)]
Protein	4.39 ± 0.81	5	812 (86.8)
Fiber	4.29 ± 0.85	5	809 (86.2)
Micronutrients	4.21 ± 0.87	5	753 (80.6)
Low-fat	3.83 ± 1.09	4	620 (66.2)
Low-calorie	3.65 ± 1.10	4	544 (58.2)

Participants were asked "How important are the following nutritional aspects of pulses in motivating you to eat them?" *A higher average score indicates greater importance, with 1 = very unimportant, 2 = somewhat unimportant, 3 = neutral, 4 = somewhat important, and 5 = very important. **Very important and somewhat important responses were added together, to show the total number of respondents who indicated that this nutritional factor was important in motivating them to eat pulses, with results displayed as *n* (%).

Table 2.6 lists other motivational reasons for eating pulses, beyond the nutritional factors shown in Table 2.5. Based on the results shown in Table 2.6, taste was the most important factor for survey participants, with nearly 91% indicating this was important. Taste was followed by health benefits, with almost 85% indicating this was important to them. The affordable price point of pulses and their environmental and sustainability benefits were rated as similarly important, with average ratings of 3.99 and 3.98, respectively. Gluten-free ranked dramatically less important compared to other factors, with the most common response option selected being "very unimportant."

When asked about potential barriers to pulse intake, the most important barriers were long cooking times (with *n* = 472, 50.5% ranking this as important), concerns about flatulence (*n*

= 366, 39.0%), and being unsure how to prepare pulses (*n* = 287, 30.8%). However, after conducting the Extension validation class, it was determined that the wording of this question and response options were confusing to participants. The question asked: "How important are the following in discouraging you from eating pulses? 'Important' reflects a factor that discourages you. 'Unimportant' represents a factor that does not discourage you." Needing to rank the importance of barriers as important is similar to a double negative structure, and this appeared to confuse some individuals. Therefore, results of the ranking of importance of barriers are not shown in detail here. More detailed responses about the importance of certain barriers can be found in the results of the final Extension class, after question wording was modified for improved clarity.

Table 2.6. Importance of other motivators to Food Habits Survey respondents

Motivator	**Average* ± SD**	**Mode**	**Total Important** [*n* (%)]**
Taste	4.52 ± 0.75	5	851 (90.9)
Health benefits	4.30 ± 0.81	5	790 (84.5)
Affordable	3.99 ± 1.00	5	679 (72.5)
Sustainability	3.98 ± 1.00	5	668 (71.4)
Family & friends***	3.51 ± 1.14	4	509 (54.6)
Tradition/cultural****	3.20 ± 1.15	3	370 (39.5)
Gluten-free	2.46 ± 1.37	1	227 (24.3)

Participants were asked "How important are the following reasons in motivating you to eat pulses?" *A higher score indicates greater importance, with 1 = very unimportant, 2 = somewhat unimportant, 3 = neutral, 4 = somewhat important, and 5 = very important. **Very important and somewhat important responses were added together, to show the total number of respondents who indicated that this nutritional factor was important in motivating them to eat pulses, with results displayed as *n* (%). ***Survey wording was "family and/or friends likes eating beans and other pulses." ****Survey wording was "part of traditional food choices/cultural reason."

A question about barriers to cooking with dry pulses was also asked, but in a different format. Respondents were asked whether "any of the following ever prevented you from cooking with dried pulses? Please select all that apply." Response totals are shown in Table 2.7. The numbers align with the literature, indicating that long cooking times can pose a major barrier to pulse consumption.

Table 2.7. Barriers to cooking dry pulses.

Barrier	*n* (out of 940)*
Long cooking times	449
Unsure how to cook dry	158
Prefer canned	118
Don't like cooking	105
Don’t have cooking equipment	68
Don’t like pulses	51

*This is the number of individuals who selected yes when asked, “Have any of the following ever prevented you from cooking with dried pulses? Please select all that apply.”

3.1.4. Topics of Interest and Preferred Resource Format

The main purpose of the survey was to use findings – in conjunction with expert input and the literature review – to inform the development of the Extension class and toolkit resources. Thus, respondents were asked about topics of interest and preferred formats. Nearly 68% of respondents indicated interest in electronic handouts and 41% in printed resources. Accordingly, handouts were developed to be posted and distributed in an online format, but formatted as a PDF such that they could easily be printed. The percentage of people who indicated interest (i.e., the sum of those who indicated very or somewhat interested) in the following topics was as follows: 1.) 74.3% indicated interest in tips to include more pulses in their diets; 2.) 62.5% in myth busting (i.e., addressing myths and misinformation related to pulses); 3.) 61.0% in nutritional information; 4.) 54.5% in flatulence and ways to address this concern; and 5.) 48.9% in the effects of elevation on the cooking of dry pulses. As many participants either did not regularly cook dry pulses and/or did not live at high elevation, it is reasonable that this topic would be of the least interest.

Most individuals indicated that they would prefer an online class (n = 555, 59.0%) to an in-person class (n = 136, 14.5%), and n = 231 (24.6%) selected no preference. Due to this response and the ability to reach audiences with a wider geographical spread, it was decided to conduct the class online.

3.2. CSU Extension Bean Toolkit

3.2.1. Bean Calendar

One thousand copies of the Bean Appetit calendar (see Figure 2.1) were printed and broadly distributed. Although most of the calendars were given to Coloradans due to the nature of the project and its ties to CSU Extension, calendars were sent to people in at least 24 states, 6 countries (USA, Canada, Mexico, South Korea, United Kingdom, Chile), and 4 continents. Some Extension agents gave them away as incentives and prizes to participate in community programs.

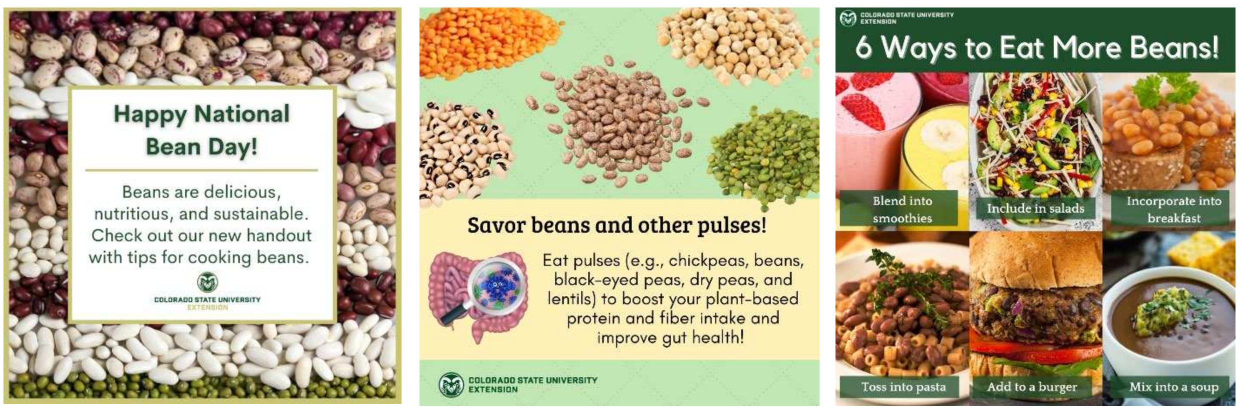
Spread the love with bean toast, a quick and tasty nutrient- and fiber-packed meal for any time of day.

(a) (b) (c)

Figure 2.1. Bean calendar. **(a)** Bean Appetit calendar front cover; **(b)** back cover (the final printed version also contains the logo of the printing company in the bottom right); **(c)** an example of text and the associated QR code that links to the Food Smart Colorado website for the associated recipe post (in this case: a bean toast).

3.2.2. Social Media

Monthly social media posts were published on Food Smart Colorado's social media platforms, Instagram and Facebook. Figure 2.2 shows examples of the images, which were also supplemented by captions with helpful information and links to accompanying pages on the Food Smart Colorado website when relevant. For instance, the post shown in Figure 2.2a read, "Happy National Bean Day!! To celebrate, check out our new handout with tips for cooking dry beans: https://foodsmartcolorado.colostate.edu/cooking-dry-beans/. Beans are a great way to start the new year off right, and then to continue enjoying all year long." Figure 2.2c had the caption, "No matter whether you made a new year's resolution to include more beans this year, or you are a longtime fan of beans, it's always nice to try new bean dishes. Beans are incredibly versatile and easy to incorporate in any meal of the day - salads, soups, pastas, and more!" Related hashtags were also included.



(a) (b) (c)

Figure 2.2. Food Smart Colorado social media bean post images. **(a)** The January 2023 post directed people to the newly created bean handouts that were part of the Extension toolkit; **(b)** This March 2023 post shared nutritional and human health benefits of beans, major motivators for consumption; **(c)** This post from June 2023 was intended to inspire audiences with the culinary versatility of beans, to help address the barrier of unfamiliarity.

Other organizations and individuals shared the social media posts, expanding audience reach. As of July 13, 2023, the post with the highest reach (n = 669) and engagement (n = 69) was from February 2022. This post shared the bean toast recipe from the Bean Appetit calendar, and the caption read, "February is American Heart Month! Did you know that beans are associated with reducing the risk of heart disease? Plus, they are delicious and versatile. Check out this quick and tasty recipe for Bean Toast: https://foodsmartcolorado.colostate.edu/bean-toast/." The reasons for posting this recipe included: 1.) inspiring people with new ways to use beans; 2.) offering a quick, simple recipe that is more likely to appeal to people because it is easy to make; and 3.) highlighting the association of beans and heart health [6,48] and linking it to the larger narrative of American Heart Month.

3.2.3. Bean Handouts

Two new CSU Extension handouts were developed as part of the Extension Bean Toolkit. "Cooking Dry Beans" (find online: https://foodsmartcolorado.colostate.edu/cooking-dry-beans/) explained how to purchase, store, and cook dry pulses. "Tips for Cooking with Dry Beans and Other Pulses" (find online: https://foodsmartcolorado.colostate.edu/tips-for-cooking-with-dry-beans-and-other-pulses/) offered specific tips to shorten cooking time. Details on the development of this second handout are detailed in our recent publication about consumer-accessible ways to cook dry pulses more quickly [171]. The handouts were distributed as part of the Extension class, as well as being made available online at Food Smart Colorado at the aforementioned links.

3.2.4. Extension Bean-Related Blog Posts

In 2022, the lead author wrote three pulse-related blogs on Live Smart Colorado, a CSU Extension blog run by Family & Consumer Science Extension Agents and Specialists at CSU that publishes weekly. For example, one of the blogs was about how beans can be a secret ingredient in smoothies: https://livesmartcolorado.colostate.edu/try-adding-this-secret-ingredient-to-your-smoothies/. This blog post was one of the most successful Live Smart Colorado posts of the year, ranking number six for top blog posts of 2022. Blogs written earlier in 2022 and in previous years were also evaluated, meaning they had more time to accumulate views throughout the year. Despite being published in June, the smoothie blog still had one of the highest rankings. This suggests that consumers were interested in this topic, which directly relates to both a barrier (i.e., unfamiliarity) and motivating factors (i.e., culinary versatility and boosting nutrition through beans) for pulse intake.

3.3. Extension Class

Sociodemographic data was only collected on the pre-survey, thus data was not collected for all participants in the validation class because not everyone completed the pre-survey. Therefore, demographic data is only shared for the final class, which had more participants and a complete data set of demographics. As this class was conducted through CSU Extension, most participants were from Colorado (83.7%). Of the 69 Coloradoans who completed the survey and chose to list their county, attendees came from 22 of Colorado's 64 counties. About 88% of participants were female and around 90% White. The largest age group was 60-69 years of age (about 31%), which falls within the average age found for Extension volunteers like Master Gardeners [184]. This was likely because CSU Extension played a key role in helping recruit participants. More detailed participant demographics for the final class are provided in Supplementary Materials S2.7.

On the validation class pre-survey, participants were also asked about what they hoped to learn in the class. This was one way to confirm whether the Food Habits Survey and literature review facilitated successful emphasis on topics of consumer interest. Indeed, responses aligned well with class content, grouping into the following categories:

- Cooking and preparation tips (example quotes: "Tips to spend less time cooking dry beans," "More about beans and ways to cook dry beans instead of canned," and "More about easiest way to prepare dry beans incl ways to shorten prep time, resources for recipes, resources for buying local");

- Health information (example quotes: “Health benefits, how to prepare and recipes,” and “Ways to reduce gas in beans, ways to add beans to foods or recipes, frequency of eating that is the best for health”);
- Benefits for the planet (example quote: “Ways that growing beans are beneficial to us and the earth”);
- Diverse ways to use beans/recipes (example quotes: “I cook pintos 95% of the time and would like more diversity,” “New recipes and ideas for preparing pulses,” and “Perhaps some more ways to incorporate dry beans other than the traditional way I fix them, and to broaden which dry beans I have in my diet”); and
- Convenient, tasty ways to eat beans more regularly (example quotes: “Fast cooking tasty recipes,” “I'd also like to have some easy to prepare recipes,” and “Tasty meals and snacks using pulses so I can consume more.”)

3.3.1. Changes to Consumption and Bean Preparation Habits

The validation class surveyed participants at multiple time points, allowing for follow-up about changes to consumption and preparation behavior. Forty participants filled out the pre-survey and 1-month follow-up surveys, which asked about frequency of consumption and usage of dry versus canned pulses. There was a significant increase in the frequency of pulse intake ($p = 0.004$), as shown in Figure 2.3. Changes seen on the higher end of pulse consumption were minor, i.e., similar numbers of participants consumed pulses 4-6 days per week or every day both before and 1 month after the class. However, there was a large jump in the number of individuals eating pulses 1-3 days per week, instead of only 1-3 days per month or less than 1 day per month. In addition, 40.4% of respondents indicated that as a result of the class, they “started cooking with dry pulses more often (as opposed to canned).”

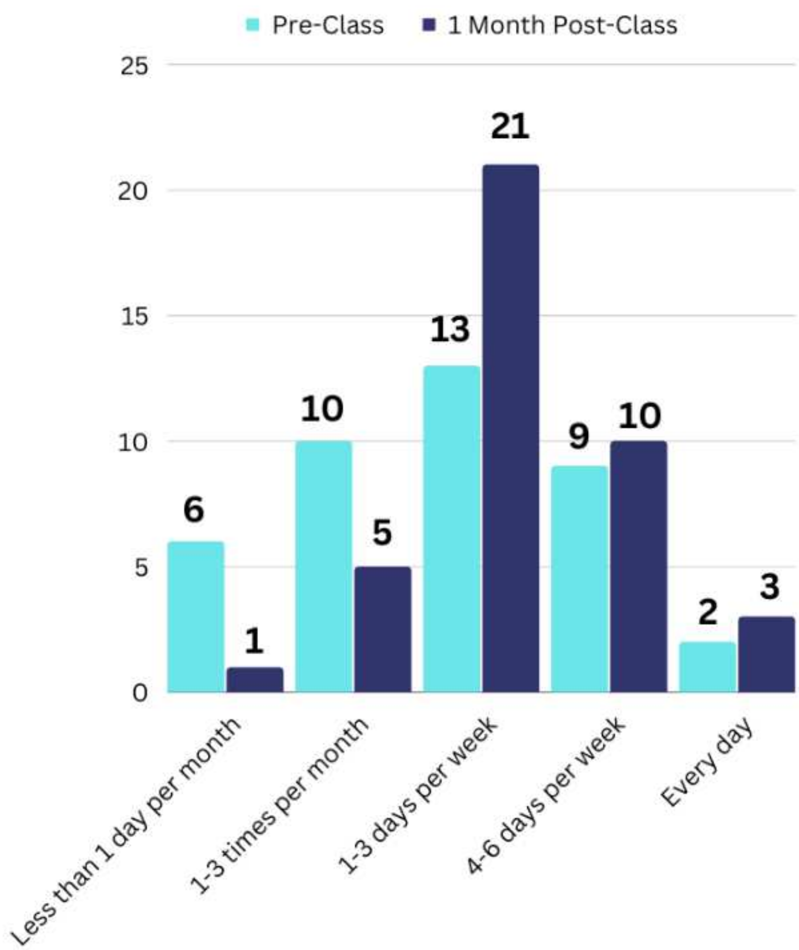


Figure 2.3. Changes in frequency of pulse consumption after participating in the validation class. "Less than 1 day per month" is shortened in the figure, but the full response option read "several days per year, but less than 1 day per month." No participants selected "never" as the response for how often they eat pulses. The actual numbers of responses out of *n* = 40 are shown above each column.

Due to only having one time point for the survey, it was not possible to assess short-term changes in behavior for the final class as was done for the validation class. However, participants were asked if they were "more likely to regularly eat more beans and other pulses" as a result of the class. The majority of participants indicated yes (*n* = 63, 73.3%). Part of why this number is not higher is that some participants commented that they already ate high levels of pulses and therefore would not be increasing this further. For example, one individual stated, "I eat quite a few as is." Similar sentiments were expressed in the validation class survey, such as "I eat dried beans twice a day [lunch + dinner] and this has not changed due to the class."

3.3.2. Changes to Knowledge and the Importance of Motivators and Barriers

The final class assessed participant knowledge about three different topics, as well as the importance of several motivators and barriers to pulse consumption (n = 86 completed the survey, although actual Zoom participant count was about 130). Table 2.8 shows changes to participant knowledge before and after the class. Significant increases in participant knowledge occurred for all three categories. The greatest improvement was seen for knowledge of the nutrition and health benefits of beans and other pulses.

Table 2.8. Pulse knowledge before and after participating in the final Extension class.

Knowledge of Pulse Nutrition and Health Benefits	**Pre: *n* (%)**	**Post: *n* (%)**
1 (low)	9 (10.5)	0
2	19 (22.1)	0
3	29 (33.7)	2 (2.3)
4	22 (25.6)	30 (34.9)
5 (high)	6 (7.0)	53 (61.6)
Average score ± SD	2.96 ± 1.10	4.60 ± 0.54
Difference (*p*-value)		1.64 (< 0.001)
Knowledge of Pulse Versatility*	**Pre: *n* (%)**	**Post: *n* (%)**
1 (low)	6 (7.0)	0
2	31 (36.0)	1 (1.2)
3	23 (26.7)	9 (10.5)
4	21 (24.4)	31 (36)
5 (high)	4 (4.7)	44 (51.2)
Average score	2.84 ± 1.03	4.39 ± 0.73
Difference (*p*-value)		1.55 (< 0.001)
Knowledge of How to Prepare Dry Pulses	**Pre: *n* (%)**	**Post: *n* (%)**
1 (low)	9 (10.5)	0
2	17 (19.8)	0
3	25 (29.1)	8 (9.3)
4	24 (27.9)	35 (40.7)
5 (high)	10 (11.6)	42 (48.8)
Average score	3.11 ± 1.18	4.40 ± 0.66
Difference (*p*-value)		1.29 (< 0.001)

*The question asked about "knowledge of ways to use beans/pulses in various dishes."

The importance of motivators and barriers before and after participation in the final class was also evaluated, as shown in Table 2.9. High numbers for motivators represent strong motivation and high numbers for barriers are strong barriers (i.e., lower numbers indicate that something is not a big barrier). Before the class, the most important nutritional motivator was protein, but after the class, dietary fiber was the most important. Overall, micronutrients (i.e., vitamins and minerals) saw the greatest increase in importance among the nutritional motivators. For the other motivators (i.e., non-nutritional motivators), before the class, taste was ranked as the most important. However, after the class, both human health benefits and sustainability ranked higher than taste. Even though "local" had the lowest of the importance rankings post-class, it increased by the greatest amount. For barriers before the class, long cooking times were the greatest barrier, followed by being unsure how to prepare pulses. People appeared to like the taste of pulses and thus did not report that taste discouraged them. All barriers saw a decrease in importance after the class, meaning they less strongly discouraged people from eating pulses. The greatest decreases in importance were seen for the top two barriers, long cooking time and unsure how to prepare, indicating that the class successfully helped mitigate these barriers.

Table 2.9. Importance of motivators* and barriers[**] before and after participating in the final Extension class.

Nutritional Motivators	**Pre: Average ± SD**	**Post: Average ± SD**	**Difference *(p-value)***
Protein	4.06 ± 0.97	4.70 ± 0.67	0.64 (<0.001)
Fiber	3.99 ± 0.93	4.76 ± 0.65	0.77 (<0.001)
Micronutrients	3.56 ± 1.06	4.71 ± 0.70	1.15 (<0.001)
Low-fat	3.51 ± 1.13	4.30 ± 1.02	0.79 (<0.001)
Low-calorie	3.47 ± 1.00	4.21 ± 1.03	0.74 (<0.001)
Other Motivators	**Pre: Average ± SD**	**Post: Average ± SD**	**Difference *(p-value)***
Taste	4.01 ± 0.91	4.51 ± 0.72	0.50 (<0.001)
Health benefits	3.70 ± 1.01	4.85 ± 0.45	1.15 (<0.001)

Table 2.9. Importance of motivators* and barriers** before and after participating in the final Extension class *(cont.)*.

Other Motivators	**Pre: Average ± SD**	**Post: Average ± SD**	**Difference (*p-value*)**
Affordable	3.76 ± 0.96	4.42 ± 0.79	0.66 (<0.001)
Sustainability	3.32 ± 1.07	4.63 ± 0.60	1.31 (<0.001)
Local	3.04 ± 1.10	4.41 ± 0.82	1.37 (<0.001)

Barriers	**Pre: Average ± SD**	**Post: Average ± SD**	**Difference *(p-value)***
Long cooking times	3.08 ± 1.34	1.97 ± 1.03	-1.11 (<0.001)
Gas/flatulence	2.67 ± 1.41	1.99 ± 1.08	-0.68 (<0.001)
Unsure how to prepare	2.95 ± 1.36	1.81 ± 1.01	-1.14 (<0.001)
Family/friends don’t like	2.24 ± 1.35	1.81 ± 1.10	-0.43 (<0.001)
Don’t like the taste	1.73 ± 1.08	1.60 ± 0.90	-0.13 (0.177)

*Participants ranked how important the listed aspects were in motivating them to eat pulses. A higher score indicates greater importance, with 1 = very unimportant, 2 = somewhat unimportant, 3 = neutral, 4 = somewhat important, and 5 = very important, therefore, a high average score means this aspect was considered highly motivating. **Participants were asked how important the listed aspects were in discouraging them from eating pulses. A 1 = does not discourage, 2 = very minimally discourages, 3 = minimally discourages, 4 = somewhat discourages, 5 = highly discourages; thus a higher number means this factor is considered a strong barrier, and a lower number means the factor does not greatly discourage participants from eating pulses.

3.3.3. Themes in the Free Response Data

Recurring themes were found in the data. In the tables below, quotes from the validation and final class have been combined because class content was the same. Additional participant quotes demonstrating these themes are provided in Supplementary Materials S2.8. Table 2.10 groups responses into themes for two separate, but similar, questions: 1.) “What information shared, if any, most motivated you to eat more pulses?”; and 2.) “What did you find most interesting about the class?”

Table 2.10. What information participants found most motivating and interesting about the Extension class.

Theme	Motivator* – Example Quote	Interesting** – Example Quote
Health Benefits	• "Health benefits! I have high cholesterol and see that adding this fiber from pulses in as many ways as possible could be very beneficial for weight management and hopefully cholesterol reduction." • "The health benefits were more than I realized."	• "Significant benefits of consuming beans from the standpoint of both heart and gut health." • "Understanding the health benefits and your gut will adjust to eating more beans."
Nutrition	• "The stats on dietary fiber were quite eye-opening." • "I didn't appreciate just how much more fiber they have than oats and other grains." • "I learned that pulses offer more nutrients than my usual breakfast of oat bran, so now it's 'beans for breakfast!' for me!"	• "The amount of fiber and protein in beans. I knew they were good for you, but I never really knew the exact reason why." • "The entire class was interesting, but the fact about our dietary fiber gap really surprised me. Also that the pulses are so much higher in protein and fiber."
Environmental Benefits	• "The tremendous health benefits for low cost, both monetary and environmental." • "How good they are for the environment as compared to meat."	• "Interesting about drought tolerant which is more and more important." • "Benefits to the soil and environment."
Affordable	• "Cost-very budget friendly." • "They are a cheaper source of protein."	• "That beans are a triple winner: highly nutritious, inexpensive, and easy on our environment."
Culinary Versatility	• "I appreciated the information and ideas of adding beans to a smoothie or making a bean dip. So many fun new ways to incorporate getting them into my diet." • "The creative ways to add pulses to dishes and the beautiful and very appetizing pictures of pulses in dishes."	• "So many different uses for beans and a reminder to use them in salads!" • "Aquafaba!!! I had no idea this was a thing or that it can be whipped like a meringue." • "Using bean flour." • "I learned about the Mayocoba beans. I had never heard of them before and saw that they were at Walmart so will see if I can find them."

Table 2.10. What information participants found most motivating and interesting about the Extension class *(cont.)*.

Culinary Versatility *(cont.)*	• "Use of pulses for every meal. Going to personally challenge myself to incorporate beans into breakfast and smoothie options."	
Local	• "I had no idea that Colorado grew and produced so many beans!" • "That there are a wide range of pulses grown locally."	• "I didn't realize Colorado grew so many beans and they can be purchased locally. I'll look into those. I also want to try the Mayocoba beans, these are new to me."
Presenter Enthusiasm	• "Honestly Chelsea's enthusiasm and passion alone was totally motivating to eat more beans!" • "Chelsea's enthusiasm, makes me want to try more beans."	• "The presenter was marvelous! She was very upbeat and engaging...and knowledgeable. I bet she could get anybody to eat beans!" • "The enthusiasm of the speaker - seriously, makes me want to buy bean and get cooking!"

*Responses to the question, "What information shared, if any, most motivated you to eat more pulses?" **Responses to the question, "What did you find most interesting about the class?" Additional participant quotes are provided in Supplementary Materials S2.8.

In addition to the themes outlined in Table 2.10 above, several participants commented that the tips provided for reducing gas helped motivate them to eat more pulses. For example, "that soaking them can reduce flatulence" and "learning what a good source of protein they are, and ways to lessen gassy side effects" were both responses to the survey question about motivation. Moreover, three additional topics were repeatedly mentioned when asked about what they found most interesting in the class. They are listed separately here and not in the table because the same theme was not found for responses to what participants found most motivating.

1. **Clarification about terminology**. Many participants were not previously familiar with the term 'pulse' (example quotes: "Definition of Pulses - did not know that term(!!)" and "That after all these years of life, I was not aware of a 'pulse'");

2. **Myth busting**. Addressing common bean myths, such as that adding salt always slows down cooking (example quote: "The idea of adding salt - that it doesn't slow down the cooking of beans"); and
3. **Format**. Participants enjoyed the class format and said that it held their interest (example quotes: "I liked hearing and seeing a little about everything. It kept me focused," "The topics covered in the class were connected seamlessly to the next topic resulting in an attention grabbing one hour!" and "It was a very cool and informative class, I really enjoyed the pacing of it, the easily digestible info, and cooking tips and recipes!").

Table 2.11 highlights the responses to the question that was asked on the post-survey for the validation class and the survey for the final survey, "What new ways, if any, are you looking forward to including pulses in meals?" For the validation class 1-month follow-up survey, participants also responded to the question, "If you have tried a new way(s) to eat pulses since the class, please share what it was and what you thought." Therefore, the table shows ways in which participants reported having actually acted upon their responses regarding what pulse dishes they were looking forward to trying.

Table 2.11. New ways in which class participants looked forward to trying and/or did try pulses.

Type of Dish	Looking Forward To* – Example Quote	New Dish They Tried** – Example Quote
Smoothies	• "My kids love smoothies so we'll add to smoothies." • "Me and those in my household very open to trying pulses in smoothies!"	• "I added beans to a smoothie. It was great! I shared that with others who said they would be interested in trying that as well."
Pulse Products	• "Bean based pasta" • "Pasta. Whole wheat pasta is not very good. Just discovered chickpea pasta and will try it."	• "Started buying chickpea chips instead of corn chips."

Table 2.11. New ways in which class participants looked forward to trying and/or did try pulses *(cont.)*.

Type of Dish	Looking Forward To* – Example Quote	New Dish They Tried** – Example Quote
Pulse Products *(cont.)*		• "My husband and I tried chickpea pasta … instead of the traditional white pasta we get. It was really good! Much better than the whole wheat pasta."
Baking & Desserts	• "The idea of making desserts more nutritious has got me inspired." • "I will try to include beans in my diet more and in baking! I made black bean brownies for the first time right after the talk." • "I like the idea of the chickpea flour for baking, too."	• "Black bean brownies. Loved them!" • "Black bean chocolate mousse. Delicious, dense and filling."
Combining with Meat	• "Half and half when we would typically use all beef." • "Adding them more to meat dishes."	• No quote received
Breakfast	• "Breakfast! Never considered that" • "I am really going to try and eat a lot more beans, and incorporate them into more breakfasts and lunches since I just have had them mainly for dinners and in soups."	• "Pulses in breakfast foods was new to me. I'm still getting used to the texture. It's a bit heavy."
Adding to Favorite Dishes	• "I want to try some of the recipes that were shown and try adding pulses to meals we already eat." • "Adding beans to meals we already make." • "I plan to toss them into whatever I make."	• "Before the class I only ate them as a side dish or in chili or bean soup. I tried making a bean dip and it worked but I'm too lazy for that. Now I just try add a bit to every lunch and dinner. For instance I add them to my salads whether that be a meal salad or a side salad."
Salads	• "More use in salads!" • "Adding beans to salads. I love one meal salads!"	• "Added canned chickpeas to a salad--very good."
Dips	• "I really like hummus and think that it will be easier to incorporate it into more meals as a start."	• "I tried the spread with the olives, and it was delicious!"

Table 2.11. New ways in which class participants looked forward to trying and/or did try pulses *(cont.)*.

Type of Dish	Looking Forward To* – Example Quote	New Dish They Tried** – Example Quote
Dips	• "Easy - first thing I'm going to try: Olive-y Bean Dip!!! YUM!"	• "Made hummus with black beans."
Aquafaba	• "Using cooking water for egg whites." • "I want to try whipping bean broth. Will use bean broth in making soup."	• "Used the bean cooking water in a smoothie."
With Other Grains & Carbohydrates	• "Adding them to pasta" • "Combing them with mashed potatoes"	• "I have put in with my oatmeal!"
New Pulse Varieties	• "Try the Mayocoba beans. Never heard of them before." • "Honestly I bought a bunch of beans and am looking forward to trying them all in different ways!"	• "I tried northern beans for the first time! Loved them."

*Responses to the question, "What new ways, if any, are you looking forward to including pulses in meals?" **For those who participated in the 1-month follow-up survey for the validation class, responses to the question, "If you have tried a new way(s) to eat pulses since the class, please share what it was and what you thought." The responses do not line up, i.e., responses of what participants actually tried have not been matched to what they indicated they are interested in trying, as these responses came from both the validation and final class and multiple surveys. Additional participant quotes are provided in Supplementary Materials S2.8.

In the surveys, participants also provided information about changes they intended to make to pulse preparation habits and intake. This information is displayed in Table 2.12. Quotes like "needing something that cooks more quickly" highlight the importance of convenience for consumers, so that pulses can fit into their busy lifestyles.

Table 2.12. Intended changes to pulse intake and preparation habits.

Theme	Example Quote
Intake	• "I obviously need to eat way more and make them a regular part of my diet." • "I would like to start the journey towards 2 c. of pulses each day." • "Found the presentation very informative and am definitely incorporating more pulses into my diet."
Use Variety	• "Look into other options when needing something that cooks more quickly (lentils instead of black beans)." • "I had never thought of adding white beans to potatoes, macaroni and kidney beans, bean toast, black beans to a chocolate smoothie, or to egg scrambles or breakfast burrito. My mindset before had been just have soups with beans, add beans to taco salads or as a side dish. So many more choices now so thank you!"
Cooking Dry Pulses	• "I've never cooked dry beans so I'm very excited to try." • "Using more of dry pulses"
Soaking	• "Adding salt to soaking!" • "Will soak beans to reduce flatulence." • "I have never tried quick soak method shared in the class today so will give it a try also."
Cooking Method	• "The slow cooker seems like a good option to try." • "I will try other cooking methods."
Freezing	• "Can cook enough to freeze and have on hand quickly." • "I also like the idea of saving time by cooking lots and freezing it."

