

# Enhancing nutrition with pulses: defining a recommended serving size for adults

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*Pulses, defined as dry-harvested leguminous crops, include several varieties of beans, peas, lentils, and chickpeas. There is no consensus around a recommended serving size of pulses within a balanced diet, which prevents the development of transregional strategies that rely on consistent messaging to drive increases in consumption. The purpose of this review is to define and disseminate an appropriate target for a minimum serving size of pulses on any given day that can be used in international or collaborative strategies to promote the consumption of pulses. Relevant data were reviewed to examine dietary guidelines across jurisdictions, determine consumption levels of pulses across the globe, evaluate the nutritional composition of pulses in the context of dietary nutrient insufficiency, and assess the impact of pulses on dietary quality. Across a variety of pulses, 100 g of cooked pulses aligned with most regional serving sizes for pulses and provides significant levels of nutrients that are underconsumed by specific age-sex groups. Moreover, 100 g of pulses provides a number of nutrients that qualify for nutrient content claims under regional regulatory frameworks. The data demonstrate that 100 g or 125 mL (0.5 metric cup) of cooked pulses is a reasonable target for aligning strategies that promote the dietary and nutritional attributes of these legumes.*

## INTRODUCTION

The Food and Agriculture Organization of the United Nations (FAO) defines pulses as dry-harvested leguminous crops, which include several varieties of beans, peas, lentils, and chickpeas (Table 1).<sup>1</sup> Pulses do not include legumes with high levels of fat/oil or moisture at the time of harvest, such as soybeans and peanuts, or fresh beans and peas, respectively. Simply put, all pulses

are legumes, but not all legumes are pulses (Figure 1). According to the FAO, pulses represent an important component of healthy diets.<sup>2</sup> In addition to their significant contribution to human nutrition and food security, pulses are associated with reduced risk factors for chronic disease,<sup>3–8</sup> foster sustainable agriculture, and support climate change mitigation.<sup>9,10</sup> Pulses have also been identified as having important potential roles in sustainable and healthy food systems.<sup>11</sup> In 2013, the

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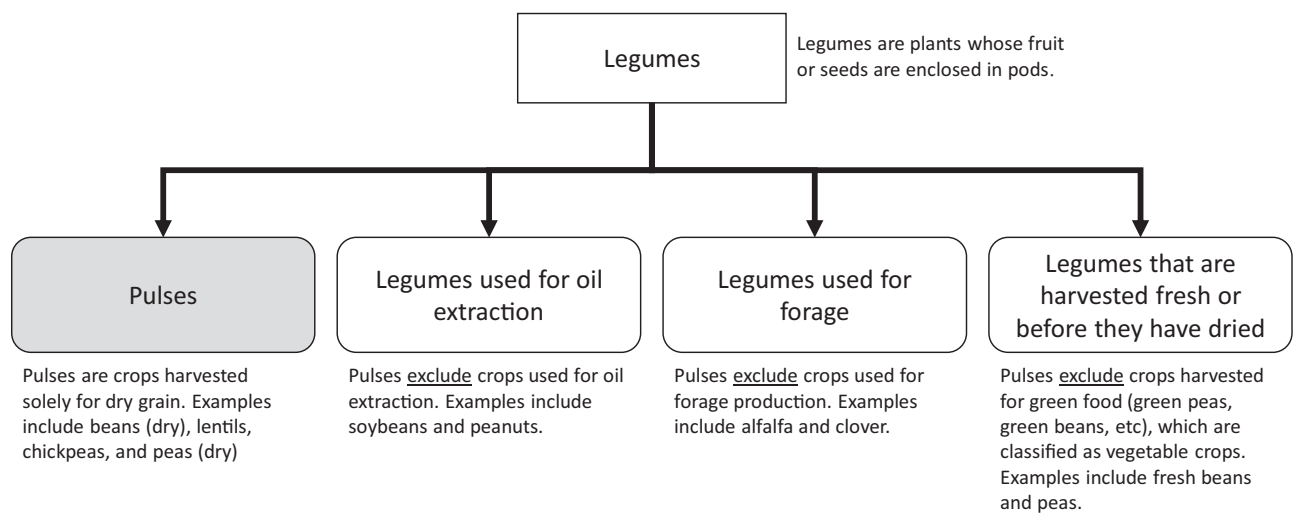
Key words: beans, chickpeas, lentils, nutrition, nutrient recommendation, peas, pulses, regulatory.

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**Table 1 Examples of pulses that are consumed globally**

Peas	Chickpeas	Lentils	Beans
Green peas (split or whole, harvested dry)	Desi chickpeas	Green lentils	Adzuki beans
Yellow peas (split or whole, harvested dry)	Kabuli chickpeas	Red lentils	Bambara beans
Pigeon peas		Yellow lentils (split or whole)	Cowpeas and black-eyed peas
			Cranberry beans
			Faba or fava beans
			Great Northern beans
			Kidney beans
			Lima beans
			Lupin beans
			Mung beans
			Mungo beans
			Navy beans
			Pink beans
			Pinto beans
			Yellow beans
			Vetch



**Figure 1 Summary of various types of legumes.**<sup>1</sup>

United Nations declared 2016 as the International Year of Pulses. Accordingly, it is anticipated that the FAO’s efforts to raise awareness about the effects of pulses on nutrition, health, and sustainability will, in part, help foster a global increase in pulse consumption that persists beyond 2016.

Like many food groups, pulses represent a diverse set of foods that vary in nutritional composition and bio-availability of nutrients. Different populations may consume different types of pulses, depending on local cuisine and food availability. Nevertheless, pulses remain a significant sustainable food for the world’s population, and there is value in deriving a standard serving of pulses on which to build global nutrition communications. Indications for establishing a standard serving size can be found in national dietary guidelines, estimations of usual dietary intake in populations, the potential nutritional contribution of a standard serving, or the impact of a standard serving on diet quality.

Thus far, there is no consensus around a recommended target amount of pulses to be consumed on any given day. This prevents the development of trans-jurisdictional or regional initiatives that rely on consistent messaging to drive an increase in the consumption of dry beans, peas, chickpeas, and lentils in exchange for a reduction in the consumption of less-healthy foods. An established benchmark would also be ideal for international or collaborative strategies that promote the consumption of pulses beyond the 2016 International Year of Pulses and align with the long-term objectives of the FAO. The purpose of this review is to summarize and disseminate information generated through initiatives that would assist in defining an appropriate target for an absolute minimum recommended serving size of pulses to be consumed on any given day in the context of a healthy diet. A broad review of relevant data included the following: (1) examination of dietary guidelines across jurisdictions; (2)