In the 1-month follow-up survey for the validation class, several individuals commented about having implemented some of the preparation and intake habits mentioned in Table 2.12. For example, one participant tried cooking beans on the stovetop, as opposed to the slow cooker, and reported, "I had always cooked pintos in the slow cooker and thought they were a little mushy. I cooked them on the stove top and liked them much better!" Another individual stated that they, "Froze cooked beans (made from dried beans) to reheat and eat again."

4. Discussion

4.1. Food Habits Survey

4.1.1. Pulse Intake Frequency and Preparation Habits

The majority of participants were from the United States, and 46.6% of respondents chose the option that indicated they consume pulses 1-3 days per week. Although this does not provide an exact number of days per week that pulses were consumed, it falls within the range of frequency of consumption found in other studies. For example, the Global Diet Quality Project shows that 39% of individuals in the United States indicated having eaten pulses the day before they were surveyed [185]. Also, a study by Mitchell and colleagues found that in 2013-2014, approximately 24% of adults ate pulses at least once over the intake period of 2 days [159]. This number is higher than a previous study by Mitchell, which reported that only 7.9% of Americans ate pulses on any given day [8].

Findings about the average frequency of pulse intake by dietary pattern (see Table 2.2) also align with prior research. Those following vegetarian and vegan diets tend to consume pulses more frequently [130,131,164]. Work by Henn and colleagues revealed a similar trend, with vegetarians and vegans consuming pulses more often, in addition to eating a wider variety of pulses [130]. Henn and team also provided a dietary pattern response option of flexitarian, defining it as "vegetarian with occasionally meat or fish." In the research herein, flexitarian was not provided as a response option, but instead there was the option of "pescatarian." In the future, it could be helpful to still include pescatarian, but to separate omnivores into flexitarians with lower meat consumption and those with higher meat consumption.

In a recent survey of university students (n = 1433) in the United States aged 18-33, 66% of respondents indicated they soaked pulses before cooking, and 66% prepared them on the stovetop, 17% in a pressure cooker, and 9% in a slow cooker [164]. Of the 882 individuals in this study who were asked about how they cooked dry pulses, 594 indicated that they regularly used the stovetop, or 67% of respondents. Although this number matches that seen by the study among college students, the percentage that indicated using a slow cooker differed, with 350 of the 882 individuals (~40%) indicating regular use of a slow cooker. These differences could be due to how the question was asked, with the current study allowing individuals to select more than one option for how they regularly cook pulses. In addition, the average age of respondents was higher in this study, so they may have better access to kitchen tools, like a slow cooker. Conversely, college students may not own these tools and therefore may rely more heavily on simple cooking practices that only require a pot and the stove.

With regards to preparation of dry pulses, the survey supported that there is confusion over the use of salt. Indeed, the impacts of salt on cooking time are one area of misinformation and myths about dry pulse cooking, as addressed in our recent paper [171]. While some people indicated not using salt due to thinking it prevents pulses from softening (n = 137), almost the exact same number (n = 139) reported they use salt because it does help with softening dry pulses. Development of resources such as the CSU Extension handouts associated with this research can help mitigate this problem.

4.1.2. Pulse Preference and Form in Which Pulses Are Eaten

When asked about their favorite types of pulses, dry beans ranked as having the highest participant liking, followed by chickpeas. Other studies in North America have found that black beans, lentils, pinto beans, and chickpeas are the most common pulses eaten [150,164,186]. In the current study, cowpeas (also called black-eyed peas) were the least familiar pulse, with nearly

10% of people indicating they had not tried cowpeas before. This highlights the potential to increase consumer exposure to and awareness of how to use this type of pulse.

Previous literature has concluded that unfamiliarity with pulses and how to use them poses a major barrier to higher intake [128,131,133]. Examining the ways in which respondents ate pulses during the last year (see Table 2.4) helps better understand current consumption habits and provide insights about what to highlight to consumers. For instance, the two least commonly selected response options were "breads, crackers, or pastas made with pulse flour" (n = 407, ~43%) and "dessert" (n = 192, ~20%). It appears that consumers are not utilizing these ways to include beans in their diets more regularly, potentially due to simply not being aware of these options. Highlighting these options through the toolkit and class could help mitigate unfamiliarity and expand consumer awareness of pulse versatility. This is reflected by the consumer interest expressed in trying these types of pulse dishes after completion of the Extension class.

Dishes like soups, chili, and refried beans were selected by more participants (n = 705, 697, and 655, respectively). This aligns with findings from Doma and colleagues, that found that when asked about their favorite recipes, chili and soup were the most commonly reported responses [133]. The manner in which the question was asked in the Food Habits Survey does not allow assessment of frequency of consumption of these dishes. However, when Winham and colleagues asked participants to indicate "eat often," "have eaten," and "never eaten" with regards to types of pulse dishes, "chili made with beans" had the highest percentage of "eat often" responses at 35.3% [164].

To address the barrier of unfamiliarity, recipes associated with the bean calendar were created, highlighting the potential to use pulse-based pastas, desserts, and salads. Versatility was covered in the class through emphasizing examples of dishes, the various forms of pulses (e.g., whole, mashed, flour), and ways to stock the pantry and home (e.g., dry, canned, frozen, and pulse-based pastas and other products).

4.1.3. Motivators and Barriers to Pulse Intake

A key purpose of the survey was to determine key motivators and barriers for the potential target audience of the Extension Bean Toolkit resources and class. Of the nutritional attributes of pulses (see Table 2.5), protein ranked as the most important, followed closely by fiber. A study on factors that influence pulse consumption in Canada also found that both protein and fiber are of key importance, although protein tends to rank above fiber [131]. In a recent study in Poland (n = 1027), 72% of participants perceived pulses to be a good source of protein. However, it is notable that this was a more common perception for women than men, with 81% of women agreeing versus only 62% of men [132].

With regards to other (i.e., non-nutritional) motivators, taste was the most important, followed by health benefits (see Table 2.6). These two response options had the lowest SDs, indicating that there was less of a spread in respondent choices and more agreement about the importance of these aspects. Other studies have also found taste and sensory aspects to be major motivators, along with health benefits [130,131,133,146]. For example, a study on five European countries found that overall health was the major driver of consumption, followed by sensory preferences [130]. Doma and team examined bean consumers (defined as those who consume beans on a daily or weekly basis) and non-consumers (defined as those who consume beans on a monthly basis or never) [133]. They found that the top two motivators were nutritional value and taste and/or texture [133]. Interestingly, the order of importance was reversed for these two groups, although the differences were slight. The authors showed that 93.8% and 92.2% of bean consumers reported that nutritional value and taste were important, respectively. Yet, non-consumers ranked taste as more important (83.6%) than nutritional value (81.2%).

The average ranking of "gluten-free" was 2.46 on a 5-point Likert scale and had the highest SD. This suggests that this attribute was largely unimportant to participants and that the perceived importance varied more widely than other motivators listed. For those not following a gluten-free diet, it is understandable that this attribute may not be important, as gluten-free is more of a niche market [131]. However, there also appears to be a lack of awareness that pulses are naturally gluten-free. For example, even among registered dietitians surveyed in a recent study, about 13% of respondents were unaware that those with celiac disease could eat beans [187].

With regards to barriers to cooking dry pulses, the major barrier was long cooking time (n = 449, ~48%). Long cooking time is an established barrier to pulse intake [128,129,171]. The next most common barrier to cooking with dry pulses was simply being unsure of how to cook dry pulses. Overall, this suggests that consumer resources with practical cooking information and tips on how to reduce cooking time could be helpful, and therefore they formed part of the resulting Extension Bean Toolkit.

4.2. CSU Extension Bean Toolkit and Class

The goal of the Extension Bean Toolkit was to implement a translational research approach and leverage the Extension network to reach a wider audience with information to encourage increased pulse consumption. The IMB model, findings from the Food Habits Survey, and a review of the literature provided key insights for toolkit development. The design of a toolkit and class differentiate this research from prior studies. Previous research focuses on investigation of motivators and barriers of pulse intake, but not on addressing consumer interests and barrier mitigation. The resources developed as part of the Extension Bean Toolkit have the potential for long-term impact through continued distribution through the Extension network for years to come. Moreover, this translational research can serve as a model for future outreach research through Extension or other organizations promoting healthy behavior change and public health.

A study on Canadian consumers found that, on an aided basis, "not knowing how to cook or prepare pulses" was one of the biggest limitations to consumption [131]. The same study examined consumer attitudes towards pulses and identified five distinct consumer groups. At one end of the spectrum, there were "Informed Champions" who already embrace pulses. "Disinterested Unreachables" were on the other end, making up a group that is unlikely to regularly incorporate pulses in their diets. The other three groups in the middle were determined to be the best segments to target when trying to increase pulse intake:

1. "Unexposed Reachables" have low consumption, largely due to lack of exposure to pulses. Health benefits resonate strongly with this group and it can be beneficial to teach them a variety of tasty, basic recipes.
2. "Forgetful Proponents" enjoyed pulses but needed a reminder to include them in their diets more frequently. Providing them with a wide variety of delicious ways and recipes in which pulses can be used was suggested. Additionally, it could be beneficial to remind them of the nutrition and health benefits of pulses.
3. "Health Driven Persuadables" find the taste, health, and environmental benefits of pulses appealing. The main barriers to higher consumption are that they do not know how to cook or prepare pulses and do not think about including them in meal planning. The authors recommended quick recipes to align well with the busy

lifestyles of this group. Teaching them how to cook pulses while communicating the health benefits of pulses – along with some of the environmental benefits – is the best way to reach this group.

The Extension Bean Toolkit includes a variety of resources that would appeal to these audiences, and to the fact that while unfamiliarity can be a barrier, culinary versatility is a motivator [128,130,133]. For instance, the Bean Appetit calendar contains creative pulse recipes, many of which are designed to be quick and easy. The calendar pages and associated social media posts included food photography, as recommended by the report from Canada, which emphasizes that "Colourful, delicious looking dishes are a must. Visually appealing pictures are key in any communications or messaging targeting the public – they will make people stop and take notice" [131] (p. 3). The report also states that a website address where consumers can find recipes is a critical component of communications. All of the bean calendar pages and the majority of the social media posts were associated with Food Smart Colorado website pages. The Extension handouts and class also detail the cooking and preparation of pulses, which would be especially important for audiences like the Health Driven Persuadables.

Social media can be a low-cost, effective way to broaden nutrition outreach [188]. For the posts in the toolkit, the health benefits of beans were a major focus. This aligns with the recommendation to focus on this and the fact that Food Habits Survey respondents indicated health as one of the main motivators to eat pulses. The environmental benefits were also mentioned, although they were not emphasized in as much detail as the health benefits. Out of the seven non-nutritional motivators assessed in the Food Habits Survey (see Table 2.6), sustainability/environmental benefits ranked fourth, or in the middle. The report from Canada also recommended that the environment be a secondary focus because preserving the environment is not likely to drive consumers to increase pulse intake, though it is important to many and is good to address [131]. Similarly, women in the previously mentioned survey of people in Polish cities recognized that pulses were environmentally friendly, but this knowledge would not impact their consumption [132].

4.3. Extension Class

4.3.1. Changes to Consumption and Bean Preparation Habits

A similar trend in changes to pulse consumption was seen with the Extension class as was with our recent Bean Cuisine citizen science project [161]. This is notable because whereas the Bean Cuisine citizen science work involved interacting with participants over an extended period of time, the Extension class only included a 1-hour online class and the accompanying surveys. Overall, the biggest change seen in both this work and the citizen science project was a large transition in the total number of individuals who ate pulses less frequently before participation to eating pulses 1-3 days per week. Yet, results were only significant for the Extension class and not the Bean Cuisine. This could partially be due to the fact that a greater number of class participants originally only ate pulses less than 1 day per month and saw an increase in consumption frequency to at least 1-3 days per week, whereas the baseline consumption frequency of citizen scientists was higher. When asked if they were "more likely to regularly eat more beans and other pulses," 73.3% of the Extension validation class participants indicated yes. This matches very well with the 71.4% of citizen scientists who marked yes on the same question [161].

The Bean Cuisine participants demonstrated an increase in the usage of dry pulses as opposed to canned [161]. This was also seen in the current research, where 40.4% of respondents indicated that as a result of the class, they "started cooking with dry pulses more often (as opposed to canned).” This suggests that the barriers of long cooking time and not being aware how to cook dry pulses [128,129] were mitigated through participation. When cooking dry pulses in the home, environmental impact also varies with cooking method and the amount cooked. For instance, cooking larger volumes at a time as opposed to a few smaller batches is one way to reduce carbon footprint [189].

Although several studies have found positive perceptions of canned beans [140,146], a recent study by Heer and Winham revealed that some Latinas have negative views of canned beans [150]. Due to the benefits of pulses for both human and environmental well-being, addressing negative perceptions is important because canned pulses represent a practical, convenient way to increase pulse consumption [190]. Dry pulses generally have a slightly lower environmental footprint than canned pulses – ranging from approximately a one- to fourfold difference – although this depends on factors like pulse type [190]. Yet, both canned pulses and dry pulses cooked in the home have a much lower environmental footprint than animal proteins [190]. Thus, it is important to highlight that choosing pulses as a dietary staple – whether canned or dry pulses cooked in the home – is an effective way for consumers to reduce their carbon footprint [105,190]. To help reduce or eliminate negative perceptions of canned pulses, tips for cooking with canned beans can be provided, e.g., drain and rinse canned pulses to reduce sodium [191]. Overall, canned pulses can be more convenient than dry pulses [190], and the goal of making it easier for consumers to increase pulse consumption is more important for environmental benefits than the form (e.g., canned, dry, frozen) in which the pulses are procured. These are topics to address in more detail in future resources or classes.

4.3.2. Changes to Knowledge and the Importance of Motivators and Barriers

Evidence-based information was shared with the public via the Extension Bean Toolkit, and the impacts of participation in this translational research were evaluated for class participants. Levels of knowledge for all assessed pulse-related topics increased after the class. The standard deviation also decreased, meaning the data clustered more tightly and knowledge levels of participants were more similar after the class than before. Knowledge of how to prepare dry pulses saw the smallest increase. This could be due to a higher baseline knowledge than the other categories, as the overall final knowledge score was similar to that for the other two topics.

There were several key differences in changes to knowledge after participation in the final Extension class as opposed to the recent Bean Cuisine citizen science project [161]. First, initial knowledge levels of the three areas assessed were lower for the Extension class participants (scores of 2.96 for nutrition and health benefits, 2.84 for versatility, and 3.11 for how to prepare dry pulses, on a scale of 1 to 5) than for citizen scientists (scores of 3.86, 3.39, and 3.55 for the same topics). This could be due to the nature of citizen science efforts, which tend to attract a group that is already highly interested in the topic and therefore likely has higher baseline knowledge [153,192]. Another potential explanation is that there may be some response-shift bias with the citizen scientists, who saw the survey questions at different time points. In contrast, the final Extension class participants only saw the questions once, when they completed a retrospective pre-/post-assessment. This is reflected in other research, such as leadership trainee self-reported ratings being significantly higher on traditional pre-tests than on retrospective pre-tests [177]. Providing questions in this retrospective format can also help establish a common metric and offer a more accurate measure of subjective growth [176].

Whether individuals participated in the class or as citizen scientists, the final knowledge scores were similar. Knowledge of pulse versatility was 4.39 for the Extension class and 4.38 for the citizen scientists, and how to prepare dry pulses was 4.40 for the class and 4.36 for citizen scientists [161]. This does not assess long-term changes to knowledge, as participation in the citizen science project could have imparted skills and improved self-efficacy regarding pulse dish preparation that may not occur during an online class. Furthermore, gains in knowledge about nutrition and health benefits saw the largest increase for the Extension class but the lowest increase for citizen scientists (an increase of 1.64 points on the 1 to 5 scale versus only 0.43 points) [161]. This might be due to the fact that while the class emphasized the health benefits of pulses, the health benefits were not a main focus of the citizen science work, which primarily highlighted pulse versatility.

For nutritional motivators, prior to participation in the final Extension class, protein was the most important (4.06), followed by fiber (3.99) (see Table 2.8). Protein and fiber were also the two most important nutritional motivators in the Food Habits Survey (see Table 2.5). There is a hyper-focus on protein in countries like the United States, despite the fact that most people consume more protein than is required [18] and under-consume dietary components like fiber [10]. In fact, of the four dietary components of public health concern in the United States [11], pulses are rich in two: dietary fiber and potassium. Therefore, pulses can play an important role in reversing the dietary fiber gap (i.e., the dramatic difference between the recommendation and amount of fiber actually consumed) and increasing consumption of these dietary components [10,24]. Improving public awareness of how pulses provide a practical and healthful solution to this problem is critical, in conjunction with practical tips of how to apply this knowledge.

After the class, fiber scored most highly (4.76), followed closely by micronutrients (4.71) and protein (4.70). Micronutrients saw the greatest increase in importance, gaining 1.15 points on a 5-point Likert scale. This could be due to several factors, such as lower baseline importance ranking (3.56) compared to protein and fiber, and less awareness of the micronutrients in pulses compared to other nutrients. For instance, although a majority of older adults correctly identified that beans are high in fiber and low in fat and cholesterol, a much smaller percentage successfully identified that beans are high in iron, potassium, and folate [147]. Even among a group of registered dietitians (RDs), the awareness of micronutrients in beans is more limited than one may expect [187]. For instance, approximately 77% of RDs recognized that beans can increase dietary folate, but 16.5% did not know this, and 6.2% disagreed with this correct statement [187]. Individuals with higher pulse intake have been found to have higher intake of micronutrients like magnesium, potassium, folate, and iron [159], so raising awareness about the micronutrient content of beans is key.

Regarding other motivators, taste (4.01) ranked as the most important prior to the class. This is in agreement with the Food Habits Survey findings and the literature, such as the report from Canada that determined liking the taste of pulses to be the most frequent reason provided for eating them [131]. Taste was followed by affordability (3.76) and health benefits (3.70) (see Table 2.9). This differed from the Food Habits Survey, where health benefits – not affordability – ranked as second in order of importance. However, after the class, health benefits (4.85) and sustainability (4.63) were rated the most highly. Differences between the order of importance of motivators could also be attributed to question design. Whereas the Food Habits Survey only asked individuals to assess the importance once and there was no intervention, the class asked people to assess pre- and post-class importance in a retrospective manner.

“Local” was the least important other motivator (i.e., non-nutritional motivator) both before and after the class, but it saw the greatest increase in importance. A magnified perceived importance of pulses being local also was observed in the Bean Cuisine project, with 69.6% of participants indicating they were more likely to choose Colorado-grown pulses (the project was based in Colorado and most participants were from Colorado, thus this reflects local). One barrier to local food purchasing is lack of time and/or an inability to prepare local foods [193]. The class helped equip participants with practical ways to overcome this barrier via class content and the handouts with cooking tips that were provided.

Participants rated long cooking times and being unsure of how to prepare pulses as the greatest barriers before taking the class. Interestingly, flatulence – which has been attributed to preventing some people from eating beans [134] – only had an average ranking of 2.67 (2 = very minimally discourages and 3 = minimally discourages). This means flatulence did not represent a major barrier. Being unsure how to prepare pulses saw the greatest change pre- and post-class, with an average ranking of 1.81 after the class (1 = does not discourage and 2 = very minimally discourages). This aligns with the increase in knowledge of pulse versatility seen due to the class.

4.3.3. Themes in the Free Response Data

When asked about what information they found most interesting and motivating in the class, health benefits and nutrition were major themes. Under health benefits, gut health was frequently mentioned, reflecting the current heightened consumer interest in gut health [194]. Regarding nutrition, protein and fiber were mentioned more frequently than micronutrients like potassium. This is likely due to high consumer interest in protein [18], but it also demonstrates the importance of further emphasis about micronutrients in future resources and class content. Culinary versatility was another prevalent theme in the data, which is in agreement with knowledge increases and a reduction in the barrier of lack of awareness of how to use pulses. Several class participants expressed an interest in trying Mayocoba beans, which they heard about for the first time in the class. The Bean Cuisine also resulted in a greater awareness of pulse variety and a liking for Mayocoba beans, with participants making statements like, "My first time having Mayocoba beans; wow, love them!" [161] (p. 11). Another theme revealed was the importance of presenter enthusiasm, which helped provide motivation to eat more beans. In education, enthusiasm is regarded as one of the most essential qualities of an effective teacher [195].

Overall, capitalizing on themes revealed in the free response data about what most intrigues and motivates consumers is one way to better capture public interest in pulses. Comments from class participants show that the tips about how to reduce gas also helped motivate them to eat more pulses (e.g., "learning…ways to lessen gassy side effects" was a response to what motivated someone). This demonstrates the importance of not only emphasizing motivators but also addressing potential barriers when trying to motivate increased pulse intake. In addition, it is important to reach a variety of people, even if they could be considered bean consumers, as shown by the quote, "Beans have always been a part of my diet, but I stopped eating them this past year; however, after the presentation, I have decided to include pulses in my diet once again."

Class participants also responded to what type of pulse dishes they looked forward to trying (see Table 2.11). A wide range of pulse dishes emerged, suggesting that participants better recognized the many versatile uses of pulses after the class. Crucially, individuals also mentioned their social circles in their responses, revealing the potential of a positive ripple effect, wherein class participants shared information and recipes with their friends and family and prepared pulse dishes for others. For example, participants expressed that they talked to their families about eating beans more frequently, shared what they learned with many friends, and that they would include pulses in their cooking (e.g., add beans to smoothies when making them with their kids). People even indicated trying recipes immediately after the class (e.g., “I made black bean brownies for the first time right after the talk”).

Responses revealed potential areas to expand upon in future resources. For example, most people who mentioned baking talked about sweet dishes, indicating that savory baking applications could also be highlighted to expand horizons. Although people were intrigued by the idea of beans for breakfast, they seemed to need more quick, tasty ideas on how to accomplish this. One individual commented “I'm still getting used to the texture. It's a bit heavy.” Thus, suggesting an array of recipes that include pulses but are light in texture could be more appealing. Other comments received agreed with previous research. For example, one individual wrote that they previously had beans “mainly for dinners and in soups” and another that “before the class I only ate them as a side dish or in chili or bean soup.” This directly aligns with findings by Doma and colleagues, which show that beans are most often consumed during the dinner meal and in dishes like soups or chilis [133].

Participants also provided helpful ideas of ways to incorporate beans, expressing that they were “too lazy” to make recipes so instead “just try to add a bit to every lunch and dinner,” for example by sprinkling them on salads. This demonstrates the potential of people to provide bottom-up, practical solutions to increase pulse intake that would resonate with other individuals. One way to capture and disseminate such solutions would be to use the National Weight Control Registry [196] as a model to create a National Bean Registry. We proposed this concept in a recent paper [24]: “The registry would prioritize a bottom-up approach, working with individuals already consuming high levels of pulses to determine what motivates their eating patterns and disseminating information collected from them, such as meal tips" [24] (p. 9).

4.4. Limitations and Future Directions

This study has several limitations. As previously explained, the participant groups had a relative lack of sociodemographic diversity, which could limit the generalizability of findings. An additional concern is the recruitment of class participants who are already familiar with and interested in beans. Although this is a consideration, it appears that people with low knowledge of pulses also enrolled (e.g., "Before this class, I truly knew nothing about beans! Learning the difference between beans and pulses, and how to cook with them was great. Everything from learning what to buy, how to store, how to soak, etc. was very helpful."). Furthermore, it is still important to remind those who are aware of beans to include them in their diet. This is suggested by participant comments that the class encouraged them to begin to include beans in their diet again and the segmentation analysis from the Canadian report that detailed approaches to reach Forgetful Proponents [131].

Another challenge was not using a survey instrument that allowed for more detailed data collection on the amount and types of pulses consumed. The current survey collected information about a range of consumption frequency, not the exact number of days per week/month, how many times per day, the volume consumed, or the timing of consumption (i.e., for what meals of the day). Lack of an assessment tool to evaluate more nuanced information about pulse consumption poses a challenge to understanding consumer behavior, and thus the ability to extract helpful and consumer-accessible tips to eat pulses more regularly [24]. Strides are being made, for instance in the more detailed assessment tool used in a recent study by Henn and colleagues [130]. Gathering information about preparation and consumption habits, motivators, and barriers is important. However, it is also critical to reach the public with the evidence-based information available to help mitigate barriers and emphasize motivators of interest. The current study suggests this can be accomplished through translational research approaches informed by the IMB model, and utilization of the Extension network. Integration of assessment tools that allow for more detailed evaluation of the impacts of adopting a translational approach can provide improved understanding of how to move the needle on pulse intake. They can also provide insights that are informative to implementing successful future public health efforts to encourage healthy behavior change.

Participants directly expressed points of future interest, such as receiving more recipes and learning "how to 'hide' the beans in our cooking especially when our spouses are tired of eating beans." In the future, these points could be addressed. An online class has benefits, like lower cost and the potential to reach a more widely geographically distributed audience. Nevertheless, an in-person class that includes an interactive cooking component could provide hands-on experience and build familiarity and confidence in preparing pulse dishes. This sentiment was expressed by one individual, "It takes energy and time to learn new recipes, and I am afraid that I am not cooking beans in the correct way, and I will waste time and money by implementing the new changes to my diet. In a perfect world, I would love to attend an in-person class about pulses that has a hands-on cooking and tasting component to eliminate my doubts and further increase my confidence in cooking dry beans." After completion of the online class, two in-person classes were conducted, although without a post-survey, so development is underway.

Additional future directions could include examining impacts on long-term pulse preparation and consumption habits and development of the aforementioned National Bean

Registry. Findings from the current research could be integral in the creation of a massive open online course (MOOC) [197,198] to educate a broad audience about pulses and encourage higher intake. Participation in the National Bean Registry and MOOC could be integrated and impacts on behavior change relating to pulses monitored. In the future, researchers could work across sectors to equip policymakers with strategies that successfully encourage increased pulse consumption. Impactful elements and information from the toolkit could be integrated into a public health campaign that promotes pulses. Increasing pulse intake has been shown to associate with dramatic benefits for sustainability and economic savings on healthcare. Switching animal proteins for pulses also has numerous benefits for sustainability [99-101]. For example, the single substitution of beans for beef in the United States has been shown to help achieve nearly 50 to 75% of the reductions necessary to meet the country's 2020 target for greenhouse gas emissions [105]. Also, regular inclusion of pulses in the diet can result in significant health care cost savings due to reductions in chronic disease rates and the associated costs of treatment [22,23]. Such findings further demonstrate the importance of an improved understanding of how to influence the healthy behavior change of adopting pulse-centric diets.

5. Conclusions

Beans and other pulses are positioned to simultaneously improve nutritional status, public health, and environmental well-being. Yet, they are dramatically under-consumed, largely due to barriers such as unfamiliarity, long cooking times, and intestinal discomfort. One way to encourage increased pulse consumption is adopting a translational approach to ensure research is disseminated to the public in a way that emphasizes motivators and mitigates barriers. The current study conducted a Food Habits Survey in conjunction with a review of the literature to assess points of consumer interest, common motivators, and how to mitigate barriers. The resulting Extension Bean Toolkit provided a variety of resources to reach a wide audience, including website pages, social media posts, and an online class. Participants saw significant gains in knowledge about the benefits of pulses and how to prepare them. Moreover, participation in the class resulted in a reduction in the degree to which barriers discouraged participants and an increase in the importance of all motivators. Participants also reported eating pulses more frequently and an intention to try new pulse dishes.

Other studies on motivators and barriers to pulse intake have focused on investigating the relative importance to participants and on categorizing respondents into different groups. Importantly, this study adopted a translational approach to create a toolkit and class. Then, evidence-based information was actually shared with the public and impacts of participation were measured. Through leveraging the Extension network, a wider audience was reached with critical information that can directly empower them to improve their own health and the health of their communities. Further expanding influence via efforts like a MOOC or the National Bean Registry could have even more widespread benefits. Overall, this study suggests that translational research can play a pivotal role in influencing positive health behaviors, like higher pulse intake. This has potential implications for policy and public health campaigns through organizations like Extension. For instance, it provides insights to guide future translational approaches and efforts designed to promote healthy behavior changes that can benefit human health and sustainability.

CHAPTER 3: BEAN CUISINE: THE POTENTIAL OF CITIZEN SCIENCE TO HELP MOTIVATE CHANGES IN PULSE KNOWLEDGE AND CONSUMPTION[10]

Summary

Pulses, or the dry, edible seeds of non-oilseed legumes (e.g., chickpeas, cowpeas, dry beans, dry peas, and lentils), are uniquely positioned to simultaneously benefit human and environmental well-being, all while being affordable and important to diverse cultural food traditions around the world. Despite the benefits they can provide, pulses are dramatically under-consumed. One key barrier preventing higher intake among consumers is a lack of familiarity with how to prepare and regularly incorporate pulses into meals. To address this barrier and actualize findings from our laboratory, we created the Bean Cuisine, a 2-week cuisine (i.e., meal plan) with 56 pulse-centric recipes corresponding to 14 unique breakfast, lunch, snack, and dinner ideas. Each meal category was largely interchangeable, i.e., the order of the breakfast recipes is not important, and one could be swapped for another if a different order were preferrable to a consumer. Fifty-six citizen scientists were recruited to provide feedback on the Bean Cuisine. Free response feedback related to project participation was very positive, and common themes included changes in pulse consumption and cooking behaviors, increased awareness of pulse variety and versatility, and

[10]This research has already been published with the journal MDPI Foods. To stay true to how the paper was published but adhere to CSU Graduate School dissertation formatting: 1.) the numbers of figures, tables, and supplementary materials referenced have a "3." appended to them to reflect being in chapter 3; 2.) keywords and journal ending statements (e.g., funding, data availability statement) are not displayed; 3.) spacing has been adjusted to match CSU formatting; and 4.) the supplementary materials mentioned in this paper can be found online at: https://www.mdpi.com/2304-8158/12/14/2667. Citation information is as follows: Didinger, C.; Bunning, M.; Thompson, H.J. Bean Cuisine: The Potential of Citizen Science to Help Motivate Changes in Pulse Knowledge and Consumption. *Foods* **2023**, *12*, 2667.

positive perceptions of citizen science. Overall, participation in the Bean Cuisine citizen science project helped create pulse advocates, empowering participants to advance well-being of their communities through pulses.

1. Introduction

Pulses are a nutrient-dense food that can be a staple in healthy dietary patterns supportive of public and planetary health. Health benefits associated with pulse consumption range from improving gut health and healthy weight management to the prevention of chronic diseases such as type 2 diabetes, cardiovascular disease, and cancers like colorectal cancer [6]. Individuals who regularly consume pulses have been found to have more nutrient-dense diets, including higher intakes of fiber, folate, and potassium and lower consumption of fat [159]. Although more research is needed to improve the quality of the evidence and build more robust support for the exact health benefits associated with pulse – as well as the amounts and types of pulses that support optimum health – this demonstrates the potential of pulses to improve diet quality. The environmental contributions of pulses include benefits for soil health, lower water requirements in comparison to other crops and sources of protein, and the potential to reduce greenhouse gas emissions [99-101].

In addition to their human and environmental health benefits, pulses have been grown around the world for millennia [199] and therefore are a traditional part of diverse cuisines [200]. Moreover, pulses are known for being available at an economical price point, one of the reasons that the Food and Agriculture Organization of the United Nations emphasizes the ability of pulses to advance food security [200].

Yet, pulses are under-consumed, which prevents us from capitalizing on their many benefits. In the United States, most people eat less than 1 cup of cooked pulses per week [11]. Globally, pulse intake is also shockingly low, estimated at around only 21 g per day, although, of course, this can vary by country and population [126]. For example, per capita, bean consumption in Eastern Africa is significantly higher, with people annually eating their body weight (50–60 kg per year, or about 137–164 g per day) in Rwanda, Burundi, and eastern Kenya [158]. Shifting the eating behavior curve so that the global population has a higher level of pulse intake can result in a win-win situation for the health of people and the planet.

There are several key barriers to higher pulse consumption, including long cooking times and concerns about digestion and flatulence [11]. Among these barriers, a primary reason for the low consumption of pulses is consumer unfamiliarity with how to prepare pulses and regularly include them in their daily diets by taking advantage of the culinary versatility of pulses [128,130,133]. One way to highlight the diverse applications of pulses is by providing the public with accessible, tasty, and creative recipes. However, the mere creation of recipes does not guarantee that people will necessarily try them. Also, the public may not have the background knowledge about the numerous benefits of pulses, nor tips on how to prepare them, to ensure they have positive experiences that will encourage them to continue cooking with pulses. Actively engaging the public through citizen science efforts is one approach to mitigating barriers to the regular inclusion of pulses in the diet, with the important added benefit of collective learning wherein the public can actively participate in research while scientists also learn from the citizen scientists. Through the Bean Cuisine project, the research team went one step further, providing not only recipes and taking steps to ensure positive experiences but actually creating a dietary pattern and menu defined by the recipes, focusing on pulses as a staple food.

Vohland and colleagues state that “citizen science broadly refers to the active engagement of the general public in scientific research tasks” [153] (p. 1). Citizen science is becoming increasingly popular, with millions of people contributing to data collection for a wide variety of projects annually [201]. Multiple benefits to science and the participants themselves are recognized, such as increasing scientific knowledge, providing educational opportunities for citizen scientists and the chance to engage in the research process, helping to democratize data collection, and offering the potential to involve a larger audience than traditional research methods and capitalize upon the diversity of ideas generated by larger numbers of people [201-203]. Citizen science has been used in an array of disciplines, but it is still relatively lacking in nutrition and food research, which can have a great impact on public health [202,204,205]. Citizen science was a practical approach for this research project because it resulted in feedback on the home cooking experience, reflective of how people will actually prepare and perceive the recipes that are part of the Bean Cuisine. Although it included a variety of pulses (i.e., the dry, edible seeds of non-oilseed legumes, including chickpeas, cowpeas, dry peas, and lentils) in addition to beans, it was called “Bean Cuisine” instead of “Pulse Cuisine” due to higher familiarity with the word bean and the bean-centric nature of the cuisine. However, it is also attractive to a broader population due to its inclusion of multiple pulse types. Due to the name of the cuisine being Bean Cuisine, the words “pulse” and “bean” may appear to be used largely interchangeably in this paper.

The Bean Cuisine was created to address the barrier of unfamiliarity with pulses, instead inspiring citizen scientists with the culinary versatility of beans and other pulses, encouraging regular inclusion in their daily diets. This represents a type of stealth health approach wherein participation in the project provides the opportunity to begin to routinize regular pulse consumption. Additionally, the Bean Cuisine presented an opportunity to share with the public recent preclinical findings, which suggest that major benefits for gut health and body weight management are achieved when at least 35% of dietary protein comes from pulses [95,96]. The Bean Cuisine thus also helps visualize what a diet that attains this level of pulse consumption may look like and the feasibility of eating this level of pulses. By using the feedback provided by citizen scientists, the Bean Cuisine was improved so that it will be more accessible and palatable to a wider audience. In addition, the research team had several key takeaways to improve future citizen science work.

2. Materials and Methods

2.1. Creation of the Bean Cuisine

The Bean Cuisine was created to provide 35% of total dietary protein from pulses. To spread consumption throughout the day and address the consumer barrier of unfamiliarity with how to use pulses, 14 days of recipes that included pulses for breakfast, lunch, snack, and dinner were created, 56 recipes in total. Recipes were collected from colleagues, including Dr. Terry Hartman, who provided bean recipes she had previously used in a clinical trial [206]. Additionally, pulse-centric food blogs and cookbooks were searched to gather recipes. Recipes were then modified to ensure that 35% of dietary protein each day came from pulses and that the cuisine also met other recommended intake levels of macro- and micronutrients. Specifically, the Bean Cuisine had recipes that included black-eyed peas, chickpeas (in flour and whole form), split peas, lentils (in whole and pasta form), and many types of dry beans, including black, Mayocoba, pinto, red kidney, and assorted white beans (e.g., great northern, cannellini, navy), and it did not include use of green, immature pulse grains.

The recipes emphasized the versatility of pulses, including applications such as:

- Sweet and savory baking with pulses (mashed cooked pulses and chickpea flour);
- Pulse pasta (e.g., lentil pasta) to demonstrate simple substitutions for ingredients normally used (e.g., wheat pasta);
- Combining beans with other grains, such as brown rice, quinoa, or oatmeal;
- Combining beans and meat;
- Simple, quick recipes like savory and sweet bean dips;
- A range of easy-to-prepare pulse salads.

The recipes were assembled into a 2-week menu plan in Nutritionist Pro (version 8.1.0, 2022, Nutritionist Pro, Axxya Systems). Citizen scientists were only provided with pulse-based recipes, but to confirm that 35% of participants' overall daily protein was coming from pulses, sides (e.g., fruit, yogurt, and beverages) were added to the Bean Cuisine in Nutritionist Pro as well. The average daily intake of pulses was about 2.5 cups of cooked pulses, which totaled about 38 g of protein from pulses.

An analysis to estimate energy, macro-, and micronutrient intakes was conducted on pulse recipes, daily intake, and the overall Bean Cuisine (see Supplementary Materials S3.1 for nutrient analysis and Supplementary Materials S3.2 for the meals report). Overall, the Bean Cuisine proved to be a healthy diet that met dietary guidelines (Nutritionist Pro is occasionally missing micronutrient levels for ingredients, which is why the percentages of a select few micronutrients – like biotin at 71% – may appear slightly low). The Bean Cuisine with added sides resulted in average daily intakes of approximately: 1999 kilocalories, 292 g of carbohydrate, 59 g of fat, and 96 g of protein. This is roughly 39.8% of total protein intake from pulses, based on numbers provided by Nutritionist Pro. Importantly, 2 key dietary components of public health concern in the United States, dietary fiber and potassium [11], were consumed in adequate amounts. Total dietary fiber intake was around 61 g, with 5143 mg of potassium. Also, cholesterol, saturated fat, and added sugars were present in low amounts in the Bean Cuisine.

2.2. Citizen Scientist Recruitment and Assignment

Colorado State University Extension and colleagues helped recruit a convenience sample of citizen scientists through emails, newsletters, and social media posts. Fifty-eight citizen scientists filled out the intake form created in Qualtrics. Each individual was then contacted via email to confirm participation. As email would be the main form of communication, we wanted to ensure they would respond. Fifty-six of the 58 participants responded, resulting in a total of 56 citizen scientists recruited to the Bean Cuisine project. There were 14 days in the project, and each individual was assigned 1 day (i.e., a breakfast, lunch, snack, and dinner recipe), resulting in 4 citizen scientists being assigned to each day of the Bean Cuisine.

The intake form asked about the participants' understanding of the commitments relating to participating in the Bean Cuisine project, motivation for participating, preparation and consumption habits for pulses, knowledge about pulse-related topics, and demographics. See Supplementary Materials S3.3 for the intake form. In addition, the intake form included questions about participants' food allergies, intolerances, and preferences. Assignment to days was made based on citizen scientists' dietary patterns and preferences. After those with dietary restrictions had been assigned, the remaining participants were randomly assigned to the open spots.

Participation as a citizen scientist included 6 main components (see Figure 3.1): the intake form (also called the sign-up form), training, and then the completion of 4 feedback forms corresponding to the 4 recipes each individual was assigned. This project was approved by the Colorado State University Institutional Review Board, protocol #3589.

Figure 3.1. Citizen scientist checklist. This is the graphic that was shown to citizen scientists in the online training session detailing participation in the Bean Cuisine project.

2.3. Citizen Scientist Kit and Training

The training served as a chance for citizen scientists and the research team to interact with one another. It also helped ensure that citizen scientists clearly understood their role in the project by providing details and the chance to ask clarifying questions. Training is also a way to improve data quality in citizen science [207,208]. Replication of data across volunteers is another way to have better data quality [208], hence the recruitment of 4 volunteers for each recipe.

Before the training, citizen scientists were all sent a citizen scientist kit (see Figure 3.2). The kit included:

- Two CSU Extension handouts were created as part of this project: 1 on cooking with dry beans and the other on tips to shorten cooking time;
- A recipe packet that included 1 explanation page with a QR code that linked to the recipe feedback form, as well as printed copies of all 4 of the recipes they had been assigned;
- A printed form detailing what they could expect to be asked about in the online feedback form – all feedback needed to be submitted virtually, but the form was provided so people could take notes on it if desired;
- A thank you;
- A pen;
- Four 1-lb bags of Colorado Proud* beans: 2 bags of pinto beans and 2 bags of Mayocoba beans (*for this Colorado Department of Agriculture funded project, all beans provided to citizen scientists were grown in Colorado or a neighboring state and processed in Colorado).

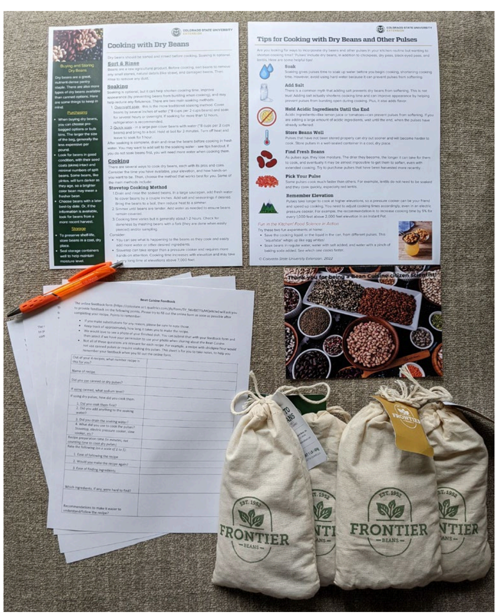


Figure 3.2. Citizen scientist kit. An image of contents in the kit mailed to citizen scientists.

The citizen scientist kits arrived around the scheduled day of the training, and participants were told to wait to begin until completing the training. Before beginning recipe feedback, citizen scientists participated in the training in 1 of 2 ways:

1. **Live training**. We provided a 1 h online training session via Zoom videoconferencing on a weekday evening to make participation easier. The research team briefed citizen scientists on the project background, explained the details of participation, and then held a Q&A. Roughly 60% of citizen scientists joined the live training. Participants were highly engaged, asking questions in the chat and unmuting to ask live questions to clarify details about expectations for project participation. For instance, participants asked about ingredient substitution and the ideal timeframe within which to complete all recipe feedback. Often, answers were already available in the instructions they received in the citizen science kit (e.g., sticking to the recipes as close as possible given dietary restrictions and preferences and ingredient availability, and noting any substitutions made in the feedback form). Additionally, some questions pertained to work being conducted at Colorado State University to learn more about current research on the health benefits of pulses that the research team is conducting (e.g., gut health promotion and chronic disease prevention);
2. **Recorded training**. We created an approximately 22 min recorded training session that performed a similar function but did not include the live Q&A for those who were unable to join the live training. Citizen scientists were encouraged to reach out with any questions. The live training can be found at the following link, which was posted as a private video (to share with citizen scientists, not for general viewing by anyone on YouTube), available at https://youtu.be/QYtLk-piuW0.

Immediately upon completion of the live training, an email was sent to all citizen scientists thanking them and including attachments of all the printed forms they had received printed in their kit (2 handouts, a recipe packet, and a PDF on what details to expect in the feedback form), for those who prefer digital copies. A link was also provided to the recorded training for those who could not join live or wanted to watch the training again. Lastly, a direct link to the feedback form was also provided. The first time that citizen scientists completed the feedback form, they needed to first confirm they had completed the training.

2.4. Citizen Scientist Feedback Form

To simplify things and reduce any potential confusion, only 1 link and associated QR code were provided to access the feedback form created in Qualtrics. Skip logic was implemented so that one of the first questions inquired, "Of the 4 recipes about which you will provide feedback, what recipe number is this for you?" For the first feedback form, participants had to confirm completion of the training and were asked to provide feedback on the training. The second and third time that participants completed the form, there were no additional questions beyond the general recipe feedback. General feedback asked for details such as:

- Whether they used canned or dry pulses they cooked themselves;
- Details about the canned pulses (e.g., sodium level) or how they prepared the dry pulses (e.g., soaking, how they cooked them – stovetop, pressure cooker, slow cooker, etc.);
- The approximate time it took to prepare the recipe;
- Level of agreement with the recipe being easy to understand, inclination to make the recipe again, and ease of procuring the ingredients;
- Recommendations about improving recipe instructions;

- Which ingredient(s) were hard to find, if any;
- Satisfaction with taste, texture, appearance, and overall acceptability of the recipe (i.e., sensory feedback);
- Whether they followed the recipe or made substitutions, and if so, details of the substitutions;
- What pulses they may recommend using in place of those already recommended in the recipe;
- What changes they would recommend making to the recipe;
- Submit a photo of the finished dish, if so inclined.

The fourth and final time they completed the form, they were asked about their pulse preparation and consumption habits, knowledge level, and overall experience participating in the project. See Supplementary Materials S3.4 for the feedback form. After completing their final feedback form, citizen scientists were sent a $20 Amazon gift card as a thank you for their valuable feedback and participation in the project.

2.5. Statistical Analyses

All statistical analyses were conducted in IBM SPSS Statistics version 28 (SPSS Inc., Chicago, IL, USA). Frequencies and percentages were calculated for categorical variables like demographics. Descriptive statistics were used on categorical variables like demographics. For Likert scale questions about knowledge and behavior that were asked of citizen scientists when they enrolled and again upon completing the project, Wilcoxon signed-rank test was used to assess if significant changes occurred. For free response questions, the lead author took notes and developed a set of summary comments, which were then grouped into themes. The themes were corroborated by the other researchers on the project.

2.6. Modifying the Bean Cuisine

The response rate was 100%, with all 56 citizen scientists completing feedback forms for each of their 4 assigned recipes. The recipes were ranked by computing an average score for each of the 7 Likert scale questions that asked about recipe preparation and sensory evaluation (1. ease of following and understanding the recipe, 2. ease of finding the ingredients, 3. inclination to make the recipe again, and satisfaction level with 4. taste, 5. texture, 6. appearance, and 7. overall acceptability). Then, the average scores were totaled to assign an overall score to each recipe. The most important questions were deemed to be agreement with the statement "I would make this recipe again" and satisfaction with "overall acceptability," as these reflect the chance people will continue to use the recipes and provide an idea of overall sensory appeal. Citizen scientists responded using 5-point Likert scales, where 1 or 2 reflected a positive score, 3 was neutral, and 4 or 5 represented dissatisfaction. Accordingly, recipes that received a 3 or higher for one of these questions were prioritized for modification and further recipe testing, as participants were only neutral or potentially disliked the recipe. Data shown in sensory tables has been reverse coded so that 5 is a high score and 1 a low score to be consistent with the scaling of the knowledge tables.

In addition, all recipes were modified based on citizen scientist feedback to free response questions. This included improvements to clarify recipe instructions and adjustments to ingredient amounts. For sample feedback, see the results section on citizen scientist feedback. Citizen scientists were also asked how long it took to prepare a recipe, and the times were averaged to provide a time estimate for the final versions of the recipes. Any modifications to ingredients that were made were also entered into Nutritionist Pro, and the resulting nutrition facts were included in the final recipe. The research team all participated in proofreading and editing the final Bean Cuisine.

2.7. Sensory Panel

Validation with experts can improve data quality [208]. Therefore, 4 recipes that had already been modified per citizen scientist feedback were tested using a sensory panel as a way of validating citizen scientist feedback and confirming palatability when the dishes were prepared by the lead author in a university teaching kitchen instead of in the home kitchen. The sensory panel consisted of 12 faculty, staff, and students with experience providing sensory evaluation input, most of whom are in the Department of Food Science and Human Nutrition at Colorado State University. More details about the recipes are provided in the results section about the sensory panel including why this representative subset was selected. The recipes showcased versatile preparations of beans, and panelists were asked to rank 4 components: taste, texture, appearance, and overall acceptability of each dish. A Likert scale from 1–5 was used (1 = extremely satisfied, 2 = somewhat satisfied, 3 = neither satisfied nor dissatisfied, 4 = somewhat dissatisfied, 5 = extremely dissatisfied). Panelists also provided written feedback and suggestions for these components, such that feedback could be incorporated into the final Bean Cuisine. Data shown in sensory tables have been reverse coded so that 5 is a high score and 1 a low score to be consistent with the scaling of the knowledge tables.

3. Results

3.1. Citizen Scientist Demographics

Participants were asked to report their dietary patterns. Most citizen scientists were omnivores (n = 39), followed by vegetarians (n = 8), pescatarians (n = 5), and vegans (n = 4). About 96% of citizen scientists were female, and the two most reported age groups were 60–69

(n = 19) and 50–59 (n = 15). The 40–49 and 70–79 age groups each had n = 7 participants. Fifty-three participants were Caucasian, and most citizen scientists had either a Bachelor's (n = 24) or Master's (n = 22) degree. Most participants were from Colorado (n = 44), as this was a Colorado-based project. However, volunteers from a total of 10 states participated. A table showing more detailed descriptive statistics about participant demographics can be found in Supplementary Materials S3.5.

3.2. Citizen Scientist Feedback and Bean Cuisine Modification

As explained above, part of the recipe feedback included responding to seven 5-point Likert scale questions. The average score for all 56 recipes is shown in Table 3.1.

Table 3.1. Average scores of the original Bean Cuisine recipes.

	Recipe Easy to Understand	**Ingredients Easy to Find**	**I Would Make This Recipe Again**	**Taste**	**Texture**	**Appearance**	**Overall Acceptability**
Average score *	4.8	4.6	3.8	4.0	4.1	4.2	4.0
Minimum score **	4.0	3.0	1.5	2.25	1.5	2.0	2.0
Maximum score	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Range	1.0	2.0	3.5	2.75	3.5	3.0	3.0

* A 1 represents a low (poorly rated) score, and 5 a high score. ** Considering the average scores for these 7 components (i.e., the total score for a recipe when averaged for the 4 individuals providing feedback), the minimum and maximum scores reflect the lowest and highest scores for the 56 recipes.

All recipes were modified based on citizen scientist feedback. For recipes that scored well and received positive feedback, modifications were minor, such as improving wording clarity, proposing optional additions to boost flavor, or incorporating tips from citizen scientists. Recipes that received lower scores (as previously detailed) were tested again by the research team. Common modifications included:

- Specifying that the amount of pulses listed is the cooked amount (example feedback: "Write whether the bean amount is for cooked or uncooked beans for clarity.");
- Providing clarity on how to cook dry lentils or split peas for recipes that included them (example feedback: "I had to look up how to cook red lentils. It would have been nice to have those with the recipe.");
- Increasing seasoning level (example feedback: "Add seasonings, possibly cumin, chili powder, taco seasoning and/or salt.");
- Adding more details to the instructions (example feedback: "Add instructions like 'do not overmix' [and] 'bake in the middle rack of the oven.'");
- Clarifying time estimates in intermediate steps (example feedback: "It would have been better to have a range like 15–20 min or until tender.");
- Suggesting serving options (e.g., with rice) and toppings (example feedback: "Pairing it with a carbohydrate like rice. Recommending avocado as a topping.").

On the recipe feedback forms, citizen scientists were asked if they followed the recipe. Despite being assigned recipes that avoided food allergies and dietary restrictions and receiving instructions to please follow the recipe as closely as possible, people only indicated following the recipe 54% of the time.

3.3. Impacts of Participation

Citizen scientists were asked about their knowledge level on three different topics prior to participation and upon completion of the project. They were also asked about preparation and consumption behaviors. The data is shown in Table 3.2.

Changes in the frequency of pulse consumption were also seen, as shown in Figure 3.3. The most noticeable shift is that more participants reported eating pulses 1–3 days per week than before the project. However, although the overall frequency of consumption appears to be increasing, the overall change was not found to be significant (*p* = 0.137), a point further expanded upon in the discussion.

Table 3.2. Pulse knowledge before and after being a Bean Cuisine citizen scientist.

Knowledge of Pulse Nutrition and Health Benefits	**Pre: *n* (%)**	**Post: *n* (%)**
1 (low)	2 (3.6)	0
2	4 (7.1)	0
3	10 (17.9)	5 (8.9)
4	24 (42.9)	30 (53.6)
5 (high)	16 (28.6)	21 (37.5)
Average score	3.86	4.29
Difference (*p*-value)		0.43 (0.002)
Knowledge of Pulse Versatility	**Pre: *n* (%)**	**Post: *n* (%)**
1 (low)	2 (3.6)	0
2	7 (12.5)	1 (1.8)
3	24 (42.9)	4 (7.1)
4	13 (23.2)	24 (42.9)
5 (high)	10 (17.9)	27 (48.2)
Average score	3.39	4.38
Difference (*p*-value)		0.99 (<0.001)
Knowledge of How to Prepare Dry Pulses	**Pre: *n* (%)**	**Post: *n* (%)**
1 (low)	2 (3.6)	1 (1.8)
2	8 (14.3)	1 (1.8)
3	15 (26.8)	4 (7.1)
4	19 (33.9)	21 (37.5)
5 (high)	12 (21.4)	29 (51.8)
Average score	3.55	4.36
Difference (*p*-value)		0.81 (<0.001)

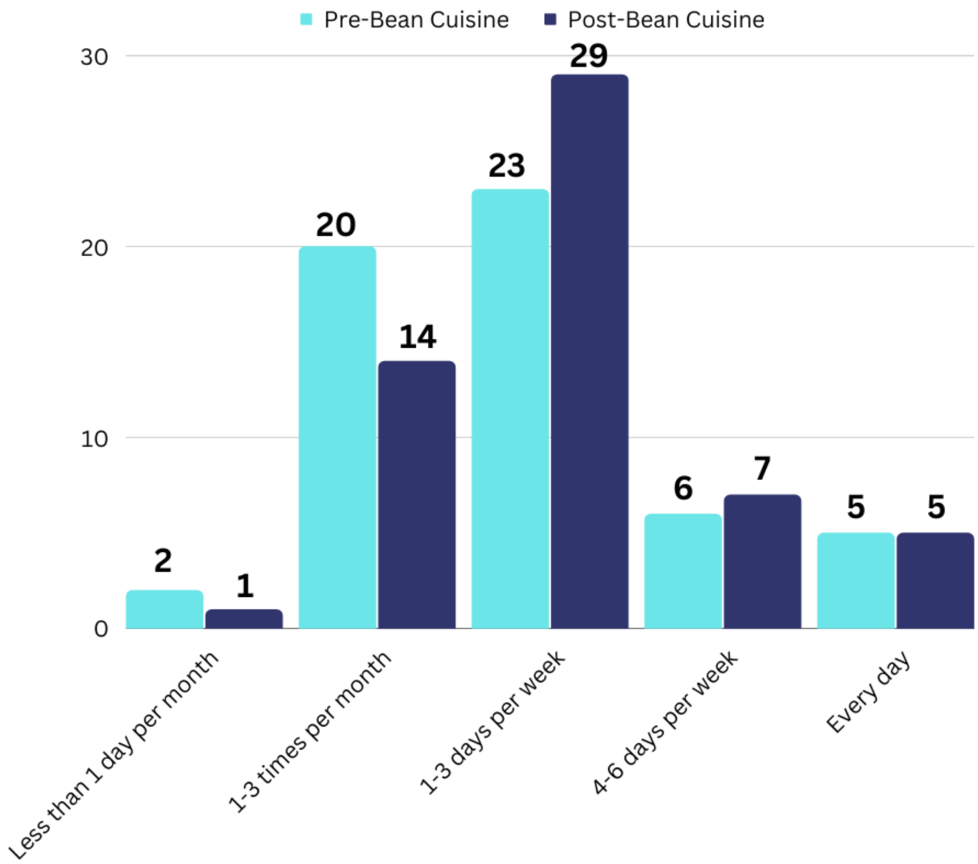


Figure 3.3. Changes in frequency of pulse consumption. "Less than 1 day per month" is shortened in the figure, but the full response option read "Several days per year, but less than 1 day per month." No participants selected "Never" as the response for how often they eat pulses. The actual numbers of responses out of *n* = 56 are shown above each column.

Citizen scientists also indicated their frequency of usage of canned pulses versus dry pulses they cooked at home. Results are reported in Figure 3.4, which shows an overall trend of increasing use of dry pulses after participation. This is most apparent in changes observed with several individuals who primarily used canned pulses before the project but later reported a similar frequency of use of canned and dry cooked in the home, indicative of more frequent cooking of dry pulses. The greater frequency of cooking dry pulses in the home is reflected in the free responses as well.

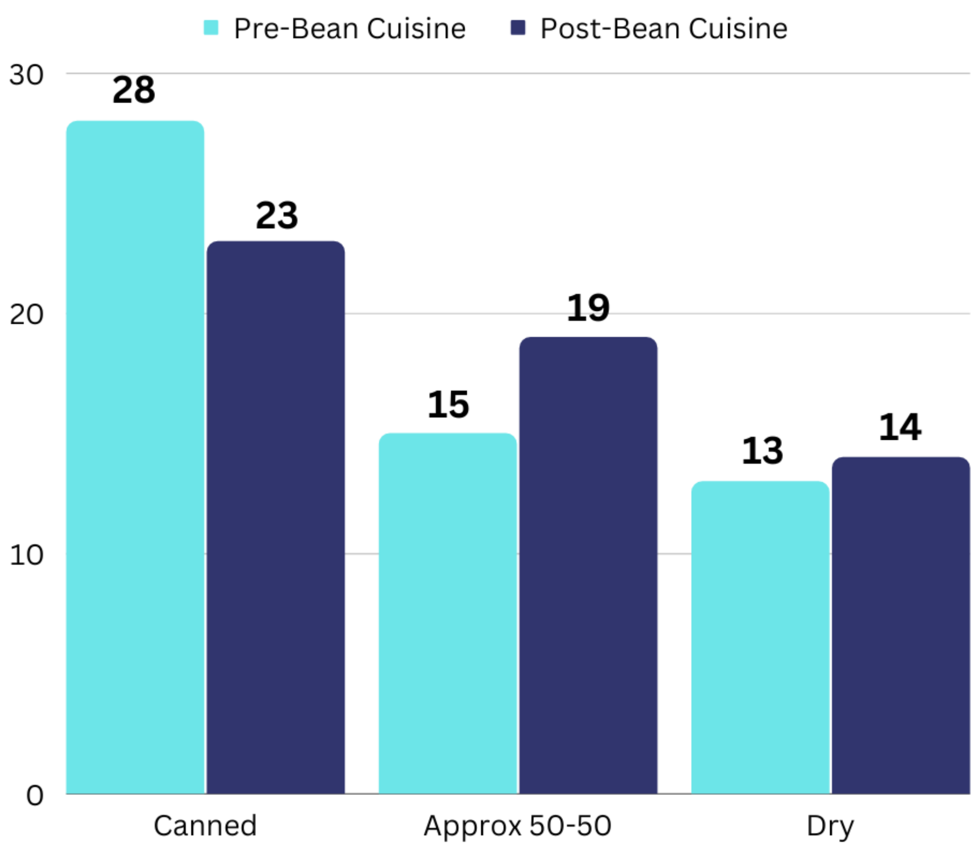


Figure 3.4. Citizen scientist usage of dry versus canned pulses, pre- and post-participation. "Approx 50-50" indicates that the participants used canned pulses and pulses cooked in the home with similar frequency. The numbers of responses are shown above the column.

As this project was funded by a Colorado Department of Agriculture grant, participants were also asked upon enrollment whether they regularly purchased Colorado-grown beans. The most common response to this question (n = 25, 44.6%) was "unsure if the beans I purchase are from Colorado or not." Participation in the project resulted in 39 individuals (69.6%) indicating they are now more likely to purchase Colorado-grown pulses.

3.4. Participation in Citizen Science

Recurring themes and examples of quotes pertaining to these themes are shown for citizen scientists' motivations for participation (Table 3.3) and their overall experience (Table 3.4).

Table 3.3. Motivation to participate in the Bean Cuisine citizen science project.

Overarching Theme	Sub-Theme	Citizen Scientist Quotes
Learning	• Want to learn about beans • Want to learn new, tasty recipes (for themselves and others) • Want to learn more ways to include beans in their diet	• "I'm interested in trying new recipes and adding legumes to my diet on a daily basis." • "I have two main interests in participating: to help with the research and to find more creative ways to use beans for preparing meals." • "I am really interested in increasing my beans/legumes knowledge through this CSU research opportunity and hope to share it with family and friends." • "I eat a lot of beans and would like to find some more recipes and some other beans or pulses I have never tried."
Health Concerns	• Personal or family health concerns • Want to adopt a more plant-based diet • Desire for affordable healthy food	• "I am interested in expanding my diet, more so towards local foods, vegetarian or low meat options, and plant-forward recipes. This seemed like a great opportunity to do a lot of those things!" • "Improve fiber in my diet." • "I'm determined to get myself into remission or better." • "My [family member] has high blood pressure, so any opportunity to learn more about nutrition and cooking is one I welcome." • "I am always looking for ways to make our diet healthier." • "I watch my grocery budget. Beans/pulses are affordable, nutritious and healthy, and also provide protein in my largely vegetarian diet."

Table 3.3. Motivation to participate in the Bean Cuisine citizen science project *(cont.)*.

Overarching Theme	Sub-Theme	Citizen Scientist Quotes
Values	• Volunteer spirit • Support local food systems • Like encouraging others to eat healthfully	• "I love participating as a volunteer." • "I have participated as a citizen scientist... for the last three years. It has been fun and enlightening." • "I am a huge supporter of Colorado Proud and love using my own organic ingredients and other locally-grown products!" • "I am passionate about encouraging others to cook healthy, nourishing food at home."
Interests	• Beans • Cooking • Gardening • Science	• "I love beans! I am a registered dietitian and former recipe developer, so this project is of interest to me." • "I love to garden and eat! I especially love to cook beans and am always excited about trying new recipes." • "I'm a bean lover who wants to get others as excited as I am about this wonderful food source. Plus, science is super fun." • "I enjoy cooking and like to try different recipes."
Enjoyment	• Fun • Like being a part of a project • Enjoy research and science	• "This sounds fun; I'd love to be a part of it!" • "We like research projects." • "I enjoy participating in research projects, especially food safety and nutrition-related research."

Table 3.4. Themes of citizen scientist overall experience in the Bean Cuisine.

Theme	Sub-Theme	Example Quote
Knowledge of Pulses	• Learn about beans • Health benefits • Ways to eat more beans • Bean/pulse cooking	• "It was fun to try new recipes and learn about an ingredient I don't use all that much." • "I also learned more about the health benefits of beans, as well as the classifications of beans and legumes and pulses." • "I really enjoyed doing this! It was great fun to try new recipes and learn more about how to incorporate beans into our daily meals." • "I really enjoyed this project, and am happy that I participated as it expanded my knowledge of how to make and use pulses in a variety of ways." • "I really was surprised about the versatility of the pulses. I like to experience different recipes but would never have thought about making smoothies with them or pairing lentils with shrimp. Making the beans and rice salad was also a pleasant surprise." • "Also, that guide to how to cook dry pulses is amazing and so useful. I've cooked with dry beans many times before but less thoughtfully, and the guide did make them taste better." • "Probably the best takeaway for me has been learning how easy it is to cook dry beans in a slow cooker! Thank you very much!"
Awareness of Pulse Variety	• Experimentation with new types of beans	• "I really like the Mayocoba beans! I had not cooked with them before, and for other recipes that need a bean that keeps its shape… this is the perfect bean!" • "Thank you for introducing me to Mayocoba beans. I really like them now!" • "The recipe was delicious! My first time having Mayocoba beans; wow, love them!"
Awareness of Pulse Versatility	• Incorporation of beans into their current routine	• "This was so simple and straightforward to make. I roast veggies regularly and, from here on, will add some beans to match whatever flavor profile I'm cooking (white beans with roasted Brussels sprouts or cabbage, etc.). Simply genius way to get more beans into a meal!"

Table 3.4. Themes of citizen scientist overall experience in the Bean Cuisine *(cont.)*.