**Table 2 Summary of dietary guidelines that endorse pulses as components of healthy diets**

Country or region	Food category (examples of pulses described in guidelines)	Serving size <sup>a</sup>	Frequency of consumption <sup>b</sup>
Australia <sup>13</sup>	Vegetables and legumes/beans (beans, lentils, and chickpeas) Lean meats and poultry, fish, eggs, tofu, nuts, and seeds and legumes/beans (beans, lentils, and chickpeas)	1 serving = 75 g (0.5 cup) 1 serving = 150 g (1 cup)	NSP: ≥ 5 servings of vegetables per day Minimum of 2 servings/wk
Brazil <sup>14</sup>	Beans (beans, lentils, chickpeas, and peas)	NP in current guide	NP in current guide
Bulgaria <sup>15</sup>	Meat and alternatives (beans, lentils, chickpeas, and peas)	1 serving = 200–300 g	Minimum of 2 servings/wk
Canada <sup>16</sup>	Meat and alternatives (kidney beans, lentils, and chickpeas)	1 serving = 0.75 cup	Use in a couple meals per week
Greece <sup>17,18</sup>	Olives, pulses, and nuts (beans)	1 serving = 100 g	3–4 servings/wk
India <sup>19</sup>	Cereals, millets, and pulses (beans and lentils)	1 serving = 30 g (dry, uncooked)	1 serving/d for nonvegetarians 2 servings/d for vegetarians
Ireland <sup>20,21</sup>	Meat, poultry, fish, beans, eggs, and nuts (beans, lentils, and peas)	0.75 of a 200-mL reference cup (≈ 150 mL)	NSP: Choose any 2 servings each day
Nordic countries <sup>22</sup>	Vegetables and fruit (beans and peas <sup>c</sup> ) Alternative to meat (beans and peas)	NP, ≈ 99 g <sup>d</sup> NP in the current guide	NP in the current guide NSP: Protein should be 10%–20% of energy intake per day for adults
Spain <sup>23–25</sup>	Legumes (beans, lentils, and chickpeas)	150–200 g (60–80 g dry)	≥ 2 servings/wk
South Africa <sup>26–29</sup>	Dry beans, peas, lentils, and soya	0.5 cup	Included in meals each week
United Kingdom <sup>30–34</sup>	Vegetables and fruit (beans, peas, and lentils) Meat, fish, eggs, beans, and other non-dairy sources of protein (beans, peas, and lentils)	1 serving = 80 g (3 heaping tablespoons) NP	NSP: Consume 5 servings of vegetables per day NSP: Eat from this food group each day
United States <sup>35</sup>	Vegetables (beans, peas, lentils, and chickpeas) Protein (beans, peas, lentils, and chickpeas)	0.5 cup <sup>e,f</sup>	1–3 cups/wk <sup>e,f,g</sup> 1–3 cups/wk <sup>e,f,g</sup>

Abbreviations: NP, not provided; NSP, nonspecific.

<sup>a</sup>Unless otherwise specified, serving sizes refer to cooked pulses.

<sup>b</sup>Unless otherwise specified, consumption frequencies refer to a single serving.

<sup>c</sup>Whether beans and peas were classified as legumes or vegetables was not specified.

<sup>d</sup>Serving size was extrapolated from fiber recommendations (3 g/MJ), average daily energy requirements of adults (18–74 years of age) based on average Nordic reference weights,<sup>22</sup> the average fiber content of 100 g of pulses (≈ 7.4 g ± 2.0) (Table 4; varieties listed in Table S1 in the Supporting Information online), and the assumption that at least 1 of 4 eating occasions per day would utilize pulses as vegetable and source of fiber. The amount of cooked pulses derived from this calculation was approximately 99 g.

<sup>e</sup>Standard portion size as outlined in the *Dietary Guidelines for Americans 2015–2020*.<sup>35</sup>

<sup>f</sup>Nutrition labeling regulations in the United States indicate that 1 cup = 240 mL.<sup>36</sup>

<sup>g</sup>The level of cups per week varies by caloric requirements (≥ 1600 kcal/d for adults) and dietary pattern (Healthy US-style Eating Pattern, Healthy Mediterranean-Style Eating Pattern, and Vegetarian Eating Pattern).<sup>35</sup>

assessment of consumption levels of pulses across the globe; (3) evaluation of the nutritional composition of pulses, with emphasis on protein, fiber, folate, iron, magnesium, potassium, and zinc, particularly within the context of dietary nutrient insufficiency; and (4) the impact of pulses on dietary quality. This review does not examine the nutritional merits of sprouted pulses, whose nutritional profile can differ significantly from that of whole pulses cooked from their postharvest dry form.

### DIETARY RECOMMENDATIONS FOR PULSES ACROSS FOOD-BASED DIETARY GUIDELINES

Food-based dietary guidelines for more than 100 countries have been summarized by the FAO.<sup>12</sup> Countries

and regions that included pulses within dietary paradigms are summarized in Table 2<sup>13–36</sup> and comprised Australia, Brazil, Bulgaria, Canada, Greece, India, Ireland, Nordic countries (Denmark, Finland, Sweden, Iceland, Norway), Spain, South Africa, the United Kingdom, and the United States.<sup>13–17,19–23,26,30,31,35</sup>

In Canada and Bulgaria, pulses are exclusively considered to be part of the Meat and Alternatives food group as a source of dietary protein.<sup>15,16</sup> Interestingly, in Australia,<sup>13</sup> Nordic countries,<sup>22</sup> the United Kingdom,<sup>30–34</sup> and the United States,<sup>35</sup> pulses are part of both the meat and alternatives and the vegetable/fruit food groups. Likewise, *Scientific Recommendations for Healthy Eating Guidelines in Ireland*<sup>20</sup> suggested that pulses be categorized as part of the vegetable and fruit

food group and the meat and alternatives food group. However, in the final iteration of Ireland's updated food pyramid, pulses were classified under a single food group, which encompassed protein-rich foods: meat, poultry, fish, eggs, beans, and nuts.<sup>21</sup>

Countries that include pulses as a component of a stand-alone food group were Greece (olives, pulses, and nuts),<sup>17</sup> India (cereal, millets and pulses),<sup>19</sup> South Africa (legume food group),<sup>26</sup> and Brazil (bean category).<sup>14</sup> While Indian dietary guidelines group pulses with cereals and millets, depending on the region of India, pulses are also identified as an individual food group. In France, legumes are listed as a food option in the starchy food category,<sup>25,37</sup> and, in the Netherlands,<sup>38</sup> pulses are identified as an option in the bread, potatoes, cereals, rice, pasta, and legumes group. These differences likely reflect both variability in dietary patterns and the manner in which pulses are traditionally consumed within meals.

Most regions provide some specificity with respect to a serving size of cooked pulses or legumes. In India, the *Dietary Guidelines for Indians—A Manual* (2010) specifies 30 g of uncooked pulses as a serving and suggests that 30 g and 60 g of whole uncooked pulses be consumed daily by nonvegetarians and vegetarians, respectively.<sup>19</sup>

While newer South African dietary guidelines have yet to address consumption frequencies for pulses,<sup>27</sup> past communications from the South African Department of Health, which promote the use of the 2012 South African dietary guidelines, recommend consumption of one-half cup servings of cooked pulses in meals each week as replacement for meat or poultry.<sup>28,29</sup> Dietary guidelines from Australia, Bulgaria, Greece, and Spain also provide recommendations for weekly consumption of pulses at varying amounts and frequencies. In Australia, one-half cup of pulses is considered a serving of vegetables, while 1 cup of cooked pulses is a serving of protein-rich food.<sup>13</sup> This reflects the units used in dietary modeling applied to develop healthy guidelines.<sup>39</sup> Australian guidelines suggest that legumes (including pulses), as a protein-rich food, be consumed on 2 occasions per week. On the other hand, the recommendation for vegetables is presented as an average daily consumption of a variety of components within the vegetables and legumes food group, namely 5 or more servings daily.<sup>13</sup>

Guidelines from Spain and Bulgaria suggest 2 or more servings of legumes (including pulses) and pulses, respectively, per week. In Spain, pulses, such as beans, peas, chickpeas, broad beans, and lentils, are encouraged in dietary patterns in which a serving ranges from 150 to 200 g (60–80 g dry).<sup>23–25</sup> In Bulgaria, a serving of cooked pulses ranges from 200 to 300 g.<sup>15</sup> Health

**Table 3 Summary of mass per one-half cup (125 mL) of cooked pulses**

Type of pulse	Mass (g) per 0.5 cup (125 mL) <sup>a,b</sup>
Large green lentils, whole	92
Large green lentils, dehulled, split	120
Medium green lentils, whole	89.5
Small green lentils, whole	168.5
(Small) red lentils, whole	98.5
(Small) red lentils, dehulled, split	126.5
Extra small red lentils	100.5
French green lentils	105
Desi chickpeas	138
Kabuli chickpeas	85.5
Dehulled split green peas	131.5
Whole yellow peas	85
Dehulled split yellow peas	126
Whole green peas	86.5
Black beans	89
Yellow beans	90
Small red beans	90
Pinto beans	90
Kidney beans	90
Great Northern beans	90.5
	Mean: 104.6 ± 22.8
	Median: 91.3 (85.0–168.5)

<sup>a</sup>Metric units: 0.5 cup = 125 mL.

<sup>b</sup>Mass values from nutrient analysis provided by Pulse Canada.<sup>40</sup>

authorities in Greece recommend 3 to 4 100-g servings of cooked pulses, olives, or nuts per week.<sup>17,18</sup> Recommendations in Canada define a serving as three-fourths of a cup (≈175 mL), with the suggestion that pulses be consumed each week at a “couple of meals.”<sup>16</sup> In the United States, suggestions regarding the consumption of pulses are integrated into both the vegetables and the protein-rich food groups, with suggested intake levels of each group varying from 1 to 3 cups per week for adults, depending on the dietary pattern adopted and the caloric requirements.<sup>35</sup> Within US dietary guidelines, a standard portion size for cooked beans, lentils, chickpeas, and split peas is one-half cup. Likewise, in UK guidelines, consumption of pulses is endorsed as a vegetable and protein-rich food.<sup>30,31</sup> However, serving sizes are outlined only for pulses as a vegetable, at 80 g of vegetables per serving.<sup>30,33</sup> Suggested frequency of consumption in the United Kingdom is also unspecific, with suggestions that 5 servings of vegetables be consumed daily and that foods from the protein group be eaten each day.<sup>30–34</sup> The *Scientific Recommendations for Healthy Eating Guidelines Ireland*<sup>20</sup> specify that three-fourths of a 200-mL reference cup (≈ 150 mL), or approximately 120 g on the basis of data in Table 3,<sup>40</sup> is a serving of cooked beans, lentils, or peas. Ireland's food pyramid suggests that 2 servings of food from the meat, poultry, fish, eggs, beans, and nuts group be consumed daily.<sup>21</sup> Although consumption of pulses is emphasized in the

2012 Nordic Nutrition Recommendations,<sup>22</sup> specific serving sizes for pulses are not provided. Therefore, for the purpose of this review, the serving size of 99 g outlined in Table 2 was derived from the following: (1) fiber recommendations (3 g/MJ) within dietary guidelines, (2) average daily energy requirements of adults (aged 18–74 years), based on average Nordic reference weights,<sup>22</sup> (3) the average fiber content of 100 g of pulses ( $\approx 7.4 \text{ g} \pm 2.0 \text{ g}$ ) (29 varieties of pulses; Table 4<sup>41</sup> lists corresponding US Department of Agriculture [USDA] Nutrient Database numbers), and (4) the assumption that at least 1 of 4 eating occasions on a single day would include pulses as a vegetable and a source of fiber. In 2015, the Ministry of Health of Brazil published *Dietary Guidelines for the Brazilian Population*<sup>14</sup> and excluded specific recommendations for food groups and serving sizes. Instead, food patterns and healthy eating habits were emphasized. However, previous food guidance from Brazil suggested that 1 serving of beans should be consumed daily, with 1 serving corresponding to 55 kcal,<sup>42</sup> or approximately 43 g on the basis of data shown in Table 4. These data suggest that dietary guidelines across the globe recommend a range of serving sizes and consumption frequencies for pulses, reflecting the nutritional contribution of these foods to the whole diet.

#### USING DIETARY GUIDANCE TO DERIVE A RECOMMENDED SERVING OF PULSES TO BE CONSUMED ON ANY GIVEN DAY

Table 2 shows the variation in dietary guidelines across regions for the serving size and frequency of consumption of pulses. This variation is not surprising, given that multiple influences contribute to regional dietary patterns, which can include, but are certainly not limited to, cultural and historical elements, food security, and the infrastructure that affect the value chain of local food systems. Despite these challenges, regional dietary guidance was used to derive a reasonable serving size of whole cooked pulses that would facilitate improvements in dietary adequacy and quality. Again, given that the infrastructure of food systems varies from region to region, a suggested frequency of consumption has not been proposed here, as this can change, depending on the needs of a population or an individual.

Table 3 provides a summary of mass equivalents (in grams) for one-half cup of cooked pulses.<sup>40</sup> Across 20 varieties of beans, lentils, chickpeas, and beans, on average, 104.6 g (SD, 22.8 g) was equivalent to one-half cup (metric value, 125 mL) of cooked pulses. The median mass of 125 mL was 91.3 g (range, 85.0–168.5 g). As noted previously, the majority of jurisdictions suggest that approximately 80 to 120 g represents a serving

size of pulses (Table 2) and is within the range of values for mass characterized as 125 mL (0.5 cup) of cooked pulses. This is true despite some minor deviations from Australian guidelines (75 g/serving as a vegetable), in which the serving size of pulses as a vegetable is just outside 1 SD of the mean for one-half cup of cooked whole pulses. In India, where daily recommendations for intake of pulses refer to the dry and uncooked form for nonvegetarians (30 g) and vegetarians (60 g), under the valid assumption that legumes absorb water and, at minimum, double in mass during cooking, dietary guidance for vegetarians, at 120 g/d, also aligns with approximately one-half cup of cooked pulses. Therefore, altogether, it is reasonable that 100 g or, more generally, one-half cup (metric value, 125 mL) of cooked pulses is a rational starting point for exploring a recommended serving size of beans, peas, lentils, and chickpeas. It is acknowledged 240 mL and 120 mL represent 1 cup and one-half cup, respectively, as household measurements for nutrition labeling regulations in the United States.<sup>36</sup> Nevertheless, on the basis of per-gram equivalents derived from metric household measurements that were described previously in Table 3, 120 mL (one-half cup in US labeling regulations) is equivalent to approximately  $100 \text{ g} \pm 22 \text{ g}$  of cooked pulses and, thus, is aligned with the approximately 100-g (0.5 metric cup) threshold serving size that is suggested herein. For the purpose of this review, unless otherwise specified, household measurements in “cups” refer to metric equivalents, and 0.5 cup equals 125 mL.

For some regions, a 100-g serving may also represent a shift toward the concept of pulses comprising the central dish within a meal. Furthermore, for countries such as Canada, Australia (as a protein-rich food), Bulgaria, and Spain, where recommendations are in excess of 100 g by a considerable amount, consumption of pulses at the 100-g level would provide nutritional benefits as intake levels approach specific target serving levels in those regions. Likewise, in countries where dietary guidelines suggest that pulses be consumed on a weekly basis, a serving of at least 100 g on days pulses are consumed can contribute levels of macro- and micronutrients to the diet.