Theme	Sub-Theme	Example Quote
Awareness of Pulse Versatility *(cont.)*	• Increased awareness of recipes and ways to use pulses	• "I make smoothies every morning. Now that I have made this recipe with beans, I use any bean I have in the fridge as leftovers and use them in my fruit/veggie smoothies." • "The Mayocoba beans were a very nice flavor in the smoothie, preferable to the organic, no-sugar protein powder I have been using. Thank you for the introduction to this change!" • "I think it was fun, and I definitely have a couple of new recipes to play around with. My favorite new idea is mixing the beans into baked oats." • "It was really fun trying new recipes! We are vegans who love beans, but the recipes got us out of our ruts."
Pulse Consumption Behavior	• Eating more pulses • Adding to recipe rotation	• "I'm more aware of ways to incorporate beans into every meal, and I'm paying more attention and trying to eat them more." • "I have been eating about one cup of beans every day! And I feel like my intestines are liking this new addition!" • "I'm going to start eating more pulses :-)" • "Definitely will integrate more pulses into my daily cooking." • "This was really good. My kids, 11 and 13, loved it. It will go into our usual recipe rotation." • "This one was really, really nice. I've enjoyed all the recipes so far, and I will probably use them again, but this one is for sure going into the rotation. It hits the golden ratio of ease in preparation, high veggie content and tastiness—while also making enough for two meals for my household!" • "The recipe was delicious. Since we eat oats every morning, we will be enjoying this recipe often." • "I loved this recipe! It is great for my gluten-free friends and is really tasty and moist. I will definitely make it again soon!"

Table 3.4. Themes of citizen scientist overall experience in the Bean Cuisine *(cont.)*.

Theme	Sub-Theme	Example Quote
Pulse Cooking Skills and Habits	• How to cook dry beans • Experimentation with pulse ingredients • Purchasing intent • Repurposing of leftovers	• "I usually use canned pulses, but I am now more experienced with dried, and they are much tastier, so I look forward to using dried pulses more in the future." • "It was great to learn of different ways to cook pulses, and I'll likely try using more dried ones than canned ones in the future (even though it's so easy to open a can!)." • "It was fun to try a new recipe that encouraged me to stretch my skills and use dry pinto beans in a recipe." • "I am now experimenting with chickpea flour and including pasta made with lentils in my recipes." • "My first time cooking with Mayocoba beans, and I really like them! I will seek them out in the future." • "I now love Mayocoba beans and will be looking for them." • "We warmed up the leftovers on a cast iron skillet with butter and topped with a drizzle of maple syrup. It was good."
Other Personal Outcomes	• Enjoyment • Fulfillment	• "It's been fun to try out recipes. The beans sent are fresh and tasty." • "It has been very fun to participate in this research AND try new bean recipes!" • "This was a fun way to participate in an interesting project that I think could really help others. I learned some new recipes, and we look forward to seeing the finished project."
Perceptions of Citizen Science	• Fun • Would participate in citizen science again • Meaningful	• "Citizen science is fun!" • "This was a great experience, and I will be looking to do more as a citizen scientist." • "Being a 'citizen scientist' is a wonderful way for a broad group of people from different backgrounds to provide their input, experience and suggestions and collect a large dataset which otherwise may be difficult to obtain." • "I really enjoyed participating in this project. I think it is a super-creative way to raise awareness about food and nutrition, and it's very meaningful to the participants."

Table 3.4. Themes of citizen scientist overall experience in the Bean Cuisine *(cont.)*.

Theme	Sub-Theme	Example Quote
Engagement and Advocacy	• Engaging others in feedback • Sharing knowledge and recipes with others • Pulse advocacy	• "I made the snickerdoodle hummus and the chicken and bean cassoulet for friends. We all enjoyed tasting them and giving feedback. I wish I had made the chickpea Dutch baby for guests. It looked like something out of a gourmet magazine." • "This recipe additionally got the approval of two football fans watching Monday night football, and they now know what Mayocoba beans are!" • "My mother-in-law was visiting us, and she really enjoyed this salad, saying it tasted really good and healthy! • "I shared the finished product with my neighbor, and she liked the different recipes also." • "All positive comments from the taste testers here." • "I don't eat a lot of sweets, so I brought it to a... happy hour. It was a hit. The beans are a secret ingredient. No one knew beans were included until I told them. Also, no one was familiar with Mayocoba beans, and these were a bunch of gardeners!" • "I served a salad at a family get-together. Everyone loved it, even my 4 and 5 year-old grandchildren." • "I served this recipe to a friend who is vegan and also limits her intake of oils. I served it with fresh veggies (red peppers and cucumbers), and it was a big hit with my friend as well as non-vegan guests." • "These were delicious, and my kids happily ate them!" • "This was so much fun. I was glad to share them with my husband, and he liked all of them. He will be making the oatmeal and Waldorf salad in the future for sure!" • "The instructions should start with soaking and cooking instructions so it's easily shared!" • "This also encouraged me to add more legume talk to my nutrition education at work."

The evaluation of overall experience (Table 3.4) is derived from quotes provided during individual recipe feedback in addition to the final feedback form when citizen scientists were explicitly asked about their experience in the project. Common participation outcomes in citizen science projects are grouped into categories such as interest, motivation, knowledge, behavior, attitudes, skills, self-efficacy, and other personal outcomes [25,26]. Free responses from the Bean Cuisine project participants fell into similar categories.

3.5. Sensory Panel

Sensory panelists ranked the taste, texture, appearance, and overall acceptability of each dish on a Likert scale of 1 to 5, with 5 being extremely satisfied and 1 extremely dissatisfied. The average scores for all dishes ranked between extremely and somewhat satisfied. Table 3.5 shows the reason a dish was included in the sensory panel, quotes about the dish from sensory panelists, and the average overall acceptability score (n = 12). Similar to citizen scientists, perception of the recipes differed, and the very same recipe received a range of scores, from rankings of "extremely satisfied" to dissatisfied. As shown in the last column of Table 3.5, the range of scores provided varied more for the dip and skillet than the smoothie and salad, with the one panelist who did not like the skillet reporting it tasted "very sweet," which the individual found unappealing.

Table 3.5. Sensory panel feedback.

Dish Name	Meal	Logic for Including in the Sensory Panel	Quotes About the Dish	Average Overall Acceptability Score*	Minimum — Maximum (Range)
Strawberry Banana Bean Smoothie	Breakfast	A smoothie gets people thinking outside of the box and in the realm of beans for breakfast. It is also fast and easy to make, improves the healthiness of smoothies, and is versatile because a wide variety of beans can be used in this recipe.	• "Interesting combination. A fascinating way to increase protein and fiber in this product." • "Great dish, tastes amazing! Unbelievable that it contains beans!"	4.5	4–5 (1)
White Bean Waldorf Salad	Lunch	Bean salads are quick recipes and make good leftovers to keep on hand. This recipe also showcases adding beans to a dish people may not originally think to add them to, encouraging them to do this with other dishes as well.	• "I very much appreciate adding the nutrition benefits of beans to a classic; it enhances flavor and nutrition." • "This is so good. I would eat this for three meals a day. I didn't think beans belonged in a Waldorf, but they DO."	4.75	4–5 (1)
Olive Bean Dip	Snack	This is a very simple, quick dip that can be made with pantry staples and fits into most schedules. It is flexible and can be prepared with almost any bean.	• "I think this is one of the most easily acceptable dishes based on how easily it can be introduced into the regular diet." • "Would love to see some fresh greens or chunks of olives."	4.18	3–5 (2)

Table 3.5. Sensory panel feedback *(cont.)*.

Dish Name	Meal	Logic for Including in the Sensory Panel	Quotes About the Dish	Average Overall Acceptability Score*	Minimum — Maximum (Range)
Turkey and Bean Skillet	Dinner	A recipe that demonstrates adding beans to a meat dish to boost nutrition and fiber and can also help cut food costs.	• "Very good as is—I would add tomatoes for acid, liquid and color." • "Small preference things here—more color, texture, and spice."	4.17	1–5 (4)

*A score of 5 indicates extremely satisfied and 4 somewhat satisfied. Overall acceptability scores for all the dishes fell within this range and were ranked as satisfying by panelists.

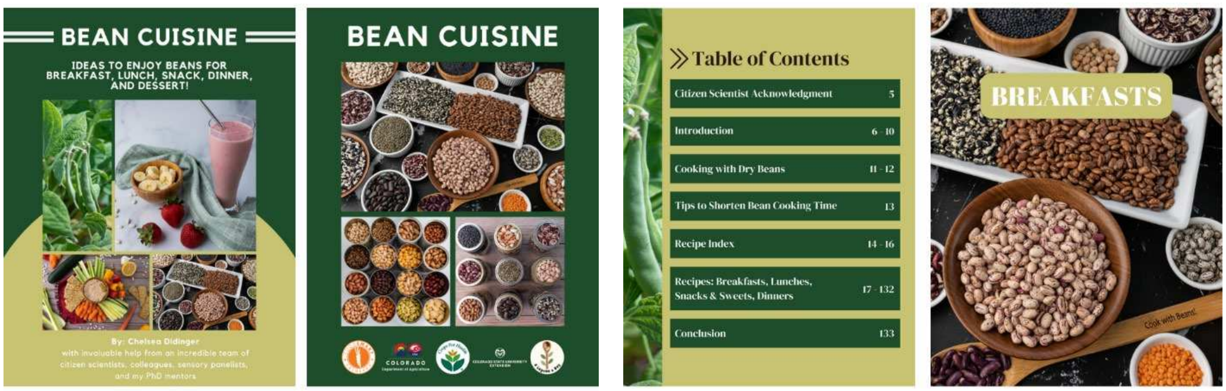
3.6. Final Bean Cuisine

Overall, the final version of the Bean Cuisine resulted in similar levels of total pulse intake as the original version. The original version contained an average of about 2.5 cups (406.6 g) of cooked pulses per day, and the final modified version contained 2.4 cups (388.8 g). Cooked weights provided by Nutritionist Pro were used for these calculations. To calculate the cooked weight of dry pulse ingredients, the dry weight of chickpea flour, lentil pasta, and dry lentils was multiplied by 2 to reflect water uptake. For the final Bean Cuisine PDF that was provided to citizen scientists, optional sides were not included so that citizen scientists could easily use and adapt the recipes to their dietary patterns and share them with friends and family to inspire others with the versatility of pulses. Moreover, as previously mentioned, each meal category was largely interchangeable, so the order in which the breakfasts, lunches, snacks, and dinners are eaten is not important.

Supplementary Materials S3.1 shows the nutrient analysis provided by Nutritionist Pro of the original 14-day Bean Cuisine, which includes all 56 pulse-centric meals (i.e., 14 breakfasts, lunches, snacks, and dinners), plus sides (e.g., beverages, yogurt, fruit, grains, and vegetables). The Original Bean Cuisine provides roughly 2000 kilocalories, 96 g of protein (~38 g protein from pulse, or ~40% of total protein), 61 g of dietary fiber, 5143 mg of potassium, and 1934 mg of sodium per day. Micronutrient levels are not available for all the ingredients in the Nutritionist Pro system, hence why some percentages of micronutrients may appear low.

Supplementary Materials S3.6 shows the nutrient analysis for the Updated Bean Cuisine, with only the pulse recipes updated and the original sides left as they were. The Updated Bean Cuisine provides approximately 2037 kilocalories, 98 g of protein (~37 g protein from pulse, or ~38% of total protein), 61 g of fiber, 5291 mg of potassium, and 2334 mg of sodium. One of the main adjustments made to the Bean Cuisine was increased seasoning levels, as is evident in the increased sodium content. However, exact nutritional content can vary with brand and other factors, and the numbers provided by Nutritionist Pro serve as an estimation. Also, seasoning amounts are optional (i.e., people could use less salt), and sides were not adjusted. If sides were also modified, then the calorie and sodium content could easily match that of the Original Bean Cuisine. However, they were kept the same to reflect changes that occurred strictly due to feedback from citizen scientists.

The final version of the Bean Cuisine was a 134-page PDF that was emailed to all 56 citizen scientists, as everyone indicated they wanted to receive the final copy. The front and back covers are shown along with the table of contents in Figure 3.5. An acknowledgment recognized the critical input provided by the citizen scientists. The introduction included background details about the project and the importance of pulses, as well as helpful handouts on how to prepare dry pulses. Recipes were grouped into four categories – breakfasts, lunches, snacks and sweets, and dinners – with 14 recipes in each for a total of 56 recipes. Each recipe had a title and contained information about the number of servings, a preparation time estimate, a photo of the finished dish, and nutrition facts. Photos provided by the citizen scientists were prioritized, with photos taken by the lead author during recipe testing used as needed. The recipes also listed ingredients and instructions, and they contained a notes section with helpful tips, including tips directly from the free response feedback provided by citizen scientists. The full Bean Cuisine can be found on the laboratory website: https://agsci.colostate.edu/cropsforhealth/.



(**a**) (**b**)

Figure 3.5. Bean Cuisine. (**a**) Bean Cuisine front and back covers; (**b**) table of contents and Breakfast divider section as an example divider section.

4. Discussion

4.1. Bean Cuisine Creation

This creation of the Bean Cuisine serves as a proof-in-concept that 35% total dietary protein provided from pulses is achievable, and the resulting dietary pattern meets dietary guidelines. The preclinical studies demonstrating the potential gut health and healthy weight outcomes of attaining this percentage of protein also examined the 70% protein level. However, when developing the Bean Cuisine, we found that attaining 70% of total protein coming from pulses was very difficult to do while still promoting a varied, healthy diet. This was because most foods contain at least some protein, so including foods like a glass of milk, yogurt, eggs, meat, or even ingredients like whole wheat pasta proved difficult due to the need to maintain 70% of protein coming from pulses. However, it is important to note two things. One, 70% of overall protein coming from plant foods was much more easily attained, and indeed vegan diets demonstrate that all protein can be provided through plant foods. Two, if considering 70% of dietary protein requirements – rather than 70% of total protein – this goal was achievable. In fact, based on estimates by Nutritionist Pro, the updated Bean Cuisine contained approximately 98 g of protein per day, and about 37.5 g of those were from pulses. So, if the protein requirement of 0.8 g/kg body weight is considered [209], this 37.5 g of protein could already attain 70% of the protein requirement for someone who weighs about 65 kg.

Overall, the Bean Cuisine serves as a stealth health approach, wherein healthy eating behaviors are encouraged through participation in the project. Using healthful ingredients to provide healthier – but still tasty – meals is an approach utilized by institutions like the Culinary Institute of America (CIA) as well. For example, the CIA explains that they adopt a stealth health approach to produce healthier recipes and meals, relying on healthful flavoring strategies and techniques instead of sodium, sugar, and saturated fat [210].

All 56 citizen scientists elected to receive the final Bean Cuisine, and several emailed the lead author during the editing process asking when it would be done, indicating they were looking forward to seeing it. Citizen scientists were emailed to ask if they were comfortable having their first name and last initial included on the Acknowledgements page. Fifty-four indicated yes, one declined, and one requested only first name and no last initial. This type of affirmative response suggests that they feel some sense of ownership in the project. Upon receiving the Bean Cuisine, many citizen scientists responded, expressing thanks, positive feedback, and excitement to try the new recipes.

4.2. Citizen Scientist Demographics

Higher participation by White, educated females matches the demographics of other citizen science projects [153,211]. A relative lack of sociodemographic diversity is a common limitation faced by many citizen science projects, which may limit generalizability to a larger audience [153,211]. It is of note, however, that although more females participated than males, many citizen scientists engaged their families and friends and incorporated their feedback. For example, on her intake form, one citizen scientist commented that she and her husband would both be participating and that "You'll be getting us both in the survey responses." Thus, the demographics of individuals providing feedback likely vary from what is shown in Supplementary Materials S3.5, and the number of individuals providing feedback exceeds 56.

4.3. Citizen Scientist Feedback and Bean Cuisine Modification

Although feedback was positive overall, of course, there was also criticism. One individual claimed to be "underwhelmed" by the recipes, several expressed the desire for more flavor, and another citizen scientist stated, "I would probably be more likely to repeat the recipes if they were a little more flavorful, containing more fat, sweetening agents, and spices." This reveals a challenge in developing healthy recipes that fall within dietary guidelines, meet a certain level of pulse consumption (35% total dietary protein coming from pulses, in this case), and appeal to everyone. Sensory feedback thus plays a critical role in determining the most and least liked recipes of a target audience and identifying recipes that need improvement [212]. Providing recipes that are largely interchangeable is another way to help ensure that there are desirable choices for people with different taste preferences, i.e., if someone finds one breakfast unappealing, they can switch it with a different breakfast and still attain a similar amount of protein from pulses.

Constructive criticism helped improve recipe clarity and taste. Citizen scientists had different views of overall recipe appeal, with ratings varying even for the same recipe. However, this is also partially due to individual taste preferences and the nature of being assigned recipes. For example, some people were assigned a recipe they would not have chosen for themselves (example quote: "Yuck! I am not a smoothie person. This did not change my attitude towards smoothies."), which resulted in a low score.

As previously mentioned, citizen scientists only indicated following the recipe 54% of the time. Sometimes modifications were minor, such as increasing the seasoning level. However, other times, modifications entailed multiple ingredient substitutions or completely diverged from the recipe (example: "I am sorry, I went totally off script here, but the result was so good. I hate yogurt, and the dip idea didn't really fit with our meal plan. So instead, I tossed the chickpeas in the hot sauce/lemon juice/dill/onion powder/parsley, plus 2 tbsp of tahini, and roasted at 375 for 30 min."). This resulted in feedback that was not always pertinent to the recipe, as significant modifications were made on occasion. Indeed, data quality is a major concern in citizen scientist projects [153,213]. Yet, due to the nature and goal of this project, this type of feedback does not represent low data quality but rather shows increased external validity [213] because it reflects what happens in the home kitchen when people use recipes, as they are prone to modify to suit their tastes. The recipes nonetheless inspired people to try pulses in new ways, thereby expanding their awareness of versatile uses, and it was a more realistic way to test how recipes work in the home kitchen.

Although we ultimately had a 100% response rate, another challenge was receiving feedback on all four recipes from all 56 citizen scientists. Some participants took longer to respond than others and required follow-up emails. Given the nature of a volunteer project, this is understandable. Nonetheless, it presents a difficulty by placing a time burden on the research team to track responses and follow up with participants. Following up with people before beginning the project to reaffirm interest, providing a welcome training kit and gift (Colorado Proud beans), offering training so people understood the project and had the opportunity to engage with the researchers, regularly following up with participants, and providing an incentive upon completion all appeared to be essential in attaining a 100% response rate, and similar approaches can be used in future citizen science efforts.

4.4. Impacts of Participation

Baseline knowledge levels of nutrition and health benefits, versatility, and preparation were already relatively high, as shown in Table 3.2. Other citizen science projects experience this as well, with individuals who are already highly interested in the topic – and thus often more knowledgeable about it – among the main participants [192,211,214]. Nonetheless, knowledge levels did vary, with one citizen scientist commenting upon completion of the project, "It was fun to try new recipes and learn about an ingredient I don't use all that much." This suggests that one potential appeal of participating was the chance to simply learn more about food they do not currently use on a regular basis.

As shown in Table 3.2, citizen scientists' self-reported knowledge significantly increased for all three categories assessed in this project: nutrition and health benefits, versatile uses of pulses, and how to prepare dry pulses. Knowledge of versatility saw the greatest increase in average score, rising from 3.39 to 4.38, for a total increase of 0.99 on a 5-point Likert scale. This makes sense, given the nature and focus of the project on showcasing different ways to include pulses in every meal. The next greatest average increase was in knowledge of how to prepare dry pulses, which rose from 3.55 to 4.36 (0.81 increase). Citizen scientists were also mailed dry beans and information on how to cook dry pulses, which could have played a role in the increase in knowledge of how to prepare dry pulses. This corresponds with the increased frequency in the use of dry pulses compared to canned, which was seen when comparing preparation habits before and after the project. It is logical that the smallest average knowledge increase was seen for nutrition and health benefits (3.86 to 4.29, for a 0.43 increase) because the only time this topic was really discussed during the project was during the orientation and training. In addition, participants already rated their knowledge of pulse nutrition and health benefits as high before participation (average score of 3.86 out of 5 before beginning).

Although the frequency of pulse consumption appeared to increase (Figure 3.3), with a greater percentage of individuals reporting eating pulses 1–3 days a week or 4–6 days a week after participation, the result was not found to be significant ($p = 0.137$). This could partly be due to the large percentage of citizen scientists who already regularly ate pulses before this project. Another challenge was the inability to assess detailed pulse intake information due to the nature of the response options; although they asked about the general frequency of consumption, they did not collect data on the exact number of days pulses were consumed and the actual amounts eaten. Indeed, a lack of validated pulse-specific dietary assessments is one of the challenges in advancing pulse research [24].

When asked during the final feedback survey if they now tried to eat more pulses as a result of participating in this citizen scientist project, $n = 40$ (71.4%) of individuals indicated yes. Combined with the overall trend of increased frequency, this suggests that pulse intake increased post-participation. However, it highlights a key takeaway. Arguably, one of the most important outcomes of participation could be increased pulse consumption. The lack of a tool to better assess the types and amounts of pulse consumed thus poses a challenge.

In a recent paper by Henn and colleagues (2022), the authors developed a tool that begins to address some of these concerns [130]. They asked about the frequency of consumption for the different types of pulses in a manner very similar to this study, but in addition to a question about the frequency of overall pulse intake, they also broke it down into pulse type (e.g., a respondent could select that they eat black beans 2–3 times a week). Moreover, they gather information on what situations different pulse types are consumed (e.g., at home, in a restaurant, on the go, at work/school, other), in which form pulses are purchased (e.g., dried, canned, processed products), and how the pulses are eaten (e.g., as a main ingredient, in a side), and what foods are prepared from pulses (e.g., stews, pasta, salad). Gathering such information will be useful in helping better understand consumer behavior and assess changes in frequency and manner of consumption. However, future citizen science efforts should also assess changes to the actual volume of intake, if possible, through a more sensitive tool. Other citizen science work has also found a similar need to develop more sensitive measures to better assess the impacts of participation [215].

Another point of interest was whether participating influenced preparation behavior. Citizen scientists received dry pinto and Mayocoba beans in the mail, as well as handouts with information about how to prepare dry pulses. Figure 3.4 suggests that post-participation, citizen scientists did seem to use dry pulses more frequently. However, the nature of the response options limited the analysis to descriptive statistics. The most notable change is a shift from using mainly canned options (n = 28 before the project) to a more even mix of canned and dry pulses. Participants still showed high usage of canned pulses after completing the project, likely due to the convenience factor [216].

Especially given that not all citizen scientists were from Colorado, it is expected that many of them may not make an effort to purchase Colorado-grown beans. Yet, the fact that the most common response selected on the intake form was "unsure if the beans I purchase are from Colorado or not" (n = 25, 44.6%) suggests that bean origin – whether from Colorado or another region – is often unknown and may not play much of a role in purchasing decisions. Participation in the project appeared to increase awareness of origin, with 69.6% of participants indicating upon completion that they are now more likely to purchase Colorado-grown pulses. This highlights the potential of spreading awareness about local products to influence future purchasing decisions in favor of local options. Barriers to local food purchasing include the inability to find identifiably local foods and a lack of time or behavior skills to prepare local foods [193]. This may be the case with dry pulses, as unfamiliarity with how to cook pulses and the versatile ways to use them is an established barrier to consumption [128]. One recommendation by Birch and colleagues (2018) to enhance appeal to consumers was to create clearer branding and labeling [217].

4.5. Participation in Citizen Science

The motivations of participants to join this project (see Table 3.3) match those in other citizen science projects, which include intrinsic interest in the project topic, desire to participate in science, and personal enjoyment [153,211]. Naturally, the desire to increase their knowledge about beans and recipes using beans was a big pull for this project. Moreover, a major theme under "Values" was volunteer spirit. Several citizen scientists were already active volunteers and/or had experience participating in other citizen science projects, suggesting the importance of positive prior experiences to encourage continued participation in public science. The Bean Cuisine was also uniquely positioned to contribute to participant health and cooking skills, and many participants expressed a desire to learn about how to incorporate more beans in their diets as a way to directly improve their health or that of their loved ones. Clearly, people recognize the importance of pulses in a healthy diet, but they do not always appear to feel confident about how to prepare them in versatile, delicious ways that foster regular inclusion in the diet. In the "Interests" theme, many stated a direct interest in beans and/or cooking, which would be expected due to the tendency of citizen scientist participants to already have an established interest in the project topic [153].

As demonstrated in Table 3.4, citizen scientists reported various knowledge gains due to participation, which matches the significant increases in knowledge of pulse health benefits, versatility, and cooking of dry pulses shown in Table 3.2. Participants also frequently commented on the surprising versatility of pulses, demonstrating an increased awareness of ways to use them in the kitchen. Importantly, not only did they find new favorite recipes, but they recognized ways to easily incorporate pulses into their current diets. For example, after realizing that pulses work well in smoothies and with roasted vegetables, participants can easily include pulses without having to learn completely new base recipes. Instead, they can make a quick modification to their dietary patterns with a simple addition of pulses to currently preferred foods (e.g., smoothies, roasted vegetables, oatmeal). Even those who reported loving beans before beginning explained how the recipes encouraged them to think outside of the box and "got us out of our ruts." Liking for Mayocoba beans, one of the beans sent to citizen scientists in their toolkit, was also commonly expressed. Many individuals had not previously tried this bean but stated an intention to now often include it in their diets, showing the potential of the introduction of new pulses to generate interest and excitement.

Citizen scientists also reported an overall positive experience and expressed a desire to continue participating in citizen science efforts. This is likely due to the fun they had, the knowledge and skills they gained that they deemed useful, and the sense of fulfillment they felt due to their meaningful contribution, e.g., “This was a fun way to participate in an interesting project that I think could really help others.”

A highly encouraging finding was the role citizen scientists adopted in their communities of sharing project knowledge and being pulse advocates. Other citizen science projects have also found that citizen scientists exhibit behaviors suggesting they act as program advocates [218,219]. Citizen science is suggested to provide deeper meaning to participants’ interests and hobbies [220]. In this sense, participation in the Bean Cuisine project could equip participants with more topic area knowledge, inspire them to explore pulse versatility, and further their interest, which naturally leads to them sharing with others. In this study, participants shared with family, neighbors, and friends, including everyone in recipe feedback. This provided greater depth of feedback, as well as creating an opportunity for shared learning about the benefits and versatility of pulses.

In this analysis of the outcomes of participation, it is evident that the benefits for citizen scientists went beyond mere knowledge gain, and cooking and consumption behavior was also impacted. This is critical because although knowledge is important, knowledge in and of itself does not successfully drive behavior change. To achieve the true adoption of healthful behaviors, it is essential to increase knowledge, motivate individuals (e.g., through participation in the project and engagement with scientists and like-minded individuals), and encourage behavioral skills (e.g., tips to cook dry pulses, preparing pulses in versatile ways) [128].

4.6. Sensory Panel

Overall, sensory panelists reported being satisfied with all the dishes (see Table 3.5). The recipe that ranked most highly was the White Bean Waldorf Salad, demonstrating the potential to increase bean consumption by adding beans to dishes people already eat, but may not think to include beans. Indeed, one sensory panelist stated, “I didn’t think beans belonged in Waldorf, but they DO.” Promoting creative ways to eat more pulses, especially when it only requires the simple addition of pulses to a dish people already include in their daily lives rather than learning a whole new recipe, is one approach to quickly increase pulse intake.

4.7. The Bean Cuisine as a Model for Stealth Health Approaches

The Bean Cuisine serves as a pilot study for future citizen science projects with broader public health goals. This work demonstrated the feasibility of actively engaging the public in similar projects that can directly improve dietary habits. Participating as citizen scientists provided an extra incentive to try new recipes and eating habits and to begin routinizing healthier dietary habits, in this case through higher pulse inclusion in the diet. Thus, citizen science efforts represent a powerful opportunity to improve public well-being – and even influence positive environmental outcomes when the food is associated with planetary benefits, as is the case with pulses [99].

Adoption of dietary patterns similar to the Bean Cuisine would reverse the current fiber gap (i.e., the dramatic difference between recommended and actual fiber intake) faced in the United States and many countries around the world [10]. Also, it would help promote adequate consumption of other dietary components of public health concern, like potassium [11]. As we increasingly face public and environmental health challenges, it is important to recognize the underutilized power in citizen science approaches and take better advantage of engagement research to shift dietary patterns for the public good.

4.8. Limitations and Future Directions

There are several key limitations to this study. As previously explained, there was a relative lack of sociodemographic diversity among participants, which may limit generalizability to a wider audience in aspects such as taste preferences. Also, those who are already interested in the topic – and therefore likely have greater baseline knowledge and potentially greater consumption levels of pulses – were more likely to participate. Again, this poses a challenge when considering the feasibility of this type of citizen science and stealth health approach on a broader audience. Due to the nature of the study and data collection tools, it was not possible to examine in-depth changes to pulse preparation and consumption habits, nor longer-term behavior changes or overall health impacts. Future studies could engage a more diverse group of citizen scientists to actually test the whole Bean Cuisine rather than providing feedback on one day of recipes. Ideally, this type of study would also collect data on health markers (e.g., stool samples to assess changes to the gut microbiome [92]) and longer-term impacts on behavior change, for instance, checking if pulse consumption remains high at several time points after completion of the project. Another measurement of interest would be any effects on intestinal discomfort [134], as concerns over flatulence pose a barrier to higher pulse consumption [128] and addressing these could be helpful in promoting increased intake. Research suggests that many individuals do not experience increased intestinal discomfort with beans and that most of those who do have discomfort see symptoms dissipate within one to three weeks [44]. Testing this finding, especially considering higher pulse intake levels than in previous studies, would be informative about the likely willingness of people to adopt such a dietary pattern. Lastly, the Bean Cuisine could be expanded, incorporating a wider variety of recipes from countries around the globe – including India, Japan, Ethiopia, Mexico, and others – to better represent and showcase the diverse culinary uses of pulses. Drawing inspiration from countries with higher pulse intake, such as Rwanda and Burundi [10], could also help inspire ways to better routinize regular pulse consumption.

5. Conclusions

Increasing the production and consumption of beans and other pulses can provide a wide array of human and environmental health benefits, all at a relatively economical price. Despite the impressive list of benefits that could be reaped through the higher incorporation of pulses into daily diets, consumption is low in many countries around the world, with one of the main barriers being a lack of familiarity with how to prepare pulses and take advantage of their versatile uses. Citizen science provides a unique approach to advancing consumption because it actively engages the public and addresses this barrier to consumption, empowering participants to be advocates for the benefits of pulse consumption within their own communities. Citizen scientists reported increases in pulse intake, usage of dry pulses, and knowledge about pulse benefits and versatility, and they explicitly stated their intentions to regularly eat pulses. This highlights how this type of outreach research can increase public knowledge and move the needle for the adoption of healthy eating behaviors, for instance, by helping routinize higher pulse consumption through a stealth health approach. Moreover, citizen scientists engaged in spreading awareness about the project and pulses, becoming stronger pulse advocates in their communities. Thus, the presented results suggest that involving the public in the research process is mutually beneficial to scientists and the public alike, broadening reach and impact beyond the doors of academic institutions to engage and benefit a wider audience. Increases in knowledge and engagement with the scientific community can be perceived as benefits for citizen scientists. However, citizen science projects are also positioned to move beyond mere increases in knowledge level to help attain participant adoption of healthy dietary patterns. To strengthen the ability of citizen science research to draw conclusions about the influence of participation upon behavior changes – such as significant impacts on pulse consumption – it is critical to design sensitive measures. Doing so will be essential to support increased recognition of the potential of citizen science to move the needle on behavior change that advances public and environmental health.

CHAPTER 4: THE EFFECTS OF ELEVATION AND SOAKING CONDITIONS ON DRY BEAN COOKING TIME[11]

Summary

Dry beans and other pulses (e.g., chickpeas, cowpeas) are nutrient-dense foods that promote human and environmental health. However, consumption is declining in many regions around the world. Addressing barriers to greater pulse intake is important to reverse this trend. Cooking time is one such barrier, with consumers viewing the long cooking times of many pulses as a hurdle to higher consumption due to lack of time or fuel availability. Equipping consumers with simple, accessible ways to reduce pulse cooking time is one way to mitigate this barrier. Accordingly, this study assessed changes to cooking time when pinto beans (*Phaseolus vulgaris* L.) were cooked at four elevations using different soaking conditions, which reflect a combination of the soaking method and salt added to the soaking solution. There were seven different cooking conditions: soaking via the overnight or quick soak method in only water or in 1% sodium chloride (NaCl) or sodium bicarbonate ($NaHCO_3$) solutions, and a no soak with no salt added comparison. Using an overnight (12-hour) soak or a quick soak resulted in similar reductions in cooking time compared to unsoaked beans. Soaking in NaCl and $NaHCO_3$ solutions

[11]This research has already been published with the journal Legume Science. To stay true to how the paper was published but adhere to CSU Graduate School dissertation formatting: 1.) the numbers of figures, tables, and the supporting information referenced has a "4." appended to reflect being in chapter 4; 2.) keywords and journal ending statements (e.g., funding, data availability statement) are not displayed; 3.) spacing has been adjusted to match CSU formatting; and 4.) the supporting material mentioned in this paper can be found online at https://onlinelibrary.wiley.com/doi/10.1002/leg3.207. Citation information is as follows: Didinger, C.; Cichy, K.; Urrea, C.; Scanlan, M.; & Thompson, H. J. The effects of elevation and soaking conditions on dry bean cooking time. *Legume Sci.* **2023**, *e207*.

further decreased cooking time than when only water was used, with the shortest cooking times seen for $NaHCO_3$. Elevation also impacted cooking time, with the longest cooking time being for unsoaked beans at the highest testing elevation. Adding either salt to the soaking water reduced the effect of elevation. This information was synthesized to give consumers practical tips to reduce cooking time.

1. Introduction

Beans and other pulses (i.e., the dry, edible seeds of non-oilseed legumes like chickpeas, cowpeas, dry peas, and lentils) are nutrient-dense foods positioned to help simultaneously improve the well-being of people and the planet [99]. Due to the wide variety of environmental benefits [99-101] and positive public health outcomes with which they are associated [6,159], combined with their relatively affordable price point, one might expect that pulse consumption is high. However, intake in many countries is low [126], which prevents capitalization on the myriad benefits that greater incorporation of pulses into food systems could provide. Some reasons for this sub-optimal consumption level are barriers that consumers face [128,130,133]. Paramount among these is the long cooking time of pulses [128,130,132]. Depending on the audience, long cooking time can present a challenge due to fuel scarcity or a perceived lack of time and thus inconvenience when preparing pulses [129]. Mitigating the barrier of long cooking times via disseminating practical tips centered around consumer-accessible cooking methods is one way to address this concern and help enable higher pulse consumption and the associated health advantages. It is also valuable to provide clarity on potential points of consumer confusion surrounding cooking dry beans, such as how different factors (e.g., elevation, cooking method) impact cooking time, to help ensure a more positive cooking experience.

To achieve this, it is important to synthesize research findings to-date to determine what methods can affect cooking time. The current literature demonstrates that soaking beans is a practical way to reduce cooking time [174,221,222]. Evidence also supports the addition of salts to the soaking water as one way to further reduce cooking time. The types of cations present in the soaking solution can impact cooking time, and soaking in bivalent salts – like those with Ca^{++} solutions – increases cooking time, whereas soaking solutions of monovalent salts like Na^{+} can result in quicker softening [223]. One potential mechanism proposed to explain this is the cross-linking between calcium ions and pectin, which can form insoluble pectates, resulting in resistance to water absorption [223,224].

Njoroge and colleagues found that soaking in sodium carbonate (Na_2CO_3) reduced cooking time [223]. Similarly, Coskuner and Karababa [173] studied the effects of soaking on chickpeas and demonstrated that both sodium chloride (NaCl) and sodium bicarbonate ($NaHCO_3$) shortened cooking time, generally with greater reductions when using $NaHCO_3$. Bhokre and Joshi [172] found that soaking cowpeas in water, a 1% NaCl solution, and a 1% $NaHCO_3$ solution resulted in reductions in cooking time of approximately 51%, 66%, and 86%, respectively, compared to unsoaked samples. The investigators found a similar trend for horsegram, with reductions of about 13% for water only, 31% for NaCl, and 45% for $NaHCO_3$ compared to unsoaked, as well as in mothbean, with 20%, 50%, and 80% decreases in cooking time. Although some studies have found slight increases in cooking time or hardness when soaking in salt solutions with NaCl and/or potassium chloride (KCl) [225,226], these same studies have found decreases in cooking time when using soaking solutions with $NaHCO_3$ [225] and potassium carbonate (K_2CO_3) [226]. Some of these differences could be attributed to different study designs. For instance, diverse pulses are used and cooking time is measured in different ways, such as the tactile (i.e., finger pressing) method and via a device like a Mattson cooker [174]. Another potential reason is the different pH of soaking solutions. Alkaline solutions may act as tenderizers [224], enhancing pectin solubilization, helping cells separate better during cooking and reducing cooking time [223]. Overall, soaking solutions that contain monovalent salt solutions appear to reduce cooking times, although NaCl sometimes is not found to have an effect [224].

Reducing cooking time with salt treatments represents a practical approach for consumers because many of these salts (e.g., table salt and baking soda) are common household items. Some websites known for food science and culinary tips, like America's Test Kitchen and Serious Eats, purport the benefits of adding salt to bean soaking water [227,228]. Yet, there is still a common belief among the public and culinary industry that the use of salt in soaking water can prevent softening, and this information is repeated even on the websites of organizations that share knowledge about how to cook pulses [229,230]. Such inconsistent messaging can result in confusion and is clearly not successful in equipping consumers with practical, evidence-based tips to mitigate an important barrier to pulse consumption: long cooking times.

Elevation is another factor that can significantly impact cooking time, with longer times seen as elevation increases [169,170]. However, the main study that examines cooking times at different elevations was published in 1996, used finger pressing and biting to assess cooking time, cooked samples in drinking water (which could vary by site location), and did not evaluate the impacts of different soaking methods or solutions [169]. In contrast, the current study used a Mattson cooker to standardize cooking time data collection. To the best of our knowledge, no studies have investigated the interaction between elevation and cooking condition. For the purposes of this paper, the cooking condition represents the combination of soaking time (i.e., overnight soak or quick soak, which are two methods commonly recommended to consumers [183]) and salt added to the soaking solution (i.e., none, NaCl, or $NaHCO_3$), with a no soak comparison.

To more effectively enable consumers to cook pulses faster – thereby mitigating a key barrier to higher consumption – it is critical to better understand the influence of cooking conditions and elevation on pulse cooking time. Thus, this study differs from other studies on dry bean cooking times because it is geared towards consumer education. After investigating practical, consumer-accessible cooking conditions at different elevations, findings were synthesized with evidence in the literature to develop a public-facing resource for dissemination through the Extension network. Therefore, a translational approach was adopted to ensure that evidence-based practical tips to reduce pulse cooking time are made available to the public.

2. Methods

2.1. Bean Material

Bean cooking time can vary with genotype [129,170,231]. Thus, all seed used was the Monterrey cultivar of pinto bean. Beans were grown in Idaho under sprinkler irrigation, and certified, untreated seed was obtained from Kelley Bean Co. The seed was harvested in fall of 2020, procured in late spring 2021, and cooking time tests occurred in summer of 2021 through winter of 2022. This is reflective of the shelf-life of beans [232], the period of time it takes for beans to be processed and packed, and how long beans would be stored after harvest before being cooked by consumers.

2.2. Cooking Conditions and Locations

To replicate common and accessible cooking conditions consumers may use in their homes, three different soaking times were used: 1.) an overnight soak (i.e., soak beans for 12 hours at room temperature, then discard the soaking water and cook in fresh water); 2.) a quick soak (i.e., bring beans to a boil and hold that for 3 minutes, allow to sit in hot water for 1 hour, then discard soaking water and cook in fresh water) [183]; and 3.) no soak. The no soak condition served as the comparison to assess how different cooking conditions impacted cooking time. Three different soaking solutions were used: 1.) only distilled water; 2.) 1% sodium chloride (NaCl); and 3.) 1% sodium bicarbonate ($NaHCO_3$). This reflects the 1% soaking solution used in other studies that assess cooking time [172,173]. Thus, three different soaking solutions were tested with the overnight soak, three with the quick soak, and a no soak condition, resulting in seven cooking conditions, as shown in Figure 4.1. For each condition that included soaking, approximately 20 grams of seed were measured and soaked in a 1:4 w/w ratio (i.e., 20 g beans and 80 g soaking solution).

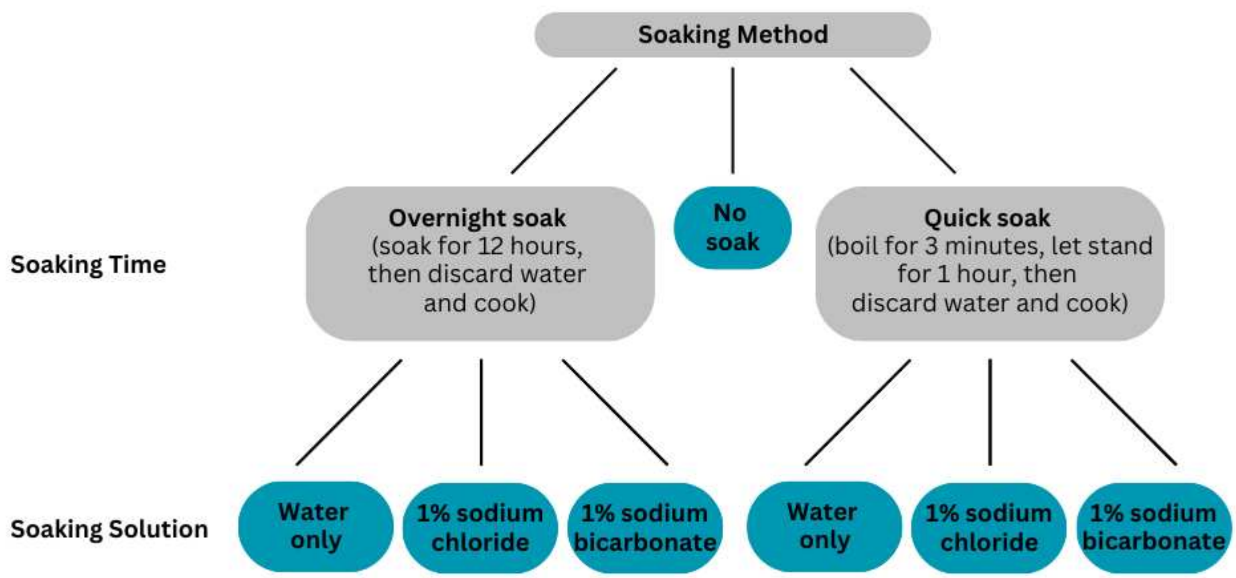


Figure 4.1. Cooking conditions. Each blue circle represents one of the seven cooking conditions, as explained in the text.

All seven conditions were tested at four different locations with different elevations, as shown in Table 4.1. The lowest elevation was East Lansing, close to sea level (263 m), and the highest was in Leadville, at over 3000 m.

Table 4.1. Elevation of different testing sites and the boiling temperature of water at that elevation.

Location	Elevation (m)	Temperature at which water boils (°C)
East Lansing, Michigan	263	99.2
Scottsbluff, Nebraska	1200	96.1
Fort Collins, Colorado	1569	94.8
Leadville, Colorado	3125	89.5

2.3. Assessing Cooking Time

An automated Mattson cooker was used to measure cooking time [233], as this is a standard way to assess the cooking time of pulses [174,234,235]. Briefly, a Mattson cooker contains 25 pins that align with the base plate, which contains 25 wells that can hold one bean each. The following video demonstrates the operation: https://www.youtube.com/shorts/3rMvHuVxKDA. After the beans had been prepared according to their cooking conditions, they were added to the wells of the Mattson cooker. Evenly weighted (approximately 63 g) piercing rods rest on top of the center of the bean in each well. The cooker was then placed into a beaker of fresh boiling distilled water on a burner. Individual beans are considered cooked when they soften enough that they are pierced by the rod, and the Mattson cooker program automatically records the pin drop time. The cooking time of the sample is determined to be when 80% of the beans have been pierced by the rods, and this has been found to equate to fully cooked samples based on mouthfeel as determined by a trained sensory panel [129,235,236]. Each cooking condition was conducted in replicate to calculate the average cooking time for a condition. Due to the extended cooking time at the Leadville location, most cooking conditions were only tested in duplicate. Other locations conducted tests in at least triplicate to calculate an average cooking time for each condition.

2.4. Water Uptake, pH, and Moisture Content

Water uptake was calculated by obtaining the weight of: 1.) the dry seeds; and 2.) the seeds after soaking, by first draining and blotting them dry. The formula used to determine the percent water uptake on a dry basis was: (soaked weight - dry weight) / (dry weight) x 100. Before soaking, the moisture content of the dry beans was recorded. Measurements of the pH of the soaking solution at the beginning and end of the soaking time were taken. Due to the research occurring in multiple sites, the equipment used differed among research teams. To measure pH, the team in Michigan used pH test paper strips; Nebraska, a Corning pH meter 440; and Colorado, a Dr. Meter pH Meter (due to needing to travel off-site for testing at the highest elevation). For moisture level, the Michigan team utilized a Dickey-John GAC 2500UGMA; Nebraska, a Dickey-John GAC 2100b; and Colorado, a John Deere Grain Moisture Tester.

2.5. Statistical Analysis

Statistical analyses were conducted in IBM SPSS Statistics version 28 (IBM Corp. Released 2021. IBM SPSS Statistics for Windows, Version 28.0. Armonk, NY: IBM Corp.). To evaluate the effects of elevation and cooking condition on bean cooking time, a two-way analysis of variance (ANOVA) was conducted, with cooking time as the dependent variable. Cooking condition and elevation were considered main effects, and the interaction between elevation and cooking condition was also assessed. Due to the large number of comparisons being made, pairwise comparisons were calculated using the more conservative Bonferroni test. Descriptive statistics, such as average cooking time for the seven cooking conditions at each elevation, were also computed in SPSS. For analyses within individual conditions, a curvilinear regression was conducted.

Percent changes in cooking time were calculated in Excel, using mean cooking times for each condition at each elevation. The following three comparisons were made:

1. Increases in cooking time seen with higher elevations: Percent increase in cooking time for a cooking condition = (site 2 mean – site 1 mean) / (site 1 mean)
2. Decreases in cooking time seen with soaking: Percent decrease in cooking time = (mean cooking time for the no soak condition – mean cooking time for comparison condition) / (mean cooking time for the no soak condition)
3. Decreases in cooking time seen with salt added: Percent decrease in cooking time = (mean cooking time for salt 1 – mean cooking time for salt 2) / (mean cooking time for salt 1)

3. Results

3.1. Average Cooking Time, Water Uptake, pH, and Moisture Content

Cooking times (in minutes) ± standard deviation (SD) for the different cooking conditions at all four elevations are shown in Table 4.2.

Table 4.3 shows the average water uptake rates for the different cooking conditions at the four locations and the average pH of the soaking solution at the end of the soaking period. The no salt, no soak condition is not shown because a water uptake measurement could not be taken due to no soak occurring. Michigan (elevation 263 m) conducted two batches of three runs for each condition, separated by one month.

Table 4.2. Average cooking times for cooking conditions at different elevations.

	No salt	Only water		NaCl		$NaHCO_3$	
Elevation (m)	No soak	Quick soak	Overnight soak	Quick soak	Overnight soak	Quick soak	Overnight soak
263	88.4 ± 7.8	37.7 ± 4.1	40.9 ± 8.3	31.5 ± 2.5	27.0 ± 2.4	21.5 ± 3.1	18.4 ± 1.9
1200	110.7 ± 3.7	58.0 ± 4.3	73.3 ± 11.9	53.7 ± 5.6	67.4 ± 22.6	37.9 ± 1.5	64.1 ± 10.4
1569	131.0 ± 6.9	64.7 ± 6.8	54.4 ± 3.1	52.2 ± 3.8	47.8 ± 1.9	33.2 ± 2.0	35.3 ± 1.5
3125	296.0 ± 21.6	165.4 ± 35.0	139.1 ± 15.0	122.4 ± 8.7	110.4 ± 3.1	64.4 ± 10.1	68.8 ± 5.8

Cooking times are shown in minutes ± SD. *NaCl* 1% sodium chloride soaking solution; *$NaHCO_3$* 1% sodium bicarbonate soaking solution.

Table 4.3. Average water uptake and pH.

Location elevation (m)		263		1200	1569	3125
Date (month-year) tests were conducted		Dec-2021	Jan-2022	Feb-2022 & Mar-2022	Aug-2021	Aug-2021
Average moisture level of seed (%)		10.9	11.1	10.5	10.1†	9.6†
Average # tests/cooking condition		3	3	3	3.4	2.1
Only water, QS	Water uptake (%)	107.1	104.1	100.9	104.9	99.5
	pH	7‡	7	6.2	6.4	6.4
Only water, OS	Water uptake (%)	98.5	83.9	41.0	92.2	56.3
	pH	7	7	6.5	6.0	6.2
NaCl, QS	Water uptake (%)	100.6	97.7	88.9	90.3	82.9
	pH	7	7	6.1	5.9	6.0
NaCl, OS	Water uptake (%)	97.7	81.2	35.0	83.5	51.1
	pH	7	7	6.0	5.7	5.8
$NaHCO_3$, QS	Water uptake (%)	104.0	105.2	96.7	97.6	92.0
	pH	9	9	9.0	9.0	9.1
$NaHCO_3$, OS	Water uptake (%)	96.5	80.2	35.3	86.2	63.8
	pH	9	9	8.4	8.2	8.5

"Average # tests/cooking condition" refers to the average number of tests run at each elevation for the cooking conditions, taking into account the no salt, no soak comparison. †The moisture level read by the Moisture Tester for the Colorado locations appeared to provide readings lower than the actual moisture content due to the device used. ‡Michigan used pH test paper strips to measure pH to the whole number. *QS* quick soak; *OS* overnight soak; *NaCl* sodium chloride soaking solution; *$NaHCO_3$* sodium bicarbonate soaking solution.

The temperature of the soaking water is one of the main factors that influences the hydration process, with higher temperatures accelerating hydration [237]. Thus, water uptake values are provided, but a statistical test evaluating the impact of elevation and cooking condition is not conducted, as this would not account for ambient temperatures, which varied with location and season.

As shown in Table 4.3, the average water uptake tended to decrease as the beans aged. This is apparent when comparing the same cooking condition in Michigan in December 2021 versus January 2022. Although similar, the pH of the NaCl soaking solution was slightly lower than that of soaking in water with no salt added. When comparing the quick soak and overnight soak within the same soaking solution (i.e., same salt), the quick soak appeared to have a higher pH. This difference was the most pronounced for the $NaHCO_3$ conditions.

The age and moisture content of the seed influences water uptake, hence cooking time tests were conducted as close together as possible and moisture content was assessed. Average moisture content fell within the standard range of 10-14% used with Mattson cooker trials [129,170]. As the table caption states, the moisture levels reported for the two Colorado locations are likely lower than the actual moisture content. This is reflected by readings that were lower than the moisture content of the same seed (that had been stored in a sealed container) when tested several months later in Michigan and Nebraska, when it would be expected that older seeds should have a lower moisture level.

3.2. Cooking Time Varies with Cooking Condition and Elevation on Cooking Time

As shown in Figure 4.2, cooking time is reduced with soaking and further reduced by the addition of salts to the soaking water.

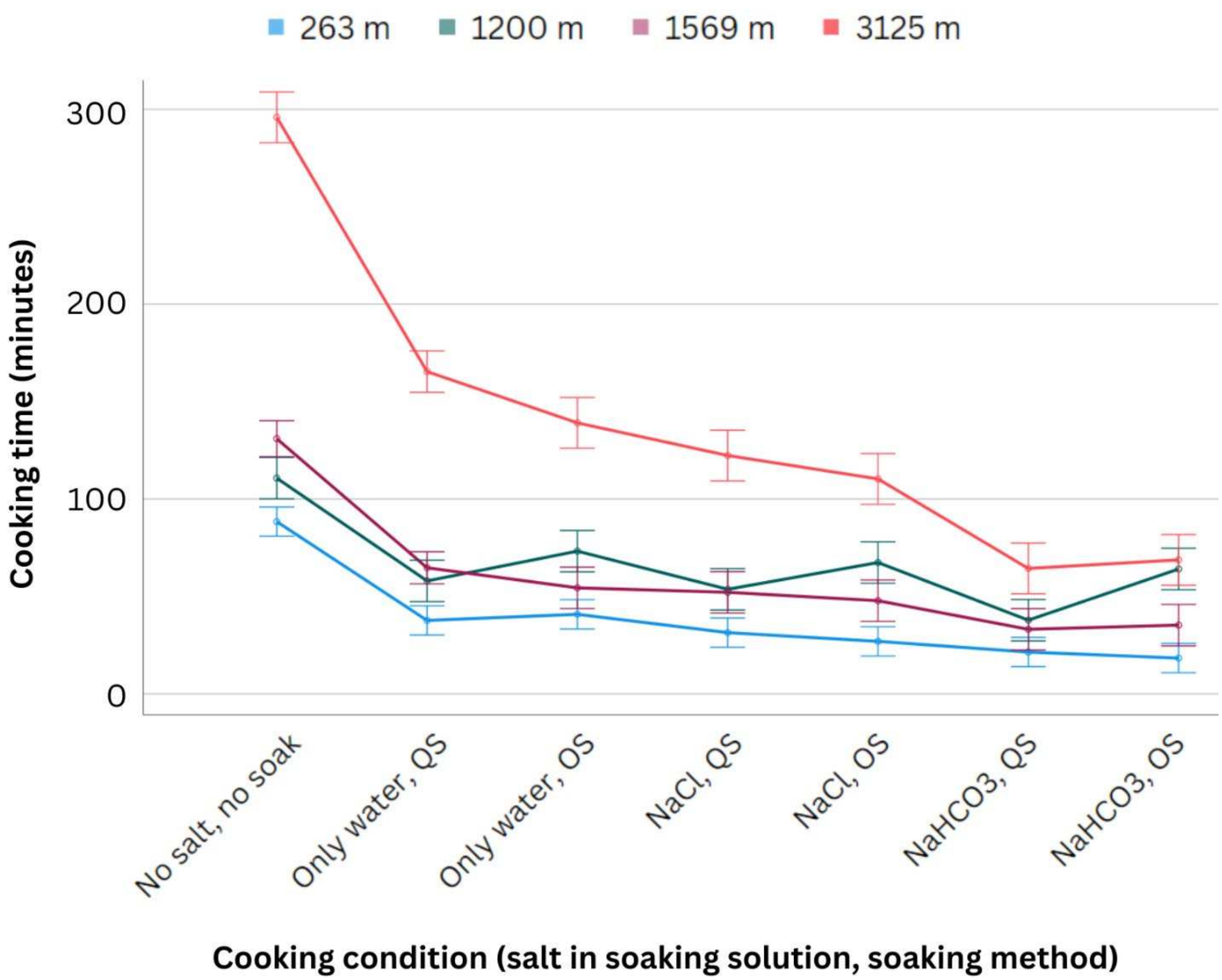


Figure 4.2. Cooking time varies with cooking condition and elevation. Plotted cooking times (minutes) are average cooking times for a particular cooking condition at the specified elevation, with errors bars showing ± standard error (SE). *QS* quick soak; *OS* overnight soak; *NaCl* sodium chloride soaking solution; $NaHCO_3$ sodium bicarbonate soaking solution.

Levene's test of equality yielded a significant result, which is addressed in the discussion. The ANOVA analysis demonstrated that elevation and cooking conditions were significant main effects (see Table 4.4). The interaction effect for cooking condition*elevation was also found to be significant, indicating that the impact of the cooking condition depends on elevation. The non-parallel lines in Figure 4.2 are also indicative of an interaction effect. Due to the large number of pairwise comparisons, results are not displayed in the paper but are available in Supporting

Information S4.1, which breaks down the cooking time trials by the four elevations and shows which cooking conditions result in significantly different cooking times at each elevation. For example, at the lowest elevation, the cooking condition of quick soak, no salt was found to be significantly different from the comparison condition of no soak, no salt ($p < 0.001$) but not the overnight soak, no salt condition ($p = 1.00$).

Table 4.4. Summary of the ANOVA for bean cooking time.

Sources of variation	*df*	Mean square	*F*	*p*
Cooking condition	6	18911.445	223.291	< 0.001
Elevation (ft)	3	36576.819	431.87	< 0.001
Cooking condition*elevation	18	1881.352	22.214	< 0.001

df degrees of freedom. Statistical significance when $p < 0.05$.

To investigate the interaction effect, conditions were examined separately, comparing the tests conducted on the same condition among the four different elevations. For the no salt, no soak condition, a quadratic fit ($R^2 = 0.986$) was better than a linear fit ($R^2 = 0.858$), as shown in Figure 3. The summary of the R^2 values is shown in Table 4.5, which demonstrates that quadratic is a better fit than linear for all the cooking conditions.

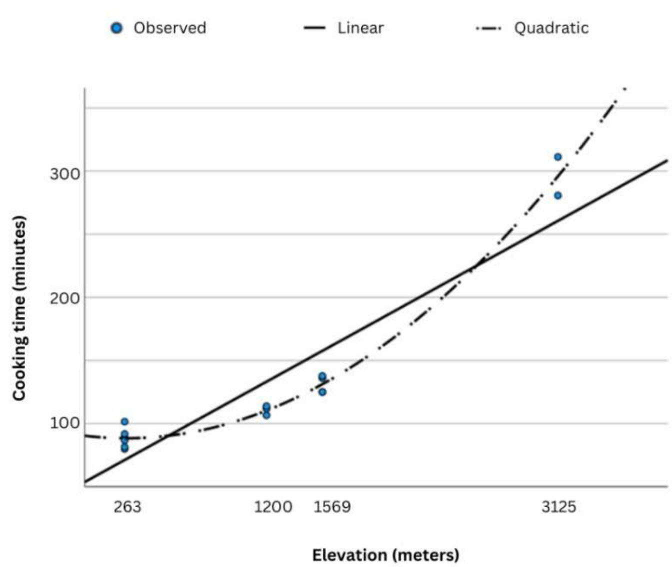


Figure 4.3. Linear and quadratic fits for the no salt, no soak cooking condition.

Table 4.5. Cooking condition curvilinear regression.

Cooking Condition	Linear, R^2 (*p*)	Quadratic, R^2 (*p*)	Difference (quadratic – linear)
No salt, no soak	0.858 (< 0.001)	0.986 (< 0.001)	0.128
Only water, quick soak	0.834 (< 0.001)	0.923 (< 0.001)	0.089
Only water, overnight soak	0.807 (< 0.001)	0.864 (< 0.001)	0.057
NaCl, quick soak	0.913 (< 0.001)	0.969 (< 0.001)	0.056
NaCl, overnight soak	0.804 (< 0.001)	0.807 (< 0.001)	0.003
$NaHCO_3$, quick soak	0.886 (< 0.001)	0.897 (< 0.001)	0.011
$NaHCO_3$, overnight soak	0.602 (0.001)	0.655 (0.003)	0.053

Statistical significance when $p < 0.05$.

3.3. Percent Changes in Cooking Time

Due to evidence of a significant interaction between elevation and cooking time, it is not advisable to statistically analyze the impact of elevation or cooking condition on cooking time. Instead, pairwise comparisons are shown in Supporting Information S4.1. However, to begin to evaluate the impacts the elevation and cooking condition may have on cooking time, percent change calculations were made. The percent increase in cooking time for each condition was calculated with increasing elevation, using the lowest elevation as the comparison. Table 4.6 shows the percent increase in cooking time that can occur with higher elevation. The longest cooking times occur at the highest elevation and are over 200% greater than those at the lowest elevation.

Table 4.7 shows percent changes with different soaking conditions compared to the no soak condition. Soaking reduced cooking time compared to the no soak condition. The percentage of the reduction varied with cooking condition and elevation, as suggested by the interaction effect. Depending on the elevation, the average reduction compared to the no soak condition ranged from 41-56% for soaking in only water, 45-67% for the sodium chloride soaking solution, and 54-77% for the sodium bicarbonate soaking solution. The greatest reductions in cooking time were seen when the beans were soaked in a 1% sodium bicarbonate solution. Although similar reductions were seen for the overnight and quick soak soaking methods for most elevations, there was greater variation between these two times for the 1200 m (Nebraska) location.

Table 4.8 shows the percent reduction in cooking time that can occur by adding different salts to the soaking solution. Compared to cooking conditions with no salt added to the soaking water, adding sodium bicarbonate resulted in greater reductions in cooking time than adding sodium chloride.

Table 4.6. Percent increase in cooking time with increasing elevation, compared to the lowest elevation (263 m).

	Only water			NaCl			$NaHCO_3$		
Elevation (m)	Quick soak	Overnight soak	Average increase vs. 263 m	Quick soak	Overnight soak	Average increase vs. 263 m	Quick soak	Overnight soak	Average increase vs. 263 m
1200	54%	79%	67%	71%	150%	110%	76%	249%	162%
1569	72%	33%	52%	66%	77%	72%	54%	92%	73%
3125	339%	240%	290%	289%	309%	299%	200%	274%	237%

The average increase represents the average of the quick and overnight soaks for the salt added to the solution (none, sodium chloride, or sodium bicarbonate). *NaCl* 1% sodium chloride soaking solution; *$NaHCO_3$* 1% sodium bicarbonate soaking solution.

Table 4.7. Percent reduction in cooking time with soaking versus no soak.

	Only water			NaCl			$NaHCO_3$		
Elevation (m)	Quick soak	Overnight soak	Average reduction vs. no soak	Quick soak	Overnight soak	Average reduction vs. no soak	Quick soak	Overnight soak	Average reduction vs. no soak
263	57%	54%	56%	64%	69%	67%	76%	79%	77%
1200	48%	34%	41%	52%	39%	45%	66%	42%	54%
1569	51%	58%	55%	60%	63%	62%	75%	73%	74%
3125	44%	53%	49%	59%	63%	61%	78%	77%	77%

The average reduction represents the average of the quick and overnight soaks for the salt added to the solution (none, sodium chloride, or sodium bicarbonate). *NaCl* 1% sodium chloride soaking solution; *$NaHCO_3$* 1% sodium bicarbonate soaking solution.

Table 4.8. Percent reduction in cooking time with salt added to the soaking solution, compared to other solutions.

	NaCl			$NaHCO_3$					
Elevation (m)	Quick soak	Overnight soak	Average reduction vs. no salt	Quick soak	Overnight soak	Average reduction vs. no salt	Quick soak	Overnight soak	Average reduction vs. NaCl
263	17%	34%	26%	43%	55%	49%	32%	32%	32%
1200	7%	8%	8%	35%	13%	22%	29%	5%	16%
1569	19%	12%	16%	49%	35%	43%	36%	26%	32%
3125	26%	21%	24%	61%	51%	56%	47%	38%	43%

The average reduction represents the average of the quick and overnight soaks for the salt added to the solution (none, sodium chloride, or sodium bicarbonate). *NaCl* 1% sodium chloride soaking solution; *$NaHCO_3$* 1% sodium bicarbonate soaking solution.

As shown in Tables 4.6 through 4.8, the trends in changes to cooking time at the Nebraska location (1200 m) appeared to differ from the other three locations. For example, in Table 4.7, the average reduction of NaCl versus only water was 67% for the Michigan site close to sea level and 62% and 61% for the two sites in Colorado, but 45% for Nebraska. This was similar for the $NaHCO_3$ solution compared to no salt added to the soaking water, with Nebraska showing a 54% reduction and the other three sites having reductions of 77%, 74%, and 77% again.

4. Discussion

4.1. Impacts of Elevation and Cooking Conditions on Cooking Time

The current study provides new insights into the effects of elevation on cooking times. As one would expect, cooking time increases with higher elevations. The previous study by Bressani and Chon (1996) that examined cooking times at several elevations also confirmed this trend, with bean cooking time increasing from 78 minutes at 0 m to 264 minutes at 2256 m, the highest elevation they tested [169]. They used black beans (Ostua variety) and did not soak prior to cooking; because multiple cooking conditions were not investigated, the interaction between elevation and cooking condition was not examined, whereas this was a focus in the current study. Moreover, the study by Bressani and Chon (1996) used finger pressing and biting to determine the cooking time of dry beans, whereas the current study standardized data collection by using a Mattson cooker. Nonetheless, some similarities are evident. Interestingly, the cooking times of similar elevations between the Bressani and Chon (1996) study align closely with the cooking times determined for the no salt, no soak condition in the present study. For instance, at 229 m, Bressani and Chon determined the cooking time to be roughly 84 minutes, and this study found pinto bean (Monterrey variety) cooking time to be about 88 minutes at 263 m. Bressani and

Chon also found the cooking time to be approximately 124 minutes at 1234 m and 129 minutes at 1524 m, and our study revealed approximate cooking times of 111 minutes at 1200 m and 131 minutes at 1569 m. Thus, similar percent increases in cooking time (for no salt, no soak) were seen with rising elevation as those in the current study (Table 4.6). A more recent paper that assessed cooking times in two of the same locations as in the current study (East Lansing, MI and Scottsbluff, NE) also revealed that cooking times were longer in Nebraska, which has a higher elevation [170], although testing only occurred at two elevations and the interaction of elevation and cooking condition was not assessed. Some of the differences in cooking times could be attributed to the lower temperatures at which water boils as elevation increases (see Table 4.1).