#### EVALUATING THE CONSUMPTION LEVEL OF PULSES ACROSS REGIONS

Insight into the range of pulse consumption across the globe is provided by 11 studies that assessed the impact of dietary pulses/legumes on nutrient intakes. Overall, consumption of cooked pulses and legumes ranged from 0.4 to 277 g/d.<sup>27,43–52</sup> It is noteworthy that studies did not always differentiate between uncooked and cooked (including canned) legumes and pulses, or

**Table 4 Aggregate nutritional composition of pulses (100 g cooked) for select nutrients compared with composition of other plant-based carbohydrate-rich cereals and pseudocereals (100 g cooked)<sup>a</sup>**

Nutrient	Unit	Type of pulse <sup>b</sup>							Cereals and pseudo-cereals				
		Beans (SD)	Lentils	Chickpeas	Peas (± SD)	Average (± SD)	Barley <sup>c</sup>	Corn <sup>d</sup>	Rice (white) <sup>e</sup>	Rice (brown) <sup>f</sup>	Quinoa <sup>g</sup>		
Energy	kcal	126 (12)	116	164	120 (2)	127 (14)	123	96	130	123	120		
Protein	g	8.68 (1.62)	9.02	8.86	7.55 (1.22)	8.62 (1.54)	2.26	3.41	2.69	2.74	4.40		
Lipid	g	0.58 (0.53)	0.4	2.6	0.39 (0.01)	0.66 (0.62)	0.44	1.50	0.28	0.97	1.92		
Carbohydrate	g	22.48 (3.59)	20.13	27.42	22.18 (1.52)	22.55 (3.49)	28.22	20.98	28.17	25.58	21.30		
Fiber	g	7.4 (2.1)	7.9	7.6	7.5 (1.1)	7.4 (2.0)	3.8	2.4	0.4	1.6	2.8		
Calcium	mg	50 (19)	19	49	33 (26)	44 (19)	11	3	10	3	17		
Iron	mg	2.31 (0.62)	3.33	2.89	1.25 (0.06)	2.27 (0.68)	1.33	0.45	0.20	0.56	1.49		
Magnesium	mg	57 (15)	36	48	45 (13)	52 (15)	22	26	12	39	64		
Phosphorus	mg	142 (23)	180	168	114 (21)	142 (24)	54	77	43	103	152		
Potassium	mg	391 (84)	369	291	304 (83)	401 (84)	93	218	35	86	172		
Zinc	mg	1.06 (0.28)	1.27	1.53	1.19 (0.27)	1.09 (0.28)	0.82	0.62	0.49	0.71	1.09		
Folate	µg	125 (40)	181	172	62 (4)	127 (43)	16	23	3	9	42		
Niacin	mg	0.592 (0.240)	1.060	0.526	0.693 (0.279)	0.574 (0.246)	2.063	1.683	0.400	2.561	0.412		
Riboflavin	mg	0.063 (0.012)	0.073	0.063	0.055 (0.002)	0.064 (0.011)	0.062	0.057	0.013	0.069	0.110		
Thiamin	mg	0.172 (0.046)	0.169	0.116	0.162 (0.040)	0.177 (0.045)	0.083	0.093	0.020	0.178	0.107		
Vitamin B <sub>6</sub>	mg	0.106 (0.040)	0.178	0.139	0.029 (0.028)	0.117 (0.045)	0.115	0.139	0.093	0.123	0.123		
USDA Nutrient Database number <sup>h</sup>		16002, 16015, 16017, 16020, 16028, 16031, 16033, 16036, 16041, 16043, 16046, 16048, 16050, 16053, 16061, 16063, 16072, 16075, 16077, 16081, 16084, 16134	16070	16057	16086, 16102	16002, 16015, 16017, 16020, 16023, 16025, 16028, 16031, 16033, 16036, 16038, 16041, 16043, 16046, 16048, 16050, 16053, 16061, 16063, 16075, 16077, 16081, 16086, 16102, 16134	20006	11168	20445	20037	20137		

<sup>a</sup>Values were rounded to nearest decimal as reported in the *USDA Nutrient Database for Standard Reference: Release 28*.<sup>41</sup> For beans, values represent the average across 25 types.<sup>41</sup> For peas, values represent the average across 2 types. See [Table S1](#) in the Supporting Information online.

<sup>b</sup>Search terms for inclusion: "beans" or "lentils" or "chickpeas" or "mature seeds," "boiled," and "without salt." Search terms for exclusion: "sprouted."<sup>41</sup>

<sup>c</sup>Barley: pearled, cooked (USDA NDB number: 20006).<sup>41</sup>

<sup>d</sup>Corn: sweet, yellow, cooked, boiled, drained, without salt (USDA NDB number: 11168).<sup>41</sup>

<sup>e</sup>Rice: white, long-grain, regular, unenriched, cooked, without salt (USDA NDB number: 20445).<sup>41</sup>

<sup>f</sup>Rice: brown, long-grain, cooked (USDA NDB number: 20037).<sup>41</sup>

<sup>g</sup>Quinoa: cooked (USDA NDB number: 20137).<sup>41</sup>

<sup>h</sup>USDA Nutrient Database (NDB) numbers: 16002, adzuki bean; 16015, black bean; 16017, turtle bean; 16020, cranberry bean; 16023, French bean; 16025, Great Northern bean; 16028, kidney bean (all types); 16031, California red kidney bean; 16033, red kidney bean; 16036, royal red kidney bean; 16041, pink bean; 16043, pinto bean; 16046, small white bean; 16048, yellow bean; 16050, white bean; 16053, fava bean; 16061, catjang cowpea; 16063, cowpeas; 16057, chickpeas (garbanzo and bengal gram); 16070, lentils; 16072, lima bean; 16075, lima bean (thin seeded); 16077, lupin; 16081, mung bean; 16084, mungo bean; 16086, peas (split); 16102, pigeon peas; 16134, yardlong beans; 11168, corn; 20006, barley; 20037, rice (brown); 20137, quinoa; 20445, rice (white).

between legumes (which include pulses) and pulses alone. Thus, in some cases, it was not possible to determine the amount of pulses consumed. Furthermore, 1 study described serving sizes as per capita amounts (11.9 g/person/d), which underestimates absolute serving sizes among consumers of pulses or legumes.<sup>50</sup> For the most part, however, in these studies, consumption levels of pulses or legumes among pulse/legume consumers appears to be substantially lower than daily or weekly amounts recommended by dietary guidelines across regions.

Nevertheless, in some studies, levels of pulse consumption among pulse consumers corresponded to approximately 100 g on the day the dietary survey was conducted. For example, in 2 separate surveys, the Australian Grains and Legumes Nutrition Council reported that legumes, including baked beans, lentils, chickpeas, and red kidney beans, were consumed by 7.9% and 24.0% of the population, at daily amounts of approximately 100 g/d and approximately 97 g/d, respectively.<sup>53</sup> Similarly, in Canada and the United States, respective intakes of pulses were 87 to 113 g/d, and more than one-half cup per day among 13.0% and 7.9% of individuals identified as pulse consumers.<sup>47,48</sup> Data from the United States, reported by Mitchell et al.,<sup>47</sup> is corroborated by Orlich et al.,<sup>49</sup> who reported that the mean consumption of legumes across all dietary patterns (vegetarian and nonvegetarian) was 62 g/d, with the 90th-percentile level being 134.5 g/d, among legume consumers. Although Orlich et al.<sup>49</sup> do not disclose which foods were included as legumes, soy-based foods were captured as a separate food category. When Adamsson et al.<sup>52</sup> evaluated consumption levels of foods commonly eaten in Nordic countries, the average intake level of legumes (characterized as brown beans and peas) was 91 g/d ( $\pm 18$  g/d) among consumers. One study of individuals of Greek descent (> 70 years of age) living in Greece and Australia reported consumption of lentils, chickpeas, and white beans as 63 g/d and 86 g/d, respectively.<sup>46</sup> This study also reported that daily consumption of legumes in Japan is more than 85 g/d among individuals over 70 years of age, although it was difficult to differentiate between pulse consumption and soy consumption.<sup>46</sup> It is important to note that most of the aforementioned studies assessed intakes on a single day and did not establish whether individuals who consumed pulses/legumes on the day of the survey consumed them daily. Nevertheless, these data demonstrate that, even in populations in which overall consumption levels appear relatively low, for those individuals who do consume pulses or legumes, 100 g or one-half cup is a reasonable intake level that can be achieved across dietary paradigms.

## ADDRESSING GLOBAL NUTRITIONAL CHALLENGES WITH 100-g/d SERVINGS OF COOKED PULSES

Previously summarized dietary guidelines demonstrated that pulses are classified under one or more food groups, such as protein-rich foods, vegetables, or cereal grains/carbohydrates. The last group is particularly interesting because cereal grains, such as rice, corn, and wheat, represent the majority of food energy consumed globally.<sup>54</sup> Furthermore, while pulses may be used to fully or partially replace animal-based protein in mixed meals, whole pulses are often consumed in a manner that is similar to the consumption of cereals such as rice, barley, and quinoa.

Table 4 provides, for a subset of nutrients, an aggregated summary of the nutritional composition of cooked whole beans, lentils, chickpeas, and peas. For analytical consistency and ease of accessibility, the USDA National Nutrient Database for Standard Reference was used to extract these data using the following search terms: *af(-sprouted +pulse type [beans, lentils, chickpeas, and \*peas] + "without +salt" + "mature +seed" +boiled)*.<sup>41</sup> To ensure that legumes were appropriately identified as pulses, the term *mature seeds* was specified in the search. The terms *boiled* and *without salt* were also included to control for the effects of processing. The term *sprouted* was included as a term to exclude from the search. Of the 32 identified entries, 25 were grouped as beans, which included cowpeas, catjang, and lupins. Moth beans and hyacinth beans were excluded from the compositional analysis because of missing data for levels of dietary fiber. Winged beans were also excluded because they are not considered a pulse, owing to their high levels of lipid (5.8 g per 100 g cooked; USDA Database no. 16136).<sup>41</sup> Two entries were grouped as peas (split and pigeon peas). One database entry for each of lentils and chickpeas was identified. The nutritional composition data across the 29 pulses included in the analysis are summarized in Table S1 in the Supporting Information online.

In addition to pulses, Table 4 includes the nutritional composition of cereals/pseudocereals. Although cereal grains and pulses contain similar levels of total carbohydrate, fat, niacin, riboflavin, thiamin, and vitamin B<sub>6</sub>, pulses have higher levels of protein, folate, iron, magnesium, potassium, and zinc. Specific types of pulses, however, may have variable utility to provide individual nutrients, depending on the needs of a population. For example, compared with beans, lentils, and chickpeas, peas have somewhat lower levels of iron, phosphorous, and folate. Given the nutrient composition of pulses, it is reasonable that enhanced consumption of these legumes as a partial replacement for cereal

grains may help address nutritional challenges across regions.

In the United States, nutrients found in pulses (such as folate, magnesium, potassium, and fiber) are consumed in insufficient quantities by meaningful proportions of individuals 2 years of age and older.<sup>55</sup> Iron is of particular concern among adolescents and pregnant and premenopausal women.<sup>55</sup> Similarly, in Canada, intakes of folate, iron, zinc, and magnesium are inadequate in a number of age-sex groups, and intakes of potassium and fiber are below Adequate Intake (AI) levels.<sup>56–58</sup> Nevertheless, data from the United States and Canada suggest that inclusion of dietary pulses could help address the above-mentioned nutritional shortfalls. Mitchell et al.<sup>47</sup> demonstrated that Americans consuming approximately one-half cup of cooked dry beans or peas on the day food intake was assessed had higher intakes of fiber, protein, folate, zinc, iron, and magnesium and lower intakes of saturated fat (% kcal) and total fat (% kcal).<sup>47</sup> Similarly, Mudryj et al.<sup>48</sup> showed that Canadians who consumed at least 99 g of cooked pulses on the survey day had higher intakes of fiber, protein, folate, magnesium, iron, and zinc compared with those who did not consume pulses on the survey day. While it was not possible to establish that pulses were the only food that varied between pulse consumers and nonconsumers, intakes of nutrients not present in substantial amounts in pulses (eg, vitamin B<sub>12</sub>, vitamin D, calcium, and riboflavin) did not differ between groups.<sup>48</sup> This suggests that pulse intake, per se, likely contributed to the intakes of nutrients that differed between groups. The above-mentioned studies align with Australian reports that showed increased intakes of protein, iron, zinc, and magnesium among pulse consumers.<sup>59</sup> Across jurisdictions, an average daily intake of 100 g of pulses can significantly enhance intakes of macro- and micronutrients.

When the scope of nutritional inadequacy is broadened to include areas outside the developed world, the potential for pulses to help address international concerns about food insecurity and malnutrition is substantial. Therefore, the potential contribution of 100 g of pulses to addressing nutrition-derived ailments linked to protein energy malnutrition and micronutrient insufficiency warrants examination.

### **100 g of cooked pulses: addressing protein energy malnutrition**

Protein energy malnutrition has been identified as a primary nutritive concern in various developing countries.<sup>60</sup> In India, for example, the *Dietary Guidelines for Indians*<sup>19</sup> identified protein energy malnutrition as a common nutrition-related problem, mainly among

young children. In these guidelines, pulses are identified among the most recommended food types that should be eaten on a daily basis. However, the Indian population's average consumption of pulses and legumes was less than 50% of the recommended amount.<sup>19</sup> Pulses and legumes are an important source of protein in the Indian diet, and when they are combined with cereals, the essential amino acid profiles of pulses and cereals are complementary. As indicated by corresponding protein efficiency ratios<sup>61</sup> and protein digestibility corrected amino scores (PDCAAs),<sup>61,62</sup> pulses and cereals are lower-quality sources of protein. Where cereal grains typically have lower levels of lysine and higher levels of sulfur-containing amino acids (methionine and cysteine), the reverse is true for pulses. Thus, given that pulses contain 2–4 times more protein than cereals, combining pulses with cereals can improve the protein quality of a meal or diet, and, therefore, can help address the issue of protein energy malnutrition. The protein quality of pulses can be enhanced even further when pulses are combined with small amounts of animal protein.

### **100 g of cooked pulses: addressing iron, folate and zinc insufficiency**

Anemia affects 800 000 million women and children across the developed and developing world.<sup>63</sup> It is believed that 50% of cases are secondary to insufficient dietary iron.<sup>63</sup> In fact, iron deficiency is the most common micronutrient deficiency and affects more than 30% of the world's population, or an estimated 2 billion people.<sup>64</sup> Given that pulses can provide about 2 to 16 times the amount of iron found in barley, corn, and rice, even partial substitutions of pulses for cereal grains may help lessen the burden of anemia secondary to iron deficiency, especially in regions where diets are largely plant based.

The global prevalence of anemia from folate deficiency is relatively low. However, it is estimated that approximately 150 000 to 210 000 neural tube defects could be prevented with adequate folate consumption during the early stages of pregnancy.<sup>65</sup> Moreover, globally, it is estimated that less than 50% of women take folic acid supplements before and during the early stages of pregnancy.<sup>64,66</sup> On average, folate levels in pulses are approximately 6 times those in corn and up to 42 times those in nonfortified rice. Increased consumption of pulses within food paradigms could help increase dietary folate levels during the periconceptional period, especially in regions where access to folic acid supplementation is low and mandatory fortification of staple grains is not widespread.

Finally, zinc deficiency has also been identified as a primary cause of morbidity among children in



developing countries.<sup>64</sup> On average, pulses can contain 2 and 3 times the amount of zinc as corn and white rice, respectively, and use of 100 g of cooked pulses as a suggested serving size could be a cost-effective and straightforward method to enhance dietary levels of zinc in at-risk populations.