Another finding that aligns with previous research is that soaking reduces cooking time [174,221,222,238]. The ranges in this study for percent reduction in cooking time when soaking in water only (average reductions of 41-56% depending on elevation, when the quick soak and overnight soak, no salt cooking conditions are combined) were similar to the reduction seen for cowpea by Bhokre and Joshi, 51% [172]. Bhokre and Joshi also witnessed reductions in cooking time of 66% for cowpea and 50% for mothbean when soaking in a 1% NaCl solution when compared to unsoaked samples, which match well with the average reductions seen when NaCl was added to the soaking solution, ranging from 45-67% in this study (Table 4.7). Both Bhokre and Joshi [172] and Coskuner and Karababa [173] found that 1% NaCl and $NaHCO_3$ soaking solutions reduced cooking times, with $NaHCO_3$ resulting in the shortest times. The same was found in the current study, where soaking in a 1% $NaHCO_3$ resulted in up to 77% shorter average cooking times (Table 4.7). However, none of these prior studies also took elevation into consideration, and testing only occurred at one location. Thus, this challenge that consumers may face was not taken into consideration in previous research.

Findings appear to be consistent that $NaHCO_3$ in soaking solutions reduces cooking time [172,173,225,239,240], as was found in the current study. Conversely, some studies have found that NaCl soaking solutions result in increased cooking times, such as Ávila and colleagues' investigation of cowpea [225] and Kwofie and fellow investigators' study on common beans [226]. Interestingly, Kwofie and colleagues even comment that the local communities in Malawi use NaCl to help soften beans [226]. However, the current study demonstrated that soaking in NaCl can reduce cooking time, which is in alignment with other studies [172,173,240,241]. These differences could be attributed to differences in pulses and in elements of experimental design, such as the water used (i.e., water with more divalent ions could result in prolonged cooking times [223]), the exact amount of salts added, and how cooking time was determined.

As beans are stored (especially under high temperature and high humidity) and age, they can develop the hard-to-cook (HTC) defect, which results in longer cooking times. The full reason for this phenomenon is not completely understood, but one of the most plausible hypotheses is the pectin-cation-phytate mechanism [223,239,242]. This model suggests that pectin methylesterase activity causes demethoxylation of pectin, and the hydrolysis of phytate by phytase results in the release of divalent cations, like Ca^{++} [243]. Cross-linking of these ions with pectin results in pectate compounds that are insoluble or more thermally stable [223,239,243]. Our findings that both NaCl and $NaHCO_3$ soaking solutions help reduce cooking time align with the pectin-cation-phytate model for the HTC phenomenon. Both of these soaking solutions contain the monovalent ion Na^+, which could play a role in increasing protein solubility and/or ion exchange, replacing some of the divalent cations like calcium and thereby weaking the cross-linkages that slow pulse softening [244].

Adding salt to the soaking solution can improve the efficacy of soaking [17], but it is also important to consider impacts on quality aspects, such as texture. Indeed, the different salts appeared to impact the final texture of the beans. The $NaHCO_3$ solution resulted in much softer beans that were more prone to losing their firmness and being smooshed. Depending on the desired result and intended use of the beans (e.g., dip, salad), consumers could view this as a positive or negative effect. The NaCl solution did not seem to impact texture as noticeably. However, more work on quality aspects and texture should be conducted before drawing conclusions, as the current study was not designed to assess minute differences in final firmness and texture. This could also include investigation into impacts on nutritional quality and the content of various components such as lectins, oxalates, and tannins. For instance, previous research suggests that soaking in distilled water can significantly decrease the content of lectins and oxalates [17,139], but the research did not examine different cooking conditions and elevation.

4.2. Effects of pH and Water Uptake on Cooking Time

It has also been proposed that pH plays an important role in cooking time, with alkaline conditions promoting β-elimination depolymerization of pectic polymers and improved solubilization [223]. Indeed, $NaHCO_3$ soaking solutions had a higher pH (see Table 4.3), and they also resulted in the fastest cooking times. The results showed that alkalinity was not the only determinant of cooking time, as the pH of the water only and the NaCl solutions were similar, yet the NaCl conditions had faster cooking times. Ultimately, it appears that type of salt (both the cation and anion) and pH both affect cooking time.

In some studies, differences in water uptake have been attributed to different genotypes [170,231]. This study shows that water uptake clearly differs from other factors, too (see Table 4.3). For instance, water uptake was often much lower in Nebraska than in Michigan, with average water uptake percentages for overnight soak conditions of 37.1% versus 89.7%. The difference was less dramatic when the quick soak method was used, suggesting that this method may result in more even water uptake. However, this only sometimes resulted in faster cooking times when overnight and quick soak were compared for the same salt added. Slight differences in how the experiment was conducted between sites cannot be ruled out as the cause for the differences seen. For example, the temperature of the soaking water influences hydration, with higher temperatures increasing the hydration rate [224]. This could be one reason for the lower water uptake rate in the higher elevation Colorado site versus the lower elevation location, despite testing having occurred in the same month. Another important factor is starting seed moisture, which should be in the range of 10-14% for optimal uptake [129].

4.3. Interaction of Elevation and Cooking Conditions

As shown in Table 4.2, a significant interaction effect was found, indicating that the effect of elevation depends on the cooking condition. When examining Figure 4.2, it is apparent that cooking time tends to increase with higher elevation. Yet, for elevations within the same cooking condition, the 95% CI are often overlapping, with the occasional exception of the highest elevation. Levene's test was found to be significant, likely due to factors like limited sample size, variation among sites (e.g., different technicians, temperature, age of the beans when tested), and the nature of the Mattson cooker procedure. For instance, for the Mattson cooker procedure, seeds that have imbibed water well are selected to be tested in the cooker, eliminating beans with less water uptake. This cannot be done for unsoaked samples. Also, water uptake varied with quick and overnight soaks. However, it is notable that water uptake percentage was not consistently associated with faster or slower cooking times within conditions, so this may not be of concern.

Table 4.2 shows that there can be a fair amount of variation for cooking time readings, even within the same elevation and cooking condition (Table 4.2), with the largest standard deviations evident in the Leadville, Colorado (i.e., the highest elevation) and Scottsbluff, Nebraska locations. As previously discussed, fewer replicates were conducted in Leadville, which could be one reason for this. Also, Nebraska had the latest testing date and the oldest beans, which could cause more of the HTC phenomenon and challenges with quick, even cooking.

When examining different elevations within the same cooking condition, quadratic fits were determined to be more appropriate, as shown in Table 4.5. However, the difference between the amount of variation accounted for between the quadratic and linear fits decreases with soaking (from about 12.8% for the no salt, no soak condition to 8.9% and 5.7% for the only water quick and overnight soaks, respectively).

4.4. Development of a Consumer Resource

One critical new contribution made by this study was the synthesis of findings from the current study with those in the literature to create an Extension handout with practical, accessible information and tips to cook dry beans. The handout specifically addresses the consumer barrier of long cooking times, as well as points of potential confusion to help mitigate confusion and ensure a more positive cooking experience. Thus, in addition to data collection on cooking times, a translational research approach [154] was incorporated so that helpful information can reach the public, something which previous studies have not done.

It is important to conduct translational research and share findings with the public. Accordingly, the study results and scientific literature were synthesized into a consumer resource (see Figure 4.4) for distribution through the Colorado State University Extension network. Most of the literature referenced in the consumer resource has already been discussed in this paper. Additional references cited to distill helpful cooking tips for consumers were about the importance of good storage conditions and avoidance of high heat and high humidity [243,244], and the fact that acidic ingredients can slow softening [245] and thus should be added at the end of the cooking process. The issue of elevation was also prominently addressed, as many consumers in states like Colorado express challenges about cooking beans, and this could largely be due to the higher elevations at which many individuals live. By providing consumers with this information, the chances that they have a more positive experience cooking pulses – and can do so more quickly – improves, helping reduce a key barrier to cooking dry pulses and promoting healthy dietary patterns.

COLORADO STATE UNIVERSITY
EXTENSION

Tips for Cooking with Dry Beans and Other Pulses

Are you looking for ways to incorporate dry beans and other pulses in your kitchen routine but wanting to shorten cooking time? 'Pulses' include dry beans, in addition to chickpeas, dry peas, black-eyed peas, and lentils. Here are some helpful tips!

Soak
Soaking gives pulses time to soak up water before you begin cooking, shortening cooking time. However, avoid using hard water because it can prevent pulses from softening.

Add Salt
There is a common myth that adding salt prevents dry beans from softening. However, adding salt actually shortens cooking time and can improve appearance by helping prevent pulses from bursting open during cooking. Plus, it adds flavor.

Hold Acidic Ingredients Until the End
Acidic ingredients—like lemon juice or tomatoes—can prevent pulses from softening. If you are adding a large amount of acidic ingredients, wait until the end, when the pulses have already softened.

Store Beans Well
Pulses that have not been stored properly can dry out sooner and will become harder to cook. Store pulses in a well-sealed container in a cool, dark, dry place.

Find Fresh Beans
As pulses age, they lose moisture. The drier they become, the longer it can take for them to cook, and eventually it may be almost impossible to get them to soften, even with extended cooking. Try to purchase pulses that have been harvested more recently.

Pick Your Pulse
Some pulses cook much faster than others. For example, lentils do not need to be soaked and they cook quickly, especially red lentils.

Remember Elevation
Pulses take longer to cook at higher elevations, so a pressure cooker can be your friend and speed up cooking. Cooking times need to be adjusted accordingly, even in an electric pressure cooker. The recommendation is to increase cooking time by 5% for every 1,000 feet above 2,000 feet elevation, so cooking at 7,000 feet above sea level may take 25% longer.

Fun in the Kitchen! Food Science in Action
Save the aquafaba, or the cooking liquid from different pulses. It whips up like egg whites and can be used as a vegan egg white substitute.

Figure 4.4. Extension handout on how to reduce pulse cooking time.

4.5. Limitations and Future Directions

As discussed above, there were several limitations in this study. The overlapping error bars (reflecting average cooking time ± SE) on Figure 4.2 combined with the significant result for Levene's test suggest that the Mattson cooker procedure, although informative for trends in cooking time, should be made more robust to differences that could be expected among different technicians and site locations. This variation highlights that it is important to conduct replicates and not rely on a single reading to determine cooking time if using a Mattson cooker.

Future studies should consider monitoring other variables, such as temperature, that can impact water uptake and potentially cooking time. Also, it would be ideal if the same instruments could be used to assess pH and moisture content. However, when conducting a multi-site experiment that also requires travel to locations far from the laboratory (i.e., Leadville, Colorado), some variation is inevitable, which again highlights the need for replication. More preferable would be the development of a procedure that is more robust to inherent variation among technicians and locations.

In addition, future work could investigate the impacts on nutrition of the different cooking conditions. Studies suggest that shorter cooking times can have better nutrition [246,247], which adding salts like NaCl and $NaHCO_3$ to the soaking solution can help promote. At the same time, it would be important to know how much sodium is contributed by adding these salts, especially for those on salt-restricted diets. Moreover, other research has found that soaking in an alkaline solution (as would be the case with $NaHCO_3$) can result in the leaching of vitamins like thiamin, riboflavin, and niacin from legumes, although the actual amount varied with the type of pulses, and bioavailability was not considered [248]. However, another study found that soaking in $NaHCO_3$ resulted in improved antioxidant activity [249]. Thus, information on the impacts of different cooking conditions on nutritional content for a wide array of pulses would be beneficial, ideally taking into account bioavailability.

Another critical aspect to consider in future research is quality issues, such as impacts on texture. Although the 80% pin drop time for the Mattson cooker has been found by a trained sensory panel to equate to fully cooked samples based on mouthfeel [236], it would be helpful to collect sensory evaluations to assess whether cooking methods affect consumer perception of aspects such as mouthfeel and flavor, as may happen when salts are added [250]. If baking soda has any adverse effects, one option is to use baking powder instead, which has also been found to reduce cooking time and improve nutritional and quality properties in fava beans [251].

Lastly, studies on the effect of the Extension consumer resource on actual behavior change and pulse preparation and consumption habits could benefit future translational work. Surveys to collect this data could be integrated into research.

5. Conclusions

Increasing pulse intake can offer a host of benefits for both human and environmental well-being. To make higher pulse intake more accessible and attractive to consumers, it is important to address potential barriers to intake. Long cooking time has been established as one of the major barriers faced by the public. Shorter cooking times are more convenient, and they may help preserve nutrition. Plus, they result in more efficient fuel utilization, which is especially important in regions where access to fuel is limited and those preparing the food are exposed to higher levels of pollution due to exhaust from the cooking processes. This research provided insights into the effects of elevation and several different, consumer-accessible cooking conditions that can greatly reduce cooking time, making the cooking of dry pulses more feasible. Providing the public with simple, affordable, consumer-accessible tips to shorten cooking time is a key step in mitigating the large barrier that cooking time poses to more pulse-centric diets. Thus, results were synthesized along with findings from the literature to create a handout for consumers that is being disseminated through the Extension network.

CHAPTER 5: CONCLUSION AND FUTURE DIRECTIONS

Summary

The work described in this dissertation details how to adopt a translational research approach to promote greater pulse intake, with the ultimate long-term goal of advancing the well-being of people and planet via healthful, sustainable dietary patterns. Three main studies comprised this research: 1.) the development and evaluation of an Extension Bean Toolkit; 2.) designing the Bean Cuisine and engaging citizen scientists; and 3.) examining consumer-accessible cooking methods to shorten cooking time for dry pulses and integrating findings with evidence in the literature to create a handout for public dissemination. Throughout these studies, the aim was to understand consumer challenges and interests, to then motivate higher pulse intake by addressing consumer barriers while emphasizing motivators.

1. Conclusions

In Chapter 2, the conducting of a Food Habits Survey provided insights into information such as consumer ranking of the importance of barriers and motivators that impact pulse intake and current pulse preparation and consumption habits. In conjunction with a review of the literature, this informed the design of the Extension Bean Toolkit, which included the development of a bean calendar and associated recipes and website pages, the creation of several handouts to help consumers cook pulses, writing of pulse-related blog posts, regular monthly social media outreach, and the 1-hour online class, Beans: Good for You, Good for the Planet. Thus, the Extension Bean Toolkit reached consumers with pulse information via multiple platforms. Participation in the Extension class resulted in significant gains in knowledge about pulse nutrition and health benefits, the versatility of pulses, and how to cook dry pulses. Notably, participants also saw significant increases in the importance of motivators of pulse consumption and decreases in the importance of barriers (i.e., barriers did not discourage them as much after taking the class). Before participating in the final Extension class, protein was considered the most important nutritional motivator, but dietary fiber ranked most highly after the class. Taste was rated as the most important of the other motivators (i.e., non-nutritional motivators) prior to the class, but after participating, health benefits were considered the most important. The barrier that saw the greatest decrease in importance due to class participation was that of being unsure how to prepare pulses, indicating that the class successfully inspired people with ideas for how to regularly incorporate pulses in the diet. About three-fourths of participants stated an intention to increase pulse intake due to the class, and indeed a significant increase in the frequency of pulse intake ($p = 0.004$) was observed after the validation class.

In Chapter 3, the focus was the creation of the Bean Cuisine and testing with citizen scientists to improve upon the cuisine and make it attractive to a wider audience, in addition to evaluating the impacts of participating in this citizen science project. The Bean Cuisine comprises of 56 pulse-centric recipes corresponding to 14 days (i.e., 2 weeks) with unique breakfast, lunch, snack, and dinner recipes for each day [161]. The Bean Cuisine was developed to visualize what 35% of dietary protein coming from pulses may look like, due to recent preclinical findings suggesting that major benefits for gut health and body weight management are achieved at this level of pulse intake or above [95,96]. Assessment in Nutritionist Pro confirmed the Bean Cuisine is a healthy meal plan that meets nutritional recommendations. Fifty-six citizen scientists participated, providing feedback on the four recipes they were assigned, and a 100% response rate was achieved. After modifying the Bean Cuisine per citizen scientist input, representative recipes were tested with a sensory panel. Citizen scientists showed significant increases in all three areas of pulse knowledge that were assessed: nutrition and health, versatility, and how to cook dry pulses. The greatest gain in knowledge occurred for pulse versatility, with the average baseline score of 3.39 increasing to 4.38 after participation (on a 5-point Likert scale of 1 to 5, with 5 representing high knowledge). This suggests that one of the primary barriers to greater pulse intake – unfamiliarity with how to prepare pulses – is mitigated through participation in such a project. Over 70% of citizen scientists indicated they now try to eat more pulses as a result of participation, and they also reported an increase in the likelihood of trying to purchase local pulses. Importantly, an analysis of free response data suggested that citizen scientists were acting as pulse advocates, sharing information about the benefits of pulses with their communities and engaging their social circles in trying the Bean Cuisine recipes. Citizen scientists also expressed having a positive experience and being willing to participate in future citizen science research.

In Chapter 4, pinto beans were cooked at four locations with different elevations, and seven cooking conditions were examined in replicate. Shortening cooking time is important to reduce the barrier of long cooking times. All cooking conditions were consumer-accessible, using ingredients and tools that most consumers already have in the kitchen. In addition to a comparison condition of no soak and no salt added, the other six cooking conditions were derived from a combination of 1.) one of two soaking methods: quick soak or overnight soak; and 2.) one of three salts added to the soaking water: none, sodium chloride (i.e., table salt), or sodium bicarbonate (i.e., baking soda). Cooking time dramatically increased with elevation, with the longest cooking times observed for the highest elevation. Soaking – either overnight or via the quick soak method – helped to reduce cooking time. The addition of salts to the soaking water further reduced cooking time, with the sodium bicarbonate soaks resulting in the shortest cooking times. This information was synthesized along with other findings from the literature to create an Extension handout to provide consumers with helpful tips to cook dry pulses more quickly in the home.

The three studies described herein comprise a translational approach that utilizes the components of the Information-Motivation-Behavioral Skills (IMB) model [151] to encourage the healthy behavior change of higher pulse intake (shown in Chapter 1, Figure 1.9). Information about the benefits of pulses and how to prepare them was made available to the public in the form of various Extension resources and the class, the citizen scientist training and toolkit, and the handout on how to cook dry pulses faster that resulted from the cooking time study. Personal motivation was appealed to through making individuals aware of the many benefits that pulses have to offer that are desirable to consumers (e.g., taste, versatility, human health, affordability, sustainability). Social motivation could occur through feeling they were part of a community of learners. This was most prominent in the Bean Cuisine citizen science project, but it also occurred in the Extension class, where individuals actively engaged in the chat and shared about their favorite pulses and recipe ideas. Information to hone the behavioral skills required to prepare pulses was provided as part of all three studies. However, behavioral skills were most actively practiced with the Bean Cuisine citizen science project, where all citizen scientists were provided with tips to prepare pulses and assigned four recipes, and then had to actually make the recipes and provide feedback. Based on evaluation of the survey data, this combination of information, motivation, and behavioral skills appeared to help encourage uptake of the desired health behavior of increasing pulse intake.

Overall, this research has addressed several knowledge gaps in the field, such as using a Mattson cooker to evaluate how elevation can impact cooking time at multiple sites, taking into consideration consumer-accessible cooking methods. Moreover, it has resulted in a better understanding of consumer barriers and motivators as relate to pulse intake. The Bean Cuisine was developed to realize and assess feasibility of the preclinical finding that benefits for gut health and healthy weight management appear to be attained when 35% or more of dietary protein came from pulses [95,96]. Testing the Bean Cuisine with citizen scientists built upon the limited number of citizen science projects in nutrition and food research, demonstrating the positive potential that citizen science can have in these fields. Multiple Extension resources – including the Extension class – were all developed as part of the Extension Bean Toolkit and are resources that will continue to be available for public benefit. To the best of my knowledge, this is the first research to evaluate how participation in a citizen science project or pulse-related class have impacted participant knowledge of pulses, the importance of barriers and motivators that affect intake, and pulse preparation and consumption habits. This type of translational research can serve as a model for other translational research and public health outreach through Extension or other organizations.

2. Limitations and Future Directions

Limitations and future directions have been addressed in more detail at the end of the discussion sections for Chapters 2, 3, and 4. In summary, in the Bean Cuisine citizen science project and Extension Bean Toolkit research, engaging a more diverse audience – both in terms of sociodemographic diversity and participant interest level in pulses – would help broaden generalizability of findings and better meet the needs and interests of more communities. Also, there is a need for a survey instrument that allows for the collection of more detailed information on the frequency, amount, and types of pulses and pulse dishes consumed. Such an instrument would allow for an improved understanding of consumption behaviors and permit researchers to extract successful strategies used by those who attain high levels of pulse consumption to then provide others with helpful tips. In addition to online translational research, it would be helpful to expand into offering in-person classes to provide hands-on opportunities to cook with pulses, as this could build participant skills and confidence in using pulses. It would also be informative to gather data on the impact of participation in this pulse-related translational research on longer-term pulse preparation and consumption behaviors. With regards to the study investigating the impacts of elevation and cooking condition on cooking time, it would be beneficial to assess whether the handout developed was found helpful by consumers, and whether it influenced their behavior.

Two future research projects that would help expand the reach of this translational research are a massive open online course and a National Bean Registry. Massive open online courses (MOOCs) provide the opportunity to expand access to free online courses globally [252]. To help broaden reach, colleagues and industry partners could help initially spread the word, along with citizen scientists and class participants. Using findings from this research, colleagues, and the literature, course content would target areas of interest, motivators, and barriers. There could be several tracks (e.g., citizen, healthcare professional, educator, culinary professional, product developer, grower) such that individuals can choose to focus on information and skills most pertinent to them. Through application of successful strategies and principles of multimedia learning applied in other successful MOOCs, it is possible that a bean MOOC would have the potential to reach millions of people over the course of several years [197].

The National Bean Registry (NBR) is modeled after the idea of the National Weight Control Registry, which provides key insights into behaviors that support long-term weight loss and maintenance [196]. Similarly, the NBR (see Figure 5.1) would catalog lifestyle patterns and behaviors of pulse consumers that promote sustained, regular high pulse intake. Also, the behaviors, strategies, and dietary patterns of consumers with different levels of pulse intake could be compared. Together, this would allow for the extraction of relevant, accessible tips on how to increase pulse intake. Thus, the NBR could help move the needle on the adoption of a consumer behavior that can simultaneously benefit human and environmental health: pulse-centric dietary patterns.

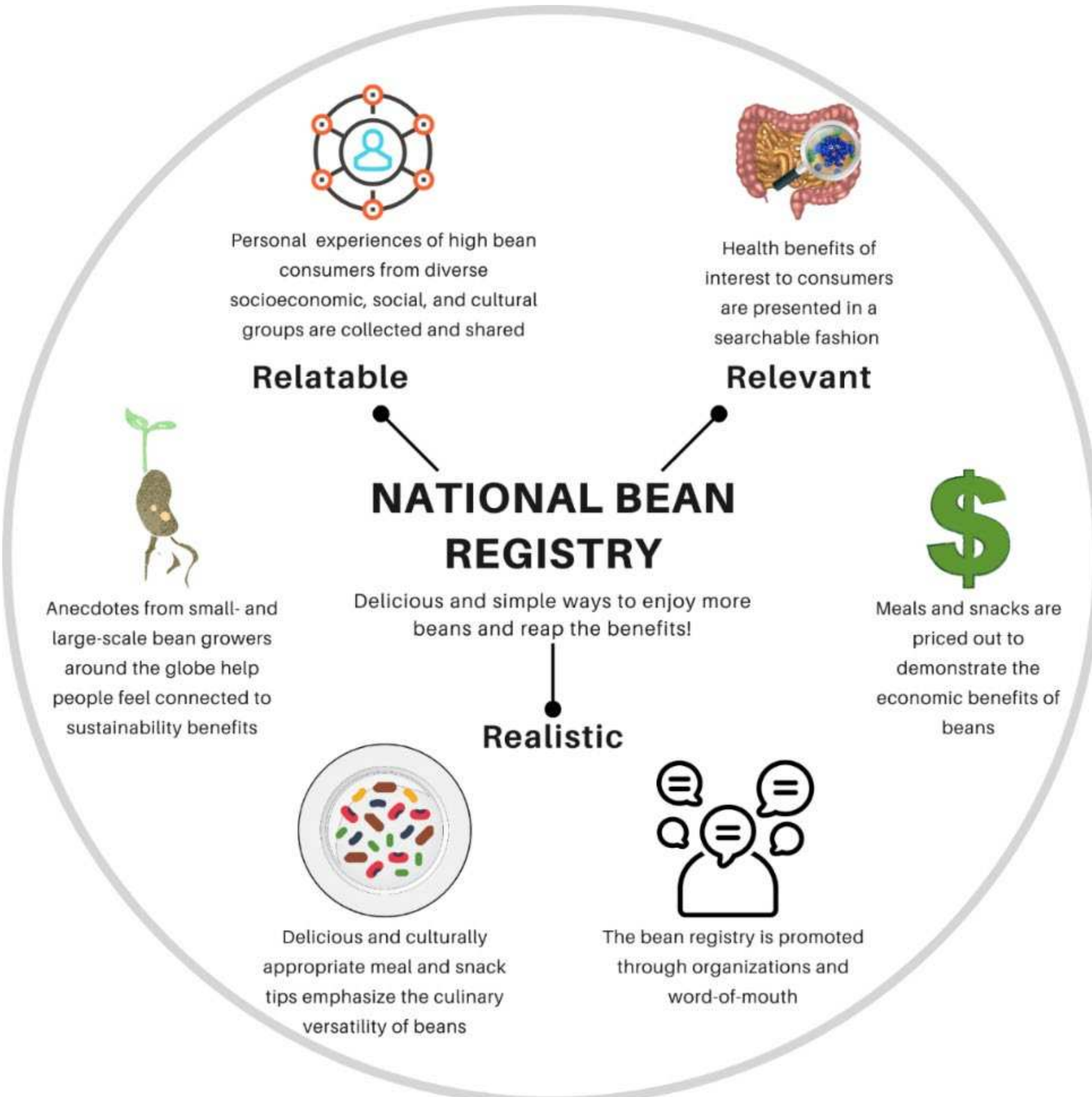


Figure 5.1.[12] National Bean Registry. The National Bean Registry should emphasize desirable health outcomes of pulse consumption through personal anecdotes and experiences of high-pulse consuming representatives from diverse social, socioeconomic, and cultural communities. This encourages individuals to feel that the tips and health benefits are more relevant, relatable, and realistic.

[12]This figure was modified from the original that was already published with the journal Legume Science and can be found online at: https://onlinelibrary.wiley.com/doi/full/10.1002/leg3.147. Instead of being titled the "National Pulse Registry" like in the publication, it is now called the "National Bean Registry" due to greater familiarity with the word bean. Citation information is as follows: Didinger, C.; Thompson, H.J. The role of pulses in improving human health: A review. *Legume Sci.* **2022**, *4*, e147.

3. Food Systems Considerations

Beans and other pulses can offer a multitude of benefits. However, it is important to recognize that there are still gaps that should be addressed, both in research and in food systems-related components and processes, such as supply chains. For example, although the consumption of pulses has been associated with a reduction in the risk for chronic disease, the ideal serving size to achieve and maximize this risk reduction has yet to be identified [9]. This is partially due to the challenges faced in many of the human studies to-date, such as low sample sizes, confounding lifestyle characteristics of participants, challenges with dietary assessment data, and lack of a tool to adequately assess pulse intake [6,24]. To help elucidate ideal serving size, there is need for robust clinical studies that take into account sociodemographic differences and the development of a dietary assessment tool – like a food frequency questionnaire – that better assesses pulse intake. For consistent messaging, a clear recommendation about intake level supportive of optimal human health is key. Moreover, a better understanding of ideal serving size will clarify key food systems components that must be addressed to realize increased production and consumption levels that result in improved nutrition and human health impacts.

Similarly, multiple factors should be considered when determining how to optimize the environmental benefits of pulses. Pulses use less water than many other foods and sources of protein [122], and they can result in the generation of significantly lower greenhouse gas emissions [103], especially when compared to red meat like beef. However, many of these comparisons that calculate differences in greenhouse gas emissions assume feedlot production of beef, which is the prevalent method in countries like the United States [105]. Even though much meat is produced in this resource-intensive manner, this is in stark contrast to some other more sustainable production models. For example, dairy and meat production from sustainably grazed animals raised on lands unsuitable for cropping can provide positive nutrient cycling and improve food security [107,253].

Furthermore, it must be acknowledged that a simple substitution of beans for beef is not always feasible because of considerations like location, growing conditions, and supply chain logistics. For one, some land that is used to produce cattle may not be suitable for pulses due to factors such as soil composition, meaning that a recommendation to grow pulses instead of beef is not always possible. Or, even if pulses could be grown, some marginal land may only be suitable for producing certain types of pulses, which can be in lower demand and not have as well-developed supply chains as other pulse types. For example, pulses like horsegram and tepary beans have been found able to grow on dry land with poor fertility [254,255], yet these pulses are not popular in countries like the United States. Overall, this suggests that even though producing pulses instead of animal proteins can offer environmental benefits, transitioning land from animal production to pulses can present challenges. Another nuance to consider is that pulses may have different potential benefits. For instance, nitrogen fixation levels are impacted by factors such as type of pulse and growing environment [112,119,256,257]. This is an important consideration, as the amount of nitrogen fixed can in turn help reduce fertilizer needs and provide benefits like improvements in soil health and water quality. Defining impacts on outcomes like soil health and gaining an improved understanding of which pulse crops can successfully grow in different locations will be essential to maximize environmental benefits.

In addition to ensuring that land is indeed favorable for growing pulse crops, there are other considerations, including localized issues like demand, access to seeds and farming technology, presence of processors, and supply chain logistics. For growers to choose to produce more pulses, there must be demand, as well as access to supply chains that allow for processing and distribution to potential markets. Just as different locations have varying environmental factors that impact the ability to grow pulses, there will be localized challenges that require unique approaches to develop or bolster supply chains.

A current research project underway in the United Kingdom, Raising the Pulse, takes many of these factors into consideration [258]. With the goal of improving consumer health and sustainability within the UK food system, fava bean production systems are being targeted in collaboration with key stakeholders in industry, retail, research, and government. Within the multidisciplinary project, there are five key projects to ensure a holistic approach and cutting-edge innovation across components of the food system. This spans from evaluation of the environmental impacts of producing fava beans with improved nutritional quality, to the development and sensory evaluation of nutritious pulse-based products (e.g., bread using fava bean flour), to a campus-wide campaign and intervention in student dining halls [258]. Through adopting a system perspective, this project recognizes the nuances of shifting trends in pulse production and consumption, and it will serve as an informative model for future work.

Overall, a transdisciplinary approach that involves collaboration among many stakeholders at different levels of the food system will be necessary to achieve long-term, impactful changes to production and consumption behaviors on local, regional, and national levels, and ultimately on a global scale. Even within the same country, strategy success is influenced by factors like region and urban versus rural. Therefore, moving forward, a holistic approach that considers the nuances of food systems is necessary to successfully capitalize on the environmental and human health benefits that pulses can offer. The adoption of a healthy behavior like increased pulse consumption can only occur with collective action towards this goal.