Increased use of pulses as part of omnivorous diets could help improve nutrient status. In some developing regions, pulses could reduce the reliance on supplementation or fortification and are already being explored as candidates for biofortification to address micronutrient deficits.<sup>67,68</sup> Pulses are also an affordable and culturally acceptable plant-based alternative in regions where both plant- and animal-based foods comprise the most prominent sources of nutrition.

### 100 g of cooked pulses: addressing potassium intake

Dietary potassium garners significant attention in the literature when the nutritional contributions of pulses are examined. Compared with barley, rice (white and whole grain), corn, and quinoa, pulses contain 2 to 11 times more potassium (Table 4). In addition to supporting electrolyte balance, potassium may help decrease the possible effects of dietary sodium on elevated blood pressure levels.<sup>69</sup> Hypertension is a risk factor for cardiovascular disease and is believed to contribute to 9.4 million deaths each year.<sup>70</sup> Thus, increasing potassium in the diet has been identified as a possible strategy to reduce hypertension.<sup>71,72</sup> Accordingly, the approximately 231 to 561 mg of potassium provided by 100 g of pulses (see Table S1 in the Supporting Information online) could help reduce sodium-to-potassium ratios. A recent meta-analysis demonstrated that ongoing consumption of pulses significantly decreased systolic blood pressure in hypertensive and nonhypertensive patients.<sup>4</sup> In addition, the Dietary Approaches to Stop Hypertension (DASH) diet recommends consumption of 5 to 6 servings of legumes weekly, with a single serving of beans and peas being identified as one-half cup<sup>73</sup> (in the US, 0.5 cup = 120 mL),<sup>36</sup> which, again, is about 100 g. As sodium reduction continues to be a focal strategy to decrease the prevalence of hypertension,<sup>74,75</sup> in addition to increased consumption fruits and vegetables, the increased emphasis of pulses in dietary patterns could serve as an effective measure to increase dietary potassium intake and help counteract the contribution of dietary sodium to elevated blood pressure.<sup>69</sup>

In summary, a comparison of the nutritional profiles of cooked pulses and cereal grains shows that 100 g of pulses has the potential to offer substantial nutrient-based advantages across spectrums of under- and overnutrition.

### CONTRIBUTION OF 100-g SERVINGS OF COOKED PULSES TO DIETARY RECOMMENDATIONS

To coincide with dietary guidance, jurisdictions adopt daily recommended consumption levels for nutrients to ensure populations are able to achieve diets that facilitate better health. *Nutrient content claims* are communicative statements found on food products that recognize foods that are a source of one or more nutrients. Thresholds for qualifying for nutrient claims differ between regions because they are based on a jurisdiction's daily nutrient recommendations. Finding alignment across regions for nutrient content claims pertaining to 100 g of cooked pulses helps to establish whether a 100-g serving of pulses would be recognized as a significant source of macro- and micronutrients across regions and could be used in nutrition education.

Table 5<sup>36,76–81</sup> outlines the nutritive criteria for nutrient claims across regions. Table 6<sup>36,61,62,77,79,82–85</sup> summarizes the potential for nutrient content claims that could be valid for 100 g of cooked pulses in Australia, Canada, Europe, and the United States, on the basis of the nutrients listed in Table 4.<sup>79,82–85</sup> Across all regions, 100 g of cooked pulses aligns with the nutritional criteria that permit content claims for the majority of nutrients found in pulses. In Australia, Canada, Europe, and the United States, 100 g of cooked pulses may be characterized as providing significant levels of fiber to diets. This is also true for protein. However, protein claims in the Canada and United States are underpinned by measures of protein quality (see Table 5). Thus, depending on the pulse evaluated, nutrient content claims for protein in these countries could vary (Tables 6 and 7<sup>36,61,62,77,79,82–85</sup>). In addition, in the United States, all nutrient content claims are evaluated per reference amount customarily consumed (RACC). Table 6 shows that, on the basis of the average amount of protein across 29 types of pulses (8.62 g) (Table 4), an average PDCAAS of 57 (peas [yellow split, 0.64; green split, 0.50], lentils (whole green, 0.63; red split, 0.54), chickpeas (0.52), pinto beans (0.59), kidney beans (0.55), black beans (0.53), and navy beans (0.67)],<sup>61,62</sup> and a 90-g RACC,<sup>36</sup> a protein claim may not be permitted. However, using an average PDCAAS of 59 (pinto beans, kidney beans, black beans, and navy beans)<sup>61,62</sup> for beans and a 130-g RACC for canned beans,<sup>36</sup> a protein claim *might* be valid. Despite the metrics of protein quality required for protein content claims in Canada and the United States, it is evident that, across regions, 8.6 g of protein per 100 g of pulses would contribute significant levels of protein to diets.

**Table 5 Summary of criteria for nutrient content claims across jurisdictions**

Nutrient	Australia <sup>76</sup>	Canada <sup>77</sup>	Europe <sup>78,79</sup>	USA <sup>36,80</sup>
Protein	For general claim: 5 g of protein per serving For "good source" claim: 10 g of protein per serving	For "good source" claim: <sup>a</sup> Protein rating ≥ 20 per reasonable daily intake For "excellent source" claim: <sup>a</sup> Protein rating ≥ 40 per reasonable daily intake	For "source" claim: Protein provides 12% of energy per serving For "high source" claim: Protein provides 20% of energy per serving	For "good source" claim: 10%–19% of DRV <sup>b</sup> /RACC ratio For "high source" claim: ≥ 20% of DRV <sup>b</sup> /RACC ratio ( <sup>b</sup> Corrected for protein quality using PDCAAS)
Fiber	For general claim: 2 g of fiber per serving "Good source" claim 4 g of fiber per serving For "excellent source" claim: 7 g of fiber per serving	For "source" claim: 2 g of fiber per reference amount For "high source" claim: 4 g of fiber per reference amount For "very high source" claim: 6 g of fiber per reference amount	For "source" claim: 3 g of fiber per 100 g; or 1.5 g of fiber per 100 kcal For "high source" claim: 6 g of fiber per 100 g; or 3 g of fiber per 100 kcal	For "good source" claim: 10%–19% of DRV/RACC ratio For "high source" claim ≥ 20% of DRV/RACC ratio
Micronutrients	For general claim: 10% of RDI per serving For "good source" claim: 25% of RDI per serving	For "source" claim: 5% of RDI per serving 200 mg of potassium per serving <sup>b</sup> For "good source" claim: 15% of RDI per serving 350 mg of potassium per serving <sup>b</sup> For "excellent source" claim: 25% of RDI per serving 550 mg of potassium per serving <sup>b</sup>	For "source" claim 15% of NRV per 100 g or 100 mL For "high source" claim 30% of NRV per 100 g or 100 mL	For "good source" claim: 10%–19% of RDI/RACC ratio For "high source" claim: ≥ 20% of RDI/RACC ratio

*Abbreviations:* DRV, Daily Reference Value; NRV, Nutrient Reference Value; PDCAAS, Protein Digestibility Corrected Amino Acid Score; RACC, Reference Amount Customarily Consumed; RDI, Recommended Dietary Intake (Australia) or Recommended Daily Intake (Canada) or Reference Daily Intake (USA).

<sup>a</sup>Protein content claims in Canada are based on a protein rating that is derived from the protein efficiency ratio methodology.<sup>77,81</sup>

<sup>b</sup>In Canada, amounts required for potassium claims do not correspond to the standard criteria for micronutrients of 5%, 15%, and 25% RDI for "source," "good source," and "excellent source," respectively.<sup>77</sup>

Interestingly, on average, 100 g of cooked pulses was shown to provide a substantial proportion of daily recommendations for a number of nutrients that were previously described as nutrients of concern worldwide (Table 6). Levels of iron provided by 100 g of cooked pulses were 12.6%, 16.2%, 16.2%, and 18.9% of daily nutrient recommendations in the United States, Europe, Canada, and Australia, respectively. A serving of 100 g of pulses provided 20% of the potassium nutrient reference values in Europe. Additionally, 100 g of cooked pulses provided 20% of the phosphorus and 63% of the folate nutrient recommendations in Europe and 26% of the fiber recommendations in the United States. Table 7 demonstrates that, in most cases, 100 g of cooked beans, lentils, chickpeas, and peas may individually qualify for the same nutrient content claims as when pulses are analyzed in aggregate. Exceptions are underlined. Notably, 100 g of cooked chickpeas may qualify for a zinc nutrient content claim in Australia, Europe, and the United States. Lentils also may qualify for a zinc content claim in the United States and for zinc, niacin, and vitamin B<sub>6</sub> content claims in Australia. In all regions, the levels of fiber and folate in 100 g of cooked pulses aligned with the highest thresholds for nutrient content claims and thus may permit terms of emphasis such as "high source."

The nutritional impact of 100 g of cooked pulses is also demonstrated when the nutritional composition of pulses is evaluated against the Institute of Medicine's Dietary Reference Intake values,<sup>86</sup> which, in some cases, are the most current guidance for daily consumption of macro- and micronutrients. For adults (≥19 years of age), 100 g of pulses provides up to 32%, 28%, 20%, and 17% of the Recommended Dietary Allowance (RDA) for folate, iron, phosphorous, and magnesium, respectively (Table 8<sup>86</sup>). A serving of 100 g of pulses also provides up to 15% to 19% of the RDA for protein. Where an RDA for a nutrient is not available, one-half cup of pulses delivers 19% to 35% of the Adequate Intake (AI) for fiber and 9% of the AI for potassium. The Institute of Medicine's AI for potassium is 4700 mg/d and is substantially greater than nutrient recommendations that permit the use of nutrient content claims in Canada and Europe, but it aligns with recently updated recommendations in the United States. Nonetheless, a comparison of the nutritional composition of pulses with regional and authoritative nutrient recommendations demonstrates that 100 g of cooked pulses can contribute significantly to the nutrient density of diets across jurisdictions. In the USDA's Healthy Eating Index, pulses are included in the greens and beans group, which is considered to be a category of food that increases

Table 6 Regional summary of nutrient content claims that could be utilized for 100 g of cooked pulses, using the aggregate nutritional data in Table 4

Nutrient	Unit	Australia <sup>82,83</sup> (≥ 4 y)		Canada <sup>77,84</sup> (≥ 2 y)		Europe <sup>79,85</sup> (adults)		United States <sup>35</sup> (≥ 4 y)					
		RV	Percent RV	Claim	RS	Percent RS	Claim	RI	Percent RI	Claim	DRV	Percent DRV	Claim <sup>b,c</sup>
Protein	g	8.62	NA <sup>b</sup>	Yes	–	NA <sup>b</sup>	Yes <sup>d</sup>	50	NA <sup>b</sup>	Yes	50	17.2%	No <sup>e</sup> Yes <sup>f,g</sup>
Fiber	g	7.4	NA <sup>b</sup>	Yes	25	NA <sup>b</sup>	Yes	25	NA <sup>b</sup>	Yes	28	26.4%	Yes
Minerals			Percent RDI/100 g	Claim	RDI	Percent RDI/100 g	Claim	NRV	Percent NRV/100 g	Claim	RDI	Percent RDI/100 g	Claim <sup>b,c</sup>
Calcium	mg	44	5.5%	No	1100	4.0%	No	800	5.5%	No	1300	3.4%	No
Iron	mg	2.27	18.9%	Yes	14	16.2%	Yes	14	16.2%	Yes	18	12.6%	Yes
Magnesium	mg	52	16.3%	Yes	250	20.8%	Yes	375	13.9%	No	420	12.4%	Yes
Phosphorus	mg	142	14.2%	Yes	1100	12.9%	Yes	700	20.3%	Yes	1250	11.4%	Yes
Potassium	mg	401	—NA	—	3500	11.5%	Yes <sup>b</sup>	2000	20.1%	Yes	4700	8.5%/10.8% <sup>f</sup>	No/Yes <sup>f</sup>
Zinc	mg	1.09	9.1%	No	9	12.1%	Yes	10	10.9%	No	11	9.9%/12.5% <sup>f</sup>	No/Yes <sup>f</sup>
Vitamins			Percent RDI/100 g	Claim	RDI	Percent RDI/100 g	Claim	NRV	Percent NRV/100 g	Claim	RDI	Percent RDI/100 g	Claim <sup>b,c</sup>
Folate	µg	127.0	63.5%	Yes	220	57.7%	Yes	200	63.5%	Yes	400	31.8%	Yes
Niacin	mg	0.574	5.7%	No	23	2.5%	No	16	3.6%	No	16	3.6%	No
Riboflavin	mg	0.064	3.8%	No	1.6	4.0%	No	1.4	4.6%	No	1.3	4.9%	No
Thiamin	mg	0.177	16.1%	Yes	1.3	13.6%	Yes	1.1	16.1%	Yes	1.2	14.8%	Yes
Vitamin B <sub>6</sub>	mg	0.117	7.3%	No	1.8	6.5%	Yes	1.4	8.4%	No	1.7	6.9%	No

Abbreviations: DRV, Daily Reference Value; NA, not applicable; NRV, Nutrient Reference Value; PDCAAS, Protein Digestibility Corrected Amino Acid Score; RACC, Reference Amount Customarily Consumed; RDI, Recommended Dietary Intake (Australia) or Recommended Daily Intake (Canada) or Reference Daily Intake (USA); RI, Reference Intake; RS, Reference Standard, RV, Reference Value.

<sup>a</sup>Averaged across 29 types of cooked pulses (Table 4).

<sup>b</sup>See claim criteria outlined in Table 5.

<sup>c</sup>Unless otherwise specified, the ability to make a nutrient content claim in the United States was based on a 90-g RACC for cooked legumes.<sup>36</sup>

<sup>d</sup>Based on an average Protein Efficiency Rating for black beans (PER: 1.61), whole green lentils (PER: 1.30), chickpeas (type unspecified) (PER: 2.32), and split yellow peas (PER: 1.42).<sup>61</sup> Reasonable daily intake for whole cooked pulses is 250 g/d.

<sup>e</sup>A PDCAAS of 57 was used and derived from the average PDCAAS value across 9 types of whole cooked pulses: peas (yellow split, 0.64; green split, 0.50), lentils (whole green, 0.63; red split, 0.54), chickpeas (0.52), pinto beans (0.59), kidney beans (0.55), black beans (0.53), and navy beans (0.67).<sup>61,62</sup>

<sup>f</sup>A 130-g RACC, corresponding to canned beans, was used for the calculation.<sup>36</sup>

<sup>g</sup>A PDCAAS of 59 was used and derived from the average PDCAAS value across 4 types of whole cooked beans: pinto beans (0.59), kidney beans (0.55), black beans (0.53), and navy beans (0.67).<sup>61,62</sup>

**Table 7 Regional summary of nutrient content claims that could be utilized for 100 g of cooked beans, lentils, chickpeas, and peas**