REFERENCES

1. Didinger, C.; Thompson, H.J. Defining nutritional and functional niches of legumes: A call for clarity to distinguish a future role for pulses in the Dietary Guidelines for Americans. *Nutrients* **2021**, *13*, 1100.
2. Food and Agriculture Organization of the United Nations. No better time to celebrate World Pulses Day. Available online: https://www.fao.org/americas/noticias/ver/en/c/1471590/ (accessed on 21 August 2023).
3. World Health Organization. Obesity and overweight. Available online: https://www.who.int/news-room/fact-sheets/detail/obesity-and-overweight (accessed on 20 August 2023).
4. World Health Organization. Noncommunicable diseases. Available online: https://www.who.int/news-room/fact-sheets/detail/noncommunicable-diseases (accessed on 20 August 2023).
5. Waters, H.; Graf, M. *The Costs of Chronic Disease in the U.S.*; The Milken Institute: Santa Monica, CA, USA, 2018. Available online: https://milkeninstitute.org/reports/costs-chronic-disease-us (accessed on 25 June 2020).
6. Didinger, C.; Foster, M.T.; Bunning, M.; Thompson, H.J. Nutrition and human health benefits of dry beans and other pulses. *Dry Beans and Pulses: Production, Processing, and Nutrition*; Wiley: Hoboken, NJ, USA, 2022; pp. 481–504.
7. Messina, V. Nutritional and health benefits of dried beans. *Am. J. Clin. Nutr.* **2014**, *100*, 437S-442S.
8. Mitchell, D.C.; Lawrence, F.R.; Hartman, T.J.; Curran, J.M. Consumption of dry beans, peas, and lentils could improve diet quality in the US population. *J. Am. Diet. Assoc.* **2009**, *109*, 909-913.
9. Marinangeli, C.P.F.; Curran, J.; Barr, S.I.; Slavin, J.; Puri, S.; Swaminathan, S.; Tapsell, L.; Patterson, C.A. Enhancing nutrition with pulses: defining a recommended serving size for adults. *Nutr. Rev.* **2017**, *75*, 990-1006.
10. Thompson, H.J.; Brick, M.A. Perspective: Closing the Dietary Fiber Gap: An ancient solution for a 21st century problem. *Adv. Nutr.* **2016**, *7*, 623-626.
11. USDA; HHS. *The Dietary Guidelines for Americans, 2020-2025*; U.S. Department of Agriculture and U.S. Department of Health and Human Services: Washington, DC, USA, 2020.
12. Chen, Y.; McGee, R.; Vandemark, G.; Brick, M.; Thompson, H.J. Dietary fiber analysis of four pulses using AOAC 2011.25: Implications for human health. *Nutrients* **2016**, *8*, 1-10.
13. Melby, C.L.; Paris, H.L.; Foright, R.M.; Peth, J. Attenuating the biologic drive for weight regain following weight loss: Must what goes down always go back up? *Nutrients* **2017**, *9*, 468.
14. McCrory, M.A.; Hamaker, B.R.; Lovejoy, J.C.; Eichelsdoerfer, P.E. Pulse consumption, satiety, and weight management. *Adv. Nutr.* **2010**, *1*, 17-30.
15. Clark, S.; Duncan, A.M. The role of pulses in satiety, food intake and body weight management. *J. Funct. Foods* **2017**, *38*, 612-623.
16. United States Department of Agriculture. FoodData Central. Available online: https://fdc.nal.usda.gov/ (accessed on 6 January 2021).

17. Azarpazhooh, E.; Ahmed, J. Composition of raw and processed dry beans and other pulses. *Dry Beans and Pulses: Production, Processing, and Nutrition*; Wiley: Hoboken, NJ, USA, 2022; pp. 129-157.
18. Katz, D.L.; Doughty, K.N.; Geagan, K.; Jenkins, D.A.; Gardner, C.D. Perspective: The public health case for modernizing the definition of protein quality. *Adv. Nutr.* **2019**, *10*, 755-764.
19. Nosworthy, M.G.; Franczyk, A.; Zimoch-Korzycka, A.; Appah, P.; Utioh, A.; Neufeld, J.; House, J.D. Impact of processing on the protein quality of pinto bean (*Phaseolus vulgaris*) and buckwheat (*Fagopyrum esculentum* Moench) flours and blends, as determined by in vitro and in vivo methodologies. J. Agric. *Food Chem.* **2017**, *65*, 3919-3925.
20. Anitha, S.; Govindaraj, M.; Kane-Potaka, J. Balanced amino acid and higher micronutrients in millets complements legumes for improved human dietary nutrition. *Cereal Chem*. **2020**, *97*, 74-84.
21. Mariotti, F. Plant protein, animal protein, and protein quality. In *Vegetarian and Plant-Based Diets in Health and Disease Prevention*; Academic Press: Cambridge, MA, USA, 2017; pp. 621–642.
22. Abdullah, M.M.H.; Marinangeli, C.P.F.; Jones, P.J.H.; Carlberg, J.G. Canadian potential healthcare and societal cost savings from consumption of pulses: A cost-of-illness analysis. *Nutrients* **2017**, *9*, 793.
23. Abdullah, M.M.; Hughes, J.; Grafenauer, S. Legume intake is associated with potential savings in coronary heart disease-related health care costs in Australia. *Nutrients* **2022**, *14*, 2912.
24. Didinger, C.; Thompson, H.J. The role of pulses in improving human health: A review. *Legume Sci.* **2022**, e147.
25. Ferreira, H.; Vasconcelos, M.; Gil, A.M.; Pinto, E. Benefits of pulse consumption on metabolism and health: A systematic review of randomized controlled trials. *Crit. Rev. Food Sci. Nutr.* **2021**, *61*, 85-96,.
26. Li, S.S.; Kendall, C.W.; de Souza, R.J.; Jayalath, V.H.; Cozma, A.I.; Ha, V.; Mirrahimi, A.; Chiavaroli, L.; Augustin, L.S.; Blanco Mejia, S., et al. Dietary pulses, satiety and food intake: A systematic review and meta-analysis of acute feeding trials. *Obesity* **2014**, *22*, 1773-1780.
27. Kim, S.J.; de Souza, R.J.; Choo, V.L.; Ha, V.; Cozma, A.I.; Chiavaroli, L.; Mirrahimi, A.; Blanco Mejia, S.; Di Buono, M.; Bernstein, A.M., et al. Effects of dietary pulse consumption on body weight: A systematic review and meta-analysis of randomized controlled trials. *Am. J. Clin. Nutr.* **2016**, *103*, 1213-1223.
28. Zafar, M.; Mills, K.; Zheng, J.; Peng, M.; Ye, X.; Chen, L. Low glycaemic index diets as an intervention for obesity: a systematic review and meta-analysis. *Obes. Rev.* **2019**, *20*, 290-315.
29. Reverri, E.J.; Randolph, J.M.; Kappagoda, C.T.; Park, E.; Edirisinghe, I.; Burton-Freeman, B.M. Assessing beans as a source of intrinsic fiber on satiety in men and women with metabolic syndrome. *Appetite* **2017**, *118*, 75-81.
30. World Cancer Research Fund/American Institute for Cancer Research. Diet, Nutrition, Physical Activity, and Cancer: A Global Perspective. 2018. Available online: https://dietandcancerreport.org (accessed on 20 August 2023).
31. World Health Organization. Diabetes. Available online: https://www.who.int/news-room/fact-sheets/detail/diabetes (accessed on 21 August 2023).

32. Becerra-Tomas, N.; Diaz-Lopez, A.; Rosique-Esteban, N.; Ros, E.; Buil-Cosiales, P.; Corella, D.; Estruch, R.; Fito, M.; Serra-Majem, L.; Aros, F., et al. Legume consumption is inversely associated with type 2 diabetes incidence in adults: A prospective assessment from the PREDIMED study. *Clin. Nutr.* **2018**, *37*, 906-913.
33. Viguiliouk, E.; Glenn, A.J.; Nishi, S.K.; Chiavaroli, L.; Seider, M.; Khan, T.; Bonaccio, M.; Iacoviello, L.; Mejia, S.B.; Jenkins, D.J.A., et al. Associations between dietary pulses alone or with other legumes and cardiometabolic disease outcomes: An umbrella review and updated systematic review and meta-analysis of prospective cohort studies. *Adv. Nutr.* **2019**, *10*, S308-S319.
34. Tang, J.; Wan, Y.; Zhao, M.; Zhong, H.; Zheng, J.S.; Feng, F. Legume and soy intake and risk of type 2 diabetes: A systematic review and meta-analysis of prospective cohort studies. *Am. J. Clin. Nutr.* **2020**, *111*, 677-688.
35. Livesey, G.; Taylor, R.; Livesey, H.F.; Buyken, A.E.; Jenkins, D.J.A.; Augustin, L.S.A.; Sievenpiper, J.L.; Barclay, A.W.; Liu, S.; Wolever, T.M.S., et al. Dietary glycemic index and load and the risk of type 2 diabetes: Assessment of causal relations. *Nutrients* **2019**, *11*, 1436.
36. Waddell, I.S.; Orfila, C. Dietary fiber in the prevention of obesity and obesity-related chronic diseases: From epidemiological evidence to potential molecular mechanisms. *Crit. Rev. Food Sci. Nutr.* **2022**, 1-16.
37. Yao, B.; Fang, H.; Xu, W.; Yan, Y.; Xu, H.; Liu, Y.; Mo, M.; Zhang, H.; Zhao, Y. Dietary fiber intake and risk of type 2 diabetes: A dose-response analysis of prospective studies. *Eur. J. Epidemiol.* **2014**, *29*, 79-88.
38. McRae, M.P. Dietary fiber intake and type 2 diabetes mellitus: An umbrella review of meta-analyses. *J. Chiropr. Med.* **2018**, *17*, 44-53.
39. Jenkins, D.J.; Kendall, C.W.; Augustin, L.S.; Mitchell, S.; Sahye-Pudaruth, S.; Blanco Mejia, S.; Chiavaroli, L.; Mirrahimi, A.; Ireland, C.; Bashyam, B., et al. Effect of legumes as part of a low glycemic index diet on glycemic control and cardiovascular risk factors in type 2 diabetes mellitus: A randomized controlled trial. *Arch. Intern. Med.* **2012**, *172*, 1653-1660.
40. World Health Organization. Cardiovascular diseases (CVDs). Available online: https://www.who.int/news-room/fact-sheets/detail/cardiovascular-diseases-(cvds) (accessed on 22 August 2023).
41. Padhi, E.M.T.; Ramdath, D.D. A review of the relationship between pulse consumption and reduction of cardiovascular disease risk factors. *J. Funct. Foods* **2017**, *38*, 635-643.
42. Vieira, N.M.; Peghinelli, V.V.; Monte, M.G.; Costa, N.A.; Pereira, A.G.; Seki, M.M.; Azevedo, P.S.; Polegato, B.F.; de Paiva, S.A.R.; Zornoff, L.A.M. Beans consumption can contribute to the prevention of cardiovascular disease. *Clin. Nutr. ESPEN* **2023**, *54*, 73-80.
43. Nchanji, E.B.; Ageyo, O.C. Do common beans (*Phaseolus vulgaris* L.) promote good health in humans? A systematic review and meta-analysis of clinical and randomized controlled trials. *Nutrients* **2021**, *13*, 3701.
44. O'Donnell, C.J.; Elosua, R. Cardiovascular risk factors. Insights from Framingham Heart Study. *Rev. Esp. Cardiol.* **2008**, *61*, 299-310.
45. Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults. Executive summary of the third report of the National Cholesterol Education Program (NCEP) Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults (adult treatment panel III). *JAMA* **2001**, *285*, 2486-2497.

46. Kabagambe, E.K.; Baylin, A.; Ruiz-Narvarez, E.; Siles, X.; Campos, H. Decreased consumption of dried mature beans is positively associated with urbanization and nonfatal acute myocardial infarction. *J. Nutr.* **2005**, *135*, 1770-1775.
47. Winham, D.M.; Hutchins, A.M. Baked bean consumption reduces serum cholesterol in hypercholesterolemic adults. *Nutr. Res.* **2007**, *27*, 380-386.
48. Doma, K.M.; Dolinar, K.F.; Dan Ramdath, D.; Wolever, T.M.; Duncan, A.M. Canned beans decrease serum total and LDL cholesterol in adults with elevated LDL cholesterol in a 4-wk multicenter, randomized, crossover study. *J. Nutr.* **2021**, *151*, 3701-3709.
49. Trinidad, T.P.; Mallillin, A.C.; Loyola, A.S.; Sagum, R.S.; Encabo, R.R. The potential health benefits of legumes as a good source of dietary fibre. *Brit. J. Nutr.* **2010**, *103*, 569-574.
50. Zhang, Z.; Lanza, E.; Kris-Etherton, P.M.; Colburn, N.H.; Bagshaw, D.; Rovine, M.J.; Ulbrecht, J.S.; Bobe, G.; Chapkin, R.S.; Hartman, T.J. A high legume low glycemic index diet improves serum lipid profiles in men. *Lipids* **2010**, *45*, 765-775.
51. Nöthlings, U.; Schulze, M.B.; Weikert, C.; Boeing, H.; Van Der Schouw, Y.T.; Bamia, C.; Benetou, V.; Lagiou, P.; Krogh, V.; Beulens, J.W. Intake of vegetables, legumes, and fruit, and risk for all-cause, cardiovascular, and cancer mortality in a European diabetic population. *J. Nutr.* **2008**, *138*, 775-781.
52. Bazzano, L.A.; He, J.; Ogden, L.G.; Loria, C.; Vupputuri, S.; Myers, L.; Whelton, P.K. Legume consumption and risk of coronary heart disease in US men and women: NHANES I epidemiologic follow-up study. *Arch. Intern. Med.* **2001**, *161*, 2573-2578.
53. Bazzano, L.A.; Thompson, A.M.; Tees, M.T.; Nguyen, C.H.; Winham, D.M. Non-soy legume consumption lowers cholesterol levels: A meta-analysis of randomized controlled trials. *Nutr. Metab. Cardiovasc. Dis.* **2011**, *21*, 94-103.
54. Viguiliouk, E.; Blanco, M.S.; Kendall, C.W.; Sievenpiper, J.L. Can pulses play a role in improving cardiometabolic health? Evidence from systematic reviews and meta-analyses. *Ann. NY. Acad. Sci.* **2017**, *1392*, 43-57.
55. Lukus, P.K.; Doma, K.M.; Duncan, A.M. The role of pulses in cardiovascular disease risk for adults with diabetes. *Am. J. Lifestyle Med.* **2020**, *14*, 571-584.
56. World Cancer Research Fund International. Eat wholegrains, vegetables, fruit and beans. Available online: https://www.wcrf.org/diet-activity-and-cancer/cancer-prevention-recommendations/eat-wholegrains-vegetables-fruit-and-beans/ (accessed on 22 August 2023).
57. Campisi, J. Aging, cellular senescence, and cancer. *Annu. Rev. Physiol.* **2013**, *75*, 685-705.
58. Zhang, X.; Meng, X.; Chen, Y.; Leng, S.X.; Zhang, H. The biology of aging and cancer: frailty, inflammation, and immunity. *Cancer J.* **2017**, *23*, 201-205.
59. Darmadi-Blackberry, I.; Wahlqvist, M.L.; Kouris-Blazos, A.; Steen, B.; Lukito, W.; Horie, Y.; Horie, K. Legumes: The most important dietary predictor of survival in older people of different ethnicities. *Asia Pac. J. Clin. Nutr.* **2004**, *13*, 217-220.
60. Campos-Vega, R.; Oomah, B.D.; Loarca-Pina, G.; Vergara-Castaneda, H.A. Common beans and their non-digestible fraction: Cancer inhibitory activity-an overview. *Foods* **2013**, *2*, 374-392.
61. Rao, S.; Chinkwo, K.A.; Santhakumar, A.B.; Blanchard, C.L. Inhibitory effects of pulse bioactive compounds on cancer development pathways. *Diseases* **2018**, *6*, 72.
62. Papandreou, C.; Becerra-Tomas, N.; Bullo, M.; Martinez-Gonzalez, M.A.; Corella, D.; Estruch, R.; Ros, E.; Aros, F.; Schroder, H.; Fito, M., et al. Legume consumption and risk

of all-cause, cardiovascular, and cancer mortality in the PREDIMED study. Clin. Nutr. **2019**, *38*, 348-356.

63. Adebamowo, C.A.; Cho, E.; Sampson, L.; Katan, M.B.; Spiegelman, D.; Willett, W.C.; Holmes, M.D. Dietary flavonols and flavonol-rich foods intake and the risk of breast cancer. *Int. J. Cancer* **2005**, *114*, 628-633.
64. Velie, E.M.; Schairer, C.; Flood, A.; He, J.-P.; Khattree, R.; Schatzkin, A. Empirically derived dietary patterns and risk of postmenopausal breast cancer in a large prospective cohort study. *Am. J. Clin. Nutr.* **2005**, *82*, 1308-1319.
65. Murtaugh, M.A.; Sweeney, C.; Giuliano, A.R.; Herrick, J.S.; Hines, L.; Byers, T.; Baumgartner, K.B.; Slattery, M.L. Diet patterns and breast cancer risk in Hispanic and non-Hispanic white women: The Four-Corners Breast Cancer Study. *Am. J. Clin. Nutr.* **2008**, *87*, 978-984.
66. Fung, T.T.; Hu, F.B.; Holmes, M.D.; Rosner, B.A.; Hunter, D.J.; Colditz, G.A.; Willett, W.C. Dietary patterns and the risk of postmenopausal breast cancer. *Int. J. Cancer* **2005**, *116*, 116-121.
67. Zhu, Z.; Jiang, W.; Thompson, H.J. Edible dry bean consumption (*Phaseolus vulgaris* L.) modulates cardiovascular risk factors and diet-induced obesity in rats and mice. *Br. J. Nutr.* **2012**, *108*, S66-73.
68. Thompson, M.D.; Thompson, H.J.; Brick, M.A.; McGinley, J.N.; Jiang, W.; Zhu, Z.; Wolfe, P. Mechanisms associated with dose-dependent inhibition of rat mammary carcinogenesis by dry bean (*Phaseolus vulgaris* L.). *J. Nutr.* **2008**, *138*, 2091-2097.
69. Thompson, M.D.; Brick, M.A.; McGinley, J.N.; Thompson, H.J. Chemical composition and mammary cancer inhibitory activity of dry bean. *Crop Sci.* **2009**, *49*, 179-186.
70. Lanza, E.; Hartman, T.J.; Albert, P.S.; Shields, R.; Slattery, M.; Caan, B.; Paskett, E.; Iber, F.; Kikendall, J.W.; Lance, P., et al. High dry bean intake and reduced risk of advanced colorectal adenoma recurrence among participants in the polyp prevention trial. *J. Nutr.* **2006**, *136*, 1896-1903.
71. Michels, K.B.; Giovannucci, E.; Chan, A.T.; Singhania, R.; Fuchs, C.S.; Willett, W.C. Fruit and vegetable consumption and colorectal adenomas in the Nurses' Health Study. *Cancer Res*. **2006**, *66*, 3942-3953.
72. Bobe, G.; Barrett, K.G.; Mentor-Marcel, R.A.; Saffiotti, U.; Young, M.R.; Colburn, N.H.; Albert, P.S.; Bennink, M.R.; Lanza, E. Dietary cooked navy beans and their fractions attenuate colon carcinogenesis in azoxymethane-induced ob/ob mice. *Nutr. Cancer* **2008**, *60*, 373-381.
73. Bennink, M. Consumption of black beans and navy beans (*Phaseolus vulgaris*) reduced azoxymethane-induced colon cancer in rats. *Nutr. Cancer* **2002**, *44*, 60-65.
74. Rondini, E.A.; Bennink, M.R. Microarray analyses of genes differentially expressed by diet (black beans and soy flour) during azoxymethane-induced colon carcinogenesis in rats. J. Nutr. Metab. **2012**, *2012*, 1-17.
75. Wang, Y.; Wang, Z.; Fu, L.; Chen, Y.; Fang, J. Legume consumption and colorectal adenoma risk: a meta-analysis of observational studies. *PLoS One* **2013**, *8*, e67335.
76. Zhu, B.; Sun, Y.; Qi, L.; Zhong, R.; Miao, X. Dietary legume consumption reduces risk of colorectal cancer: evidence from a meta-analysis of cohort studies. *Sci. Rep.* **2015**, *5*, 8797.
77. Park, S.Y.; Murphy, S.P.; Wilkens, L.R.; Henderson, B.E.; Kolonel, L.N. Legume and isoflavone intake and prostate cancer risk: The Multiethnic Cohort Study. *Int. J. Cancer* **2008**, *123*, 927-932.

78. Li, J.; Mao, Q. Legume intake and risk of prostate cancer: A meta-analysis of prospective cohort studies. *Oncotarget* **2017**, *8*, 44776-44784.
79. Kirsh, V.A.; Peters, U.; Mayne, S.T.; Subar, A.F.; Chatterjee, N.; Johnson, C.C.; Hayes, R.B. Prospective study of fruit and vegetable intake and risk of prostate cancer. *J. Natl. Cancer Inst. 2007*, *99*, 1200-1209.
80. Smit, E.; Garcia-Palmieri, M.R.; Figueroa, N.R.; McGee, D.L.; Messina, M.; Freudenheim, J.L.; Crespo, C.J. Protein and legume intake and prostate cancer mortality in Puerto Rican men. *Nutr. Cancer* **2007**, *58*, 146-152.
81. Miclotte, L.; Van de Wiele, T. Food processing, gut microbiota and the globesity problem. *Crit. Rev. Food Sci. Nutr.* **2020**, *60*, 1769-1782.
82. Buford, T.W. (Dis)Trust your gut: The gut microbiome in age-related inflammation, health, and disease. *Microbiome* **2017**, *5*, 80.
83. Zinocker, M.K.; Lindseth, I.A. The Western diet-microbiome-host interaction and its role in metabolic disease. *Nutrients* **2018**, *10*, 365.
84. Makki, K.; Deehan, E.C.; Walter, J.; Bäckhed, F. The impact of dietary fiber on gut microbiota in host health and disease. *Cell Host Microbe* **2018**, *23*, 705-715.
85. Myhrstad, M.C.W.; Tunsjo, H.; Charnock, C.; Telle-Hansen, V.H. Dietary fiber, gut microbiota, and metabolic regulation-current status in human randomized trials. *Nutrients* **2020**, *12*, 859.
86. Chambers, E.S.; Preston, T.; Frost, G.; Morrison, D.J. Role of gut microbiota-generated short-chain fatty acids in metabolic and cardiovascular health. *Curr. Nutr. Rep.* **2018**, *7*, 198-206.
87. Kadyan, S.; Sharma, A.; Arjmandi, B.H.; Singh, P.; Nagpal, R. Prebiotic potential of dietary beans and pulses and their resistant starch for aging-associated gut and metabolic health. *Nutrients* **2022**, *14*, 1726.
88. Clemente, A.; Olias, R. Beneficial effects of legumes in gut health. *Curr. Opin. Food Sci.* **2017**, *14*, 32-36.
89. Fernando, W.M.; Hill, J.E.; Zello, G.A.; Tyler, R.T.; Dahl, W.J.; Van Kessel, A.G. Diets supplemented with chickpea or its main oligosaccharide component raffinose modify faecal microbial composition in healthy adults. *Benef. Microbes* **2010**, *1*, 197-207.
90. Dominianni, C.; Sinha, R.; Goedert, J.J.; Pei, Z.; Yang, L.; Hayes, R.B.; Ahn, J. Sex, body mass index, and dietary fiber intake influence the human gut microbiome. *PLoS One* **2015**, *10*, e0124599.
91. Chen, Y.; Chang, S.K.C.; Zhang, Y.; Hsu, C.Y.; Nannapaneni, R. Gut microbiota and short chain fatty acid composition as affected by legume type and processing methods as assessed by simulated in vitro digestion assays. *Food Chem.* **2020**, *312*, 126040.
92. Marinangeli, C.P.F.; Harding, S.V.; Zafron, M.; Rideout, T.C. A systematic review of the effect of dietary pulses on microbial populations inhabiting the human gut. *Benef. Microbes* **2020**, *11*, 457-468.
93. Monk, J.M.; Wu, W.; Lepp, D.; Wellings, H.R.; Hutchinson, A.L.; Liddle, D.M.; Graf, D.; Pauls, K.P.; Robinson, L.E.; Power, K.A. Navy bean supplemented high-fat diet improves intestinal health, epithelial barrier integrity and critical aspects of the obese inflammatory phenotype. *J. Nutr. Biochem.* **2019**, *70*, 91-104.
94. Ojo, B.A.; Lu, P.; Alake, S.E.; Keirns, B.; Anderson, K.; Gallucci, G.; Hart, M.D.; El-Rassi, G.D.; Ritchey, J.W.; Chowanadisai, W., et al. Pinto beans modulate the gut

microbiome, augment MHC II protein, and antimicrobial peptide gene expression in mice fed a normal or western-style diet. *J. Nutr. Biochem.* **2021**, *88*, 108543.
95. Lutsiv, T.; McGinley, J.N.; Neil-McDonald, E.S.; Weir, T.L.; Foster, M.T.; Thompson, H.J. Relandscaping the gut microbiota with a whole food: dose-response effects to common bean. *Foods* **2022**, *11*, 1153.
96. Lutsiv, T.; Weir, T.L.; McGinley, J.N.; Neil, E.S.; Wei, Y.; Thompson, H.J. Compositional changes of the high-fat diet-induced gut microbiota upon consumption of common pulses. *Nutrients* **2021**, *13*, 3992.
97. McGinley, J.N.; Fitzgerald, V.K.; Neil, E.S.; Omerigic, H.M.; Heuberger, A.L.; Weir, T.L.; McGee, R.; Vandemark, G.; Thompson, H.J. Pulse crop effects on gut microbial populations, intestinal function, and adiposity in a mouse model of diet-induced obesity. *Nutrients* **2020**, *12*, 593.
98. Willett, W.; Rockström, J.; Loken, B.; Springmann, M.; Lang, T.; Vermeulen, S.; Garnett, T.; Tilman, D.; DeClerck, F.; Wood, A., et al. Food in the Anthropocene: The EAT–Lancet Commission on healthy diets from sustainable food systems. *Lancet* **2019**, *393*, 447-492.
99. Foyer, C.H.; Lam, H.M.; Nguyen, H.T.; Siddique, K.H.; Varshney, R.K.; Colmer, T.D.; Cowling, W.; Bramley, H.; Mori, T.A.; Hodgson, J.M., et al. Neglecting legumes has compromised human health and sustainable food production. *Nat. Plants* **2016**, *2*, 16112.
100. Stagnari, F.; Maggio, A.; Galieni, A.; Pisante, M. Multiple benefits of legumes for agriculture sustainability: An overview. *Chem. Biol. Technol. Agric.* **2017**, *4*, 2
101. Peoples, M.B.; Hauggaard-Nielsen, H.; Huguenin-Elie, O.; Jensen, E.S.; Justes, E.; Williams, M. The contributions of legumes to reducing the environmental risk of agricultural production. In *Agroecosystem Diversity*; Elsevier: Amsterdam, Netherlands, 2019; pp. 123–143.
102. Vermeir, I.; Weijters, B.; De Houwer, J.; Geuens, M.; Slabbinck, H.; Spruyt, A.; Van Kerckhove, A.; Van Lippevelde, W.; De Steur, H.; Verbeke, W. Environmentally sustainable food consumption: A review and research agenda from a goal-directed perspective. *Front. Psychol.* **2020**, *11*, 1603.
103. Our World in Data. Greenhouse gas emissions per 100 grams of protein. Available online: https://ourworldindata.org/grapher/ghg-per-protein-poore (accessed on 20 August 2023).
104. Poore, J.; Nemecek, T. Reducing food's environmental impacts through producers and consumers. *Science* **2018**, *360*, 987-992.
105. Harwatt, H.; Sabaté, J.; Eshel, G.; Soret, S.; Ripple, W. Substituting beans for beef as a contribution toward US climate change targets. *Clim. Change* **2017**, *143*, 261-270.
106. Nijdam, D.; Rood, T.; Westhoek, H. The price of protein: Review of land use and carbon footprints from life cycle assessments of animal food products and their substitutes. *Food Policy* **2012**, *37*, 760-770.
107. Tilman, D.; Clark, M. Global diets link environmental sustainability and human health. *Nature* **2014**, *515*, 518-522.
108. Ritchie, H. Food waste is responsible for 6% of global greenhouse gas emissions. Available online: https://ourworldindata.org/food-waste-emissions (accessed on 21 August 2023).
109. Munesue, Y.; Masui, T.; Fushima, T. The effects of reducing food losses and food waste on global food insecurity, natural resources, and greenhouse gas emissions. *Environ. Econ. Policy Stud.* **2015**, *17*, 43-77.
110. Marchi, B.; Zanoni, S. Cold chain energy analysis for sustainable food and beverage supply. *Sustainability* **2022**, *14*, 11137.

111. Menegat, S.; Ledo, A.; Tirado, R. Greenhouse gas emissions from global production and use of nitrogen synthetic fertilisers in agriculture. *Sci. Rep.* **2022**, *12*, 14490.
112. Peoples, M.B.; Hauggaard-Nielsen, H.; Jensen, E.S. The potential environmental benefits and risks derived from legumes in rotations. In *Nitrogen fixation in crop production*; Agronomy Monographs: USA, 2009; pp. 349-385.
113. Sabaté, J.; Sranacharoenpong, K.; Harwatt, H.; Wien, M.; Soret, S. The environmental cost of protein food choices. *Public Health Nutr.* **2015**, *18*, 2067-2073.
114. Gu, B.; Zhang, X.; Lam, S.K.; Yu, Y.; van Grinsven, H.J.; Zhang, S.; Wang, X.; Bodirsky, B.L.; Wang, S.; Duan, J. Cost-effective mitigation of nitrogen pollution from global croplands. *Nature* **2023**, *613*, 77-84.
115. Rani, K.; Rani, A.; Sharma, P.; Dahiya, A.; Punia, H.; Kumar, S.; Sheoran, S.; Banerjee, A. Legumes for agroecosystem services and sustainability. In *Advances in Legumes for Sustainable Intensification*, Elsevier: 2022; pp. 363-380.
116. Kumar, S.; Meena, R.S.; Lal, R.; Singh Yadav, G.; Mitran, T.; Meena, B.L.; Dotaniya, M.L.; EL-Sabagh, A. Role of legumes in soil carbon sequestration. In *Legumes for Soil Health and Sustainable Management*; Springer: Singapore, 2018; pp. 109-138.
117. Liu, C.; Plaza-Bonilla, D.; Coulter, J.A.; Kutcher, H.R.; Beckie, H.J.; Wang, L.; Floc'h, J.-B.; Hamel, C.; Siddique, K.H.; Li, L. Diversifying crop rotations enhances agroecosystem services and resilience. *Adv. Agron.* **2022**, *173*, 299-335.
118. Ferreira, H.; Pinto, E.; Vasconcelos, M.W. Legumes as a cornerstone of the transition toward more sustainable agri-food systems and diets in Europe. *Front. Sustain. Food Syst.* **2021**, *5*, 694121.
119. Parker, T.A.; Gallegos, J.A.; Beaver, J.; Brick, M.; Brown, J.K.; Cichy, K.; Debouck, D.G.; Delgado-Salinas, A.; Dohle, S.; Ernest, E. Genetic resources and breeding priorities in Phaseolus beans: Vulnerability, resilience, and future challenges. *Plant Breed. Rev.* **2022**, *46*, 289-420.
120. Gan, Y.; Hamel, C.; O'Donovan, J.T.; Cutforth, H.; Zentner, R.P.; Campbell, C.A.; Niu, Y.; Poppy, L. Diversifying crop rotations with pulses enhances system productivity. *Sci. Rep.* **2015**, *5*, 14625.
121. Magrini, M.-B.; Anton, M.; Chardigny, J.-M.; Duc, G.; Duru, M.; Jeuffroy, M.-H.; Meynard, J.-M.; Micard, V.; Walrand, S. Pulses for sustainability: Breaking agriculture and food sectors out of lock-in. *Front. Sustain. Food Syst.* **2018**, *2*, 64.
122. Our World in Data. Freshwater withdrawals per 100 grams of protein. Available online: https://ourworldindata.org/grapher/water-per-protein-poore (accessed on 20 August 2023).
123. Our World in Data. Eutrophying emissions per 100 grams of protein. Available online: https://ourworldindata.org/grapher/eutrophying-emissions-protein (accessed on 21 August 2023).
124. Our World in Data. Land use per 100 grams of protein. Available online: https://ourworldindata.org/grapher/land-use-protein-poore (accessed on 20 August 2023).
125. Vandemark, G.J.; Brick, M.A.; Osorno, J.M.; Kelly, J.D.; Urrea, C.A. Edible grain legumes. In *Yield Gains in Major US Field Crops*; CSSA Special Publications: Madison, WI, USA, 2014; pp. 87-123.
126. Rawal, V.; Navarro, D.K. The global economy of pulses. Food and Agriculture Organization of the United Nations: Rome, Italy, 2019.
127. Food and Agriculture Organization of the United Nations. Food Balances (2010-). Available online: https://www.fao.org/faostat/en/#data/FBS (accessed on 24 August 2023).

128. Didinger, C.; Thompson, H. Motivating pulse-centric eating patterns to benefit human and environmental well-being. *Nutrients* **2020**, *12*, 3500.
129. Cichy, K.A.; Wiesinger, J.A.; Berry, M.; Nchimbi-Msolla, S.; Fourie, D.; Porch, T.G.; Ambechew, D.; Miklas, P.N. The role of genotype and production environment in determining the cooking time of dry beans (*Phaseolus vulgaris* L.). *Legume Sci.* **2019**, *1*, e13.
130. Henn, K.; Goddyn, H.; Olsen, S.B.; Bredie, W.L. Identifying behavioral and attitudinal barriers and drivers to promote consumption of pulses: A quantitative survey across five European countries. *Food Qual. Prefer.* **2022**, *98*, 104455.
131. Reid, I. Factors influencing pulse consumption in Canada. *Ipsos Reid: Calgary, AB, Canada* **2010**.
132. Szczebyło, A.; Rejman, K.; Halicka, E.; Laskowski, W. Towards more sustainable diets—Attitudes, opportunities and barriers to fostering pulse consumption in Polish cities. *Nutrients* **2020**, *12*, 1589.
133. Doma, K.M.; Farrell, E.L.; Leith-Bailey, E.R.; Soucier, V.D.; Duncan, A.M. Motivators, barriers and other factors related to bean consumption in older adults. *J. Nutr. Gerontol. Geriatr.* **2019**, *38*, 397-413.
134. Winham, D.M.; Hutchins, A.M. Perceptions of flatulence from bean consumption among adults in 3 feeding studies. *Nutr. J.* **2011**, *10*, 1-9.
135. Duarte, M.; Vasconcelos, M.; Pinto, E. Pulse consumption among Portuguese adults: potential drivers and barriers towards a sustainable diet. *Nutrients* **2020**, *12*, 3336.
136. Geraldo, R.; Santos, C.S.; Pinto, E.; Vasconcelos, M.W. Widening the perspectives for legume consumption: The case of bioactive non-nutrients. *Front. Plant Sci.* **2022**, *13*, 56.
137. Petroski, W.; Minich, D.M. Is there such a thing as "anti-nutrients"? A narrative review of perceived problematic plant compounds. *Nutrients* **2020**, *12*, 2929.
138. Nciri, N.; Cho, N.; El Mhamdi, F.; Ben Ismail, H.; Ben Mansour, A.; Sassi, F.H.; Ben Aissa-Fennira, F. Toxicity Assessment of Common Beans (*Phaseolus vulgaris* L.) Widely Consumed by Tunisian Population. *J. Med. Food.* **2015**, *18*, 1049-1064.
139. Shi, L.; Arntfield, S.D.; Nickerson, M. Changes in levels of phytic acid, lectins and oxalates during soaking and cooking of Canadian pulses. *Food Res. Int.* **2018**, *107*, 660-668.
140. Palmer, S.M.; Winham, D.M.; Oberhauser, A.M.; Litchfield, R.E. Socio-ecological barriers to dry grain pulse consumption among low-income women: A mixed methods approach. *Nutrients* **2018**, *10*, 1108.
141. Melendrez-Ruiz, J.; Buatois, Q.; Chambaron, S.; Monnery-Patris, S.; Arvisenet, G. French consumers know the benefits of pulses, but do not choose them: An exploratory study combining indirect and direct approaches. *Appetite* **2019**, *141*, 104311.
142. Aggarwal, A.; Rehm, C.D.; Monsivais, P.; Drewnowski, A. Importance of taste, nutrition, cost and convenience in relation to diet quality: Evidence of nutrition resilience among US adults using National Health and Nutrition Examination Survey (NHANES) 2007–2010. *Prev. Med.* **2016**, *90*, 184-192.
143. Kourouniotis, S.; Keast, R.; Riddell, L.; Lacy, K.; Thorpe, M.; Cicerale, S. The importance of taste on dietary choice, behaviour and intake in a group of young adults. *Appetite* **2016**, *103*, 1-7.
144. Liem, D.G.; Russell, C.G. The influence of taste liking on the consumption of nutrient rich and nutrient poor foods. *Front. Nutr.* **2019**, *6*, 174.

145. Food and Agriculture Organization of the United Nations. International year of pulses: Nutritious seeds for a sustainable future. Rome, Italy, 2016.
146. Heer, M.M.; Winham, D.M. Food behaviors, health, and bean nutrition awareness among low-income men: A pilot study. *Int. J. Environ. Res. Public Health* **2020**, *17*, 1039.
147. Doma, K.M.; Farrell, E.L.; Leith-Bailey, E.R.; Soucier, V.D.; Duncan, A.M. Older adults' awareness and knowledge of beans in relation to their nutrient content and role in chronic disease risk. *Nutrients* **2019**, *11*, 2680.
148. Wognum, P.M.; Bremmers, H.; Trienekens, J.H.; van der Vorst, J.G.A.J.; Bloemhof, J.M. Systems for sustainability and transparency of food supply chains – Current status and challenges. *Adv. Eng. Inform.* **2011**, *25*, 65-76.
149. United Nations. Transforming our world: The 2030 Agenda for Sustainable Development. Available online: https://sdgs.un.org/2030agenda (accessed on 25 August 2023).
150. Heer, M.M.; Winham, D.M. Bean preferences vary by acculturation level among Latinas and by ethnicity with Non-Hispanic White women. *Int.J. Envir. Res. Public Health* **2020**, *17*, 2100.
151. Fisher, W.A.; Fisher, J.D.; Harman, J. The Information–Motivation–Behavioral Skills Model: A General Social Psychological Approach to Understanding and Promoting Health Behavior. In *Social Psychological Foundations of Health and Illness*, Suls, J., Wallston, K.A., Eds. Blackwell Publishing Ltd: 2004.
152. Fleary, S.A.; Joseph, P.; Chang, H. Applying the information-motivation-behavioral skills model to explain adolescents' fruits and vegetables consumption. *Appetite* **2020**, *147*, 104546.
153. Vohland, K.; Land-Zandstra, A.; Ceccaroni, L.; Lemmens, R.; Perelló, J.; Ponti, M.; Samson, R.; Wagenknecht, K. *The Science of Citizen Science*; Springer Nature: Cham, Switzerland, 2021.
154. Woolf, S.H. The meaning of translational research and why it matters. *JAMA* **2008**, *299*, 211-213.
155. Scudder, A.T.; Welk, G.J.; Spoth, R.; Beecher, C.C.; Dorneich, M.C.; Meyer, J.D.; Phillips, L.A.; Weems, C.F. Transdisciplinary translational science for youth health and wellness: Introduction to a special issue. In Proceedings of Child & Youth Care Forum, 2021; pp. 1-12.
156. Gutter, M.S.; O'Neal, L.J.; Riportella, R.; Sugarwala, L.; Mathias, J.; Vilaro, M.J.; Paige, S.R.; Szurek, S.M.; Navarro, G.; Baralt, C. Promoting community health collaboration between CTSA programs and Cooperative Extension to advance rural health equity: insights from a national Un-Meeting. *J. Clin. Transl. Sci.* **2020**, *4*, 377-383.
157. Our World in Data. Cost of living crisis hits poorest the hardest, warns UNCTAD. Available online: https://news.un.org/en/story/2022/07/1122842 (accessed on 2 August 2023).
158. Pan-Africa Bean Research Alliance. The Promise of Beans. Available online: https://www.pabra-africa.org/the-promise-of-beans/ (accessed on 14 May 2023).
159. Mitchell, D.C.; Marinangeli, C.P.; Pigat, S.; Bompola, F.; Campbell, J.; Pan, Y.; Curran, J.M.; Cai, D.J.; Jaconis, S.Y.; Rumney, J. Pulse intake improves nutrient density among US adult consumers. *Nutrients* **2021**, *13*, 2668.
160. Mudryj, A.N.; Yu, N.; Hartman, T.J.; Mitchell, D.C.; Lawrence, F.R.; Aukema, H.M. Pulse consumption in Canadian adults influences nutrient intakes. *Br. J. Nutr.* **2012**, *108 Suppl 1*, S27-36.

161. Didinger, C.; Bunning, M.; Thompson, H.J. Bean Cuisine: The potential of citizen science to help motivate changes in pulse knowledge and consumption. *Foods* **2023**, *12*, 2667.
162. Buys, D.R.; Rennekamp, R. Cooperative extension as a force for healthy, rural communities: Historical perspectives and future directions. *Am. J. Public Health* **2020**, *110*, 1300-1303.
163. Monroe, M. The value of a toolkit. *J. Ext.* **2000**, *38*.
164. Winham, D.M.; Davitt, E.D.; Heer, M.M.; Shelley, M.C. Pulse knowledge, attitudes, practices, and cooking experience of Midwestern US university students. *Nutrients* **2020**, *12*, 3499.
165. Murray, E.K.; Auld, G.; Baker, S.S.; Barale, K.; Franck, K.; Khan, T.; Palmer-Keenan, D.; Walsh, J. Methodology for developing a new EFNEP food and physical activity behaviors questionnaire. *J. Nutr. Educ. Behav.* **2017**, *49*, 777-783. e771.
166. Auld, G.; Baker, S.; Conway, L.; Dollahite, J.; Lambea, M.C.; McGirr, K. Outcome effectiveness of the widely adopted EFNEP curriculum eating smart· being active. *J. Nutr. Educ. Behav.* **2015**, *47*, 19-27.
167. Auld, G.; Baker, S.; McGirr, K.; Osborn, K.S.; Skaff, P. Confirming the reliability and validity of others' evaluation tools before adopting for your programs. *J. Nutr. Educ. Behav.* **2017**, *49*, 441-450. e441.
168. Hume, C.; Ball, K.; Salmon, J. Development and reliability of a self-report questionnaire to examine children's perceptions of the physical activity environment at home and in the neighbourhood. *Int. J. Behav. Nutr. Phys. Act.* **2006**, *3*, 1-6.
169. Bressani, R.; Chon, C. Effects of altitude above sea level on the cooking time and nutritional value of common beans. *Plant Foods Hum. Nutr.* **1996**, *49*, 53-61.
170. Sadohara, R.; Izquierdo, P.; Couto Alves, F.; Porch, T.; Beaver, J.; Urrea, C.A.; Cichy, K. The *Phaseolus vulgaris* L. Yellow Bean Collection: genetic diversity and characterization for cooking time. *Genet. Resour. Crop Evol.* **2022**, *69*, 1627-1648.
171. Didinger, C.; Cichy, K.; Urrea, C.; Scanlan, M.; Thompson, H. The effects of elevation and soaking conditions on dry bean cooking time. *Legume Sci.* **2023**.
172. Bhokre, C.K.; Joshi, A.A. Effect of soaking on physical functional and cooking time of cowpea, horsegram and mothbean. *Food Sci. Res. J.* **2015**, *6*, 357-362.
173. Coşkuner, Y.; Karababa, E. Effect of location and soaking treatments on the cooking quality of some chickpea breeding lines. *Int. J. Food Sci. Technol.* **2003**, *38*, 751-757.
174. Wood, J.A. Evaluation of cooking time in pulses: A review. *Cereal Chem.* **2017**, *94*, 32-48.
175. Fernandes, A.C.; Nishida, W.; da Costa Proença, R.P. Influence of soaking on the nutritional quality of common beans (*Phaseolus vulgaris* L.) cooked with or without the soaking water: A review. *Int. J. Food Sci. Technol.* **2010**, *45*, 2209-2218.
176. Geldhof, G.J.; Warner, D.A.; Finders, J.K.; Thogmartin, A.A.; Clark, A.; Longway, K.A. Revisiting the utility of retrospective pre-post designs: the need for mixed-method pilot data. *Eval. Program Plann.* **2018**, *70*, 83-89.
177. Thomas, E.V.; Wells, R.; Baumann, S.D.; Graybill, E.; Roach, A.; Truscott, S.D.; Crenshaw, M.; Crimmins, D. Comparing traditional versus retrospective pre-/post-assessment in an interdisciplinary leadership training program. *Matern. Child Health J.* **2019**, *23*, 191-200.
178. Randall, W.S.; Mello, J.E. Grounded theory: an inductive method for supply chain research. *Int. J. Phys. Distrib.Logist. Manag.* **2012**, *42*, 863-880.

179. Thomas, D.R. A general inductive approach for analyzing qualitative evaluation data. *Am. J. Eval.* **2006**, *27*, 237-246.
180. Farrell, E.L.; Doma, K.M.; Leith-Bailey, E.R.; Soucier, V.D.; Duncan, A.M. Health claims and information sources in relation to bean consumption in older adults. *Appetite* **2019**, *140*, 318-327.
181. Fade, S.; Swift, J. Qualitative research in nutrition and dietetics: data analysis issues. *J. Hum. Nutr. Diet.* **2011**, *24*, 106-114.
182. Burnette, C.B.; Luzier, J.L.; Weisenmuller, C.M.; Boutte, R.L. A systematic review of sociodemographic reporting and representation in eating disorder psychotherapy treatment trials in the United States. *Int. J. Eat. Disord.* **2022**, *55*, 423-454.
183. The Bean Institute. The Traditional Four-Step Method. Available online: https://beaninstitute.com/the-traditional-four-step-method/ (accessed on 20 May 2023).
184. Dorn, S.T.; Newberry, M.G.; Bauske, E.M.; Pennisi, S.V. Extension master gardener volunteers of the 21st century: Educated, prosperous, and committed. *Hort. Technol.* **2018**, *28*, 218-229.
185. Global Diet Quality Project. Pulses. Available online: https://www.dietquality.org/indicators/pulses/map (accessed on 15 August 2023).
186. Masuda, K. Pulses as culturally important foods among university students in Canada. *Food Res.* **2018**, *7*, 1-6.
187. Winham, D.M.; Hutchins, A.M.; Thompson, S.V.; Dougherty, M.K. Arizona Registered Dietitians show gaps in knowledge of bean health benefits. *Nutrients* **2018**, *10*, 52.
188. Tobey, L.N.; Manore, M.M. Social media and nutrition education: The food hero experience. *J. Nutr. Educ. Behav.* **2014**, *46*, 128-133.
189. Bandekar, P.A.; Putman, B.; Thoma, G.; Matlock, M. Cradle-to-grave life cycle assessment of production and consumption of pulses in the United States. *J. Environ. Manag.* **2022**, *302*, 114062.
190. Henn, K.; Zhang, X.; Thomsen, M.; Rinnan, Å.; Bredie, W.L. The versatility of pulses: Are consumption and consumer perception in different European countries related to the actual climate impact of different pulse types? *Future Foods* **2022**, *6*, 100202.
191. Duyff, R.L.; Mount, J.R.; Jones, J.B. Sodium reduction in canned beans after draining, rinsing. *J. Cul. Sci. Technol.* **2011**, *9*, 106-112.
192. Raddick, M.J.; Bracey, G.; Gay, P.L.; Lintott, C.J.; Murray, P.; Schawinski, K.; Szalay, A.S.; Vandenberg, J. Galaxy zoo: Exploring the motivations of citizen science volunteers. *arXiv preprint arXiv:0909.2925* **2009**.
193. Qi, L.; Rabinowitz, A.N.; Liu, Y.; Campbell, B. Buyer and nonbuyer barriers to purchasing local food. *Agric. Res. Econ. Rev.* **2017**, *46*, 443-463.
194. Williams, G.M.; Tapsell, L.C.; Beck, E.J. Gut health, the microbiome and dietary choices: An exploration of consumer perspectives. *Nutr. Diet.* **2023**, *80*, 85-94.
195. Zhang, Q. Assessing the effects of instructor enthusiasm on classroom engagement, learning goal orientation, and academic self-efficacy. *Commun. Teach.* **2014**, *28*, 44-56.
196. Thomas, J.G.; Bond, D.S.; Phelan, S.; Hill, J.O.; Wing, R.R. Weight-loss maintenance for 10 years in the National Weight Control Registry. *Am. J. Prev. Med.* **2014**, *46*, 17-23.
197. Oakley, B.A.; Sejnowski, T.J. What we learned from creating one of the world's most popular MOOCs. *NPJ Sci. Learn.* **2019**, *4*, 1-7.
198. Zhu, M. Designing and delivering MOOCs to motivate participants for self-directed learning. *Open Learning: J. Open, Dist. e-Learn.* **2022**, 1-20.

199. Schmutz, J.; McClean, P.E.; Mamidi, S.; Wu, G.A.; Cannon, S.B.; Grimwood, J.; Jenkins, J.; Shu, S.; Song, Q.; Chavarro, C. A reference genome for common bean and genome-wide analysis of dual domestications. *Nat. Genet.* **2014**, *46*, 707-713.
200. Calles, T.; Xipsiti, M.; del Castello, R. Legacy of the international year of pulses. *Environ. Earth Sci.* **2019**, *78*, 1-8.
201. Callaghan, C.T.; Rowley, J.J.; Cornwell, W.K.; Poore, A.G.; Major, R.E. Improving big citizen science data: Moving beyond haphazard sampling. *PLoS Biol.* **2019**, *17*, e3000357.
202. Armstrong, B.; Reynolds, C.; Bridge, G.; Oakden, L.; Wang, C.; Panzone, L.; Schmidt Rivera, X.; Kause, A.; Ffoulkes, C.; Krawczyk, C. How does Citizen Science compare to online survey panels? A comparison of food knowledge and perceptions between the Zooniverse, Prolific and Qualtrics UK Panels. *Front. Sustain. Food Syst.* **2021**, *4*, 575021.
203. Wang, Y.; Kaplan, N.; Newman, G.; Scarpino, R. CitSci. org: A new model for managing, documenting, and sharing citizen science data. *PLoS Biol.* **2015**, *13*, e1002280.
204. Armstrong, B.; Bridge, G.; Oakden, L.; Reynolds, C.; Wang, C.; Panzone, L.A.; Rivera, X.S.; Kause, A.; Ffoulkes, C.; Krawczyk, C. Piloting citizen science methods to measure perceptions of carbon footprint and energy content of food. *Front. Sustain. Food Syst.* **2020**, *4*, 120.
205. Lukyanenko, R.; Wiggins, A.; Rosser, H.K. Citizen science: An information quality research frontier. *Inf. Syst. Front.* **2020**, *22*, 961-983.
206. Hartman, T.J.; Albert, P.S.; Zhang, Z.; Bagshaw, D.; Kris-Etherton, P.M.; Ulbrecht, J.; Miller, C.K.; Bobe, G.; Colburn, N.H.; Lanza, E. Consumption of a legume-enriched, low-glycemic index diet is associated with biomarkers of insulin resistance and inflammation among men at risk for colorectal cancer. *J. Nutr.* **2010**, *140*, 60-67.
207. Fritz, S.; See, L.; Carlson, T.; Haklay, M.; Oliver, J.L.; Fraisl, D.; Mondardini, R.; Brocklehurst, M.; Shanley, L.A.; Schade, S. Citizen science and the United Nations sustainable development goals. *Nat. Sustain.* **2019**, *2*, 922-930.
208. Kosmala, M.; Wiggins, A.; Swanson, A.; Simmons, B. Assessing data quality in citizen science. *Front. Ecol. Environ.* **2016**, *14*, 551-560.
209. Phillips, S.M.; Paddon-Jones, D.; Layman, D.K. Optimizing adult protein intake during catabolic health conditions. *Adv. Nutr.* **2020**, *11*, S1058-S1069.
210. Rosenbloom, C. From stealth health to nutritious and delicious: The culinary institute of America's healthy menus R&D collaborative. *Nutr. Today* **2014**, *49*, 153-159.
211. Domroese, M.C.; Johnson, E.A. Why watch bees? Motivations of citizen science volunteers in the Great Pollinator Project. *Biol. Conserv.* **2017**, *208*, 40-47.
212. Ng, M.K.; Moore, C.J.; Adhikari, K.; Andress, E.L.; Henes, S.T.; Lee, J.S.; Cox, G.O. Application of a sensory evaluation methodology for recipes utilized in federal nutrition education programs. *J. Sens. Stud.* **2022**, *37*, e12752.
213. Onwezen, M.C.; Bouwman, E.P.; van Trijp, H.C. Participatory methods in food behaviour research: a framework showing advantages and disadvantages of various methods. *Foods* **2021**, *10*, 470.
214. Tinati, R.; Luczak-Roesch, M.; Simperl, E.; Hall, W. An investigation of player motivations in Eyewire, a gamified citizen science project. *Comput. Hum. Behav.* **2017**, *73*, 527-540.
215. Brossard, D.; Lewenstein, B.; Bonney, R. Scientific knowledge and attitude change: The impact of a citizen science project. *Int. J. Sci. Ed.* **2005**, *27*, 1099-1121.

216. Margier, M.; Georgé, S.; Hafnaoui, N.; Remond, D.; Nowicki, M.; Du Chaffaut, L.; Amiot, M.-J.; Reboul, E. Nutritional composition and bioactive content of legumes: Characterization of pulses frequently consumed in France and effect of the cooking method. *Nutrients* **2018**, *10*, 1668.
217. Birch, D.; Memery, J.; Kanakaratne, M.D.S. The mindful consumer: Balancing egoistic and altruistic motivations to purchase local food. *J. Retail. Consum. Serv.* **2018**, *40*, 221-228.
218. Wright, D.R.; Underhill, L.G.; Keene, M.; Knight, A.T. Understanding the motivations and satisfactions of volunteers to improve the effectiveness of citizen science programs. *Soc. Nat. Resour.* **2015**, *28*, 1013-1029.
219. Forrester, T.D.; Baker, M.; Costello, R.; Kays, R.; Parsons, A.W.; McShea, W.J. Creating advocates for mammal conservation through citizen science. *Biol. Conserv.* **2017**, *208*, 98-105.
220. Bonney, R.; Phillips, T.B.; Ballard, H.L.; Enck, J.W. Can citizen science enhance public understanding of science? *Public Underst. Sci.* **2016**, *25*, 2-16.
221. Martínez-Manrique, E.; Jacinto-Hernández, C.; Garza-García, R.; Campos, A.; Moreno, E.; Bernal-Lugo, I. Enzymatic changes in pectic polysaccharides related to the beneficial effect of soaking on bean cooking time. *J. Sci. Food Agric.* **2011**, *91*, 2394-2398.
222. Jeffery, H.R.; Mudukuti, N.; Buell, C.R.; Childs, K.L.; Cichy, K. Gene expression profiling of soaked dry beans (*Phaseolus vulgaris* L.) reveals cell wall modification plays a role in cooking time. *Plant Genome* **2023**, *16*, e20364.
223. Njoroge, D.M.; Kinyanjui, P.K.; Chigwedere, C.M.; Christiaens, S.; Makokha, A.O.; Sila, D.N.; Hendrickx, M.E. Mechanistic insight into common bean pectic polysaccharide changes during storage, soaking and thermal treatment in relation to the hard-to-cook defect. *Food Res. Int.* **2016**, *81*, 39-49.
224. Kinyanjui, P.K.; Njoroge, D.M.; Makokha, A.O.; Christiaens, S.; Ndaka, D.S.; Hendrickx, M. Hydration properties and texture fingerprints of easy-and hard-to-cook bean varieties. *Food Sci. Nutr.* **2015**, *3*, 39-47.
225. Ávila, B.P.; Santos dos Santos, M.; Nicoletti, A.M.; Alves, G.D.; Elias, M.C.; Monks, J.; Gularte, M.A. Impact of different salts in soaking water on the cooking time, texture and physical parameters of cowpeas. *Plant Foods Hum. Nutr.* **2015**, *70*, 463-469.
226. Kwofie, E.M.; Mba, O.I.; Ngadi, M. Classification, force deformation characteristics and cooking kinetics of common beans. *Processes* **2020**, *8*, 1227.
227. Gritzer, D. How to Cook Dried Beans. Available online: https://www.seriouseats.com/how-to-cook-dried-beans (accessed on 28 June 2023).
228. America's Test Kitchen. Salty Soak for Beans. Available online: https://www.americastestkitchen.com/cooksillustrated/how_tos/5803-salty-soak-for-beans (accessed on 28 June 2023).
229. Alberta Pulse Growers. Preparing Pulses. Available online: https://albertapulse.com/eating-pulses/prep-storage/ (accessed on 28 June 2023).
230. Pulses Asia. How to Prepare U.S. Pulses. Available online: https://pulses.asia/preparation/ (accessed on 28 June 2023).
231. Katuuramu, D.N.; Luyima, G.B.; Nkalubo, S.T.; Wiesinger, J.A.; Kelly, J.D.; Cichy, K.A. On-farm multi-location evaluation of genotype by environment interactions for seed yield and cooking time in common bean. *Sci. Rep.* **2020**, *10*, 3628.
232. United States Agency for International Development. Beans Commodity Fact Sheet. Available online: https://2012-2017.usaid.gov/what-we-do/agriculture-and-food-

security/food-assistance/resources/beans-commodity-fact-sheet (accessed on 26 August 2023).
233. Wang, N.; Daun, J.K. Determination of cooking times of pulses using an automated Mattson cooker apparatus. *J. Sci. Food Agric.* **2005**, *85*, 1631-1635.
234. Wiesinger, J.A.; Osorno, J.M.; McClean, P.E.; Hart, J.J.; Glahn, R.P. Faster cooking times and improved iron bioavailability are associated with the down regulation of procyanidin synthesis in slow-darkening pinto beans (*Phaseolus vulgaris* L.). *J. Funct. Foods* **2021**, *82*, 104444.
235. Bassett, A.N.; Cichy, K.; Ambechew, D. Cooking Time and Sensory Analysis of a Dry Bean Diversity Panel. Publications from USDA-ARS. 2017.
236. Bassett, A.; Kamfwa, K.; Ambachew, D.; Cichy, K. Genetic variability and genome-wide association analysis of flavor and texture in cooked beans (*Phaseolus vulgaris* L.). *Theor. Appl. Genet.* **2021**, *134*, 959-978.
237. Miano, A.C.; Sabadoti, V.D.; Augusto, P.E.D. Enhancing the hydration process of common beans by ultrasound and high temperatures: Impact on cooking and thermodynamic properties. *J. Food Eng.* **2018**, *225*, 53-61.
238. Bassett, A.; Hooper, S.; Cichy, K. Genetic variability of cooking time in dry beans (*Phaseolus vulgaris* L.) related to seed coat thickness and the cotyledon cell wall. *Food Res. Int.* **2021**, *141*, 109886.
239. Chigwedere, C.M.; Olaoye, T.F.; Kyomugasho, C.; Kermani, Z.J.; Pallares, A.P.; Van Loey, A.M.; Grauwet, T.; Hendrickx, M.E. Mechanistic insight into softening of Canadian wonder common beans (*Phaseolus vulgaris*) during cooking. *Food Res. Int.* **2018**, *106*, 522-531.
240. Schoeninger, V.; Coelho, S.R.M.; Christ, D.; Sampaio, S.C. Processing parameter optimization for obtaining dry beans with reduced cooking time. *LWT-Food Sci. Technol.* **2014**, *56*, 49-57.
241. Bertoldo, J.G.; Rocha, F.d.; Barili, L.D.; Vale, N.M.d.; Coimbra, J.L.M.; Guidolin, A.F. Salts concentrations in combination with soaking time: Effect in bean cooking time. *Food Sci. Technol*. **2010**, *30*, 510-515.
242. Kruger, J.; Minnis-Ndimba, R.; Mtshali, C.; Minnaar, A. Novel in situ evaluation of the role minerals play in the development of the hard-to-cook (HTC) defect of cowpeas and its effect on the in vitro mineral bioaccessibility. *Food Chem.* **2015**, *174*, 365-371.
243. Yi, J.; Njoroge, D.M.; Sila, D.N.; Kinyanjui, P.K.; Christiaens, S.; Bi, J.; Hendrickx, M.E. Detailed analysis of seed coat and cotyledon reveals molecular understanding of the hard-to-cook defect of common beans (*Phaseolus vulgaris* L.). *Food Chem.* **2016**, *210*, 481-490.
244. Pirhayati, M.; Soltanizadeh, N.; Kadivar, M. Chemical and microstructural evaluation of 'hard-to-cook'phenomenon in legumes (pinto bean and small-type lentil). *Int. J. Food Sci. Technol.* **2011**, *46*, 1884-1890.
245. Munthali, J.; Nkhata, S.G.; Masamba, K.; Mguntha, T.; Fungo, R.; Chirwa, R. Soaking beans for 12 h reduces split percent and cooking time regardless of type of water used for cooking. *Heliyon* **2022**, *8*, e10561.
246. Wiesinger, J.A.; Cichy, K.A.; Tako, E.; Glahn, R.P. The fast cooking and enhanced iron bioavailability properties of the Manteca yellow bean (*Phaseolus vulgaris* L.). *Nutrients* **2018**, *10*, 1609.
247. Wainaina, I.; Wafula, E.; Sila, D.; Kyomugasho, C.; Grauwet, T.; Van Loey, A.; Hendrickx, M. Thermal treatment of common beans (*Phaseolus vulgaris* L.): Factors

determining cooking time and its consequences for sensory and nutritional quality. *Compr. Rev. Food Sci. Food Saf.* **2021**, *20*, 3690-3718.
248. Prodanov, M.; Sierra, I.; Vidal-Valverde, C. Influence of soaking and cooking on the thiamin, riboflavin and niacin contents of legumes. *Food Chem.* **2004**, *84*, 271-277.
249. Sikora, M.; Świeca, M.; Gawlik-Dziki, U.; Złotek, U.; Baraniak, B. Nutritional quality, phenolics, and antioxidant capacity of mung bean paste obtained from seeds soaked in sodium bicarbonate. *LWT* **2018**, *97*, 456-461.
250. Amin, S.; Borchgrevink, C.P. A Culinology® perspective of dry beans and other pulses. *Dry Beans and Pulses: Production, Processing, and Nutrition*; Wiley: Hoboken, NJ, USA, 2022; pp. 453-480.
251. Abdel-Aleem, W.M.; Abdel-Hameed, S.M.; Latif, S.S. Effect of soaking and cooking on nutritional and quality properties of faba bean. *Nutr. Food Sci. Int. J.* **2019**, *9*, 67-75.
252. Albelbisi, N.; Yusop, F.D.; Salleh, U.K.M. Mapping the factors influencing success of massive open online courses (MOOC) in higher education. *Eurasia J. Math. Sci. Tech. Ed.* **2018**, *14*, 2995-3012.
253. Eisler, M.C.; Lee, M.R.; Tarlton, J.F.; Martin, G.B.; Beddington, J.; Dungait, J.A.; Greathead, H.; Liu, J.; Mathew, S.; Miller, H. Agriculture: Steps to sustainable livestock. *Nature* **2014**, 507, 32-34.
254. Bhartiya, A.; Aditya, J.; Kant, L. Nutritional and remedial potential of an underutilized food legume horsegram (*Macrotyloma uniflorum*): A review. *J. Anim. Plant Sci.* **2015**, *25*, 908-920.
255. Mwale, S.E.; Shimelis, H.; Mafongoya, P.; Mashilo, J. Breeding tepary bean (*Phaseolus acutifolius*) for drought adaptation: A review. *Plant Breed.* **2020**, *139*, 821-833.
256. Akter, Z.; Pageni, B.; Lupwayi, N.Z.; Balasubramanian, P. Biological nitrogen fixation by irrigated dry bean (*Phaseolus vulgaris* L.) genotypes. *Can. J. Plant Sci*. **2018**, 9*8*, 1159-1167.
257. Meena, R.S.; Das, A.; Yadav, G.S.; Lal, R. *Legumes for Soil Health and Sustainable Management*. Springer: Singapore, 2018.
258. Lovegrove, J.A.; O'Sullivan, D.M.; Tosi, P.; Millan, E.; Todman, L.C.; Bishop, J.; Chatzifragkou, A.; Clegg, M.E.; Hammond, J.; Jackson, K.G. 'Raising the Pulse': The environmental, nutritional and health benefits of pulse-enhanced foods. *Nutr. Bull.* **2023**, *48*, 134-143.