Nutrient	Ability to make a nutrient content claim per 100 g of cooked pulses by type (yes/no) <sup>a,b</sup>															
	Australia <sup>82,83</sup>			Canada <sup>77,84</sup>			Europe <sup>79,85</sup>			USA <sup>36,d</sup>						
	Beans	Lentils	Chickpeas	Peas	Beans	Lentils	Chickpeas	Peas	Beans	Lentils	Chickpeas	Peas	Beans	Lentils	Chickpeas	Peas
<b>Macronutrients</b>																
Protein	Yes	Yes	Yes	Yes	Yes <sup>c</sup>	Yes <sup>c</sup>	Yes <sup>c</sup>	Yes <sup>c</sup>	Yes	Yes	Yes	Yes	No <sup>e</sup> /Yes <sup>f,g</sup>	No <sup>e</sup>	No <sup>e</sup>	No <sup>e</sup>
Fiber	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
<b>Minerals</b>																
Calcium	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No
Iron	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	No
Magnesium	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	No
Phosphorus	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
Potassium	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No/Yes <sup>f</sup>	No	No	No
Zinc	No	Yes	Yes	No	Yes	Yes	Yes	Yes	No	No	Yes	No	No/Yes <sup>f</sup>	Yes	Yes	No
<b>Vitamins</b>																
Folate	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Niacin	No	Yes	No	No	No	No	No	No	No	No	No	No	No	No	No	No
Riboflavin	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No
Thiamin	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes
Vitamin B <sub>6</sub>	No	Yes	No	No	Yes	Yes	Yes	No	No	No	No	No	No	No	No	No

Abbreviations: PDCAAS, Protein Digestibility Corrected Amino Acid Score; PEC, Protein Efficiency Ratio; RACC, Reference Amount Customarily Consumed.

<sup>a</sup>Underlined, boldface cells represent occurrences in which the ability to make a nutrient content claim differs from occurrences in which the pulses were evaluated in aggregate in Table 6.

<sup>b</sup>Unless otherwise specified, nutrient values from Table 4 were used to quantify the ability to make nutrient content claims per 100 g of cooked beans, lentils, chickpeas, and peas.

<sup>c</sup>PER calculations were based on black beans (PER: 1.61), whole green lentils (PER: 1.3), chickpeas (type unspecified) (PER: 2.32), and split yellow peas (PER: 1.42).<sup>61</sup> Reasonable daily intake for whole cooked pulses is 250 g/d.<sup>84</sup>

<sup>d</sup>Unless otherwise specified, the ability to make a nutrient content claim in the United States was based on a 90-g RACC for cooked legumes.<sup>36</sup>

<sup>e</sup>PDCAAS values corresponding to various types of whole cooked pulses were used: beans [pinto beans (0.59), kidney beans (0.55), black beans (0.53), navy beans (0.67)], peas [yellow split (0.64) and green split (0.50)], lentils [whole green (0.63) and red split (0.54)], and chickpeas (0.52).<sup>61,62</sup>

<sup>f</sup>A 130-g RACC, corresponding to canned beans, was used for the calculation.<sup>36</sup>

<sup>g</sup>A PDCAAS of 59 was used and derived from the average PDCAAS value across 4 types of whole cooked beans: pinto beans (0.59), kidney beans (0.55), black beans (0.53), and navy beans (0.67).<sup>61,62</sup>

**Table 8 Summary of the contribution of 100 g of cooked pulses to the Institute of Medicine's Dietary Reference Intakes**

Nutrient	RDA and AI <sup>a</sup> (adults > 18 y) <sup>86</sup>		Amount of nutrient in 100 g of pulses <sup>b</sup>	RDA/AI
	Males	Females		
Protein (g/d)	56	46	8.62	15–19%
Fiber (g/d)	30–38 <sup>c</sup>	21–25 <sup>c</sup>	7.4	19–35%
Folate ( $\mu$ g/d)		400	127	32%
Iron (mg/d)	8	8–18	2.27	13–28%
Magnesium (mg/d)	400–420	310–320	52	12–17%
Phosphorous (mg/d)		700	142	20%
Potassium (mg/d)		4700 <sup>c</sup>	401	9%

Abbreviations: AI, Adequate Intake; RDA, Recommended Daily Allowance.

<sup>a</sup>From Dietary Reference Intakes Tables and Application: DRI Values Summary.<sup>86</sup>

<sup>b</sup>Averaged across the 29 types of pulses listed in Table 4.

<sup>c</sup>An RDA for this nutrient is not available. This value is represented as an AI.

nutrient adequacy and index scores.<sup>87</sup> The effects of 100 g of cooked pulses on diet quality are also supported by the above-mentioned data from Australia, Canada, and the United States, where consumption of pulses (legumes in Australia) significantly enhanced daily intakes of macro- and micronutrients linked to beans, lentils, chickpeas, and peas.<sup>47,48,59</sup>

## DISCUSSION

Enhanced incorporation of pulses into human diets has the potential to make substantial contributions to nutritional adequacy. Since recommendations for pulse consumption vary across regions, there is value in defining an amount of pulses that can be consistently promoted by health authorities and the agriculture sector in conjunction with the International Year of Pulses and beyond. Here, 100 g (one-half cup or 125 mL) of cooked pulses was evaluated as a recommended single-day threshold for consumption of beans, lentils, chickpeas, and peas. Given the nutritional composition of pulses, it is evident that levels of protein, fiber, folate, iron, potassium, and zinc from beans, lentils, chickpeas, and peas could help address some of the nutritional shortfalls that affect the developed and developing world. Moreover, the potential eligibility of 100 g of cooked pulses for numerous nutrient content claims across regions speaks to the nutrient density of pulses and their contribution to dietary quality. The compiled data demonstrate that 100 g or 125 mL (one-half metric cup) of cooked pulses is a reasonable target for aligning strategies that promote the dietary and nutritional attributes of these legumes.

While this review examines and suggests a minimum threshold amount of pulses that one could reasonably consume in a single day, it is difficult to suggest a consumption frequency for the 100-g serving that aligns with the needs of an entire population. Regional dietary guidelines contain specific nutritional recommendations

to address the dietary needs of a specific population. In some regions, pulses are commonly consumed foods and are a dietary staple. In these cases, 100 g of pulses can be reasonably consumed daily without difficulty. However, in other regions, where a wide variety of foods are available, this 100-g quantity could be consumed to positively impact dietary quality on any given day. This is reflected in dietary guidelines where, depending on the region, weekly or daily suggestions are made for the incorporation of pulses into dietary paradigms (Table 2). While the suggested target of a 100-g serving does not replace regional dietary guidelines, it does provide a nutritionally relevant level of pulses that can be used in international or collaborative communications that promote the consumption of pulses. Consumption frequency of any food is a function of numerous inputs, including cultural acceptance, infrastructure of the food value chain, and, for some, food security. In regions where pulse consumption is relatively low, 100 g of cooked pulses can be promoted on an occasional basis and still facilitate meaningful enhancements to nutrient intakes.

If pulses are to be used as an affordable vehicle to help address micronutrient deficiencies, a daily consumption frequency would likely be required and could work in concert with supplementation and fortification initiatives. Generally, given that 100 g of pulses provides significant levels of nutrients, the 100-g consumption level for a single day can be suggested as a target over a broad range of consumption frequencies that accommodate the needs of specific demographics. However, given that regions can have different nutritional challenges, it is realistic that the 100-g serving suggested here could be increased as required. Nevertheless, as a pragmatic approach, the recommended level of cooked pulses suggested in this review should and could be reasonably consumed as a single serving (although the nutritional benefits of 100 g could also be realized if cooked pulses were consumed as smaller servings throughout a single day).

The consumption of pulses could increase at the expense of other foods within the diet, especially in areas where a variety of foods are consistently available. In Canada, for example, pulses are classified as an alternative to animal-based protein sources.<sup>16</sup> In some developing regions, however, increased pulse consumption could occur in addition to the consumption of foods already available. It is reasonable that enhanced consumption of animal-based foods in developing regions would be a more efficient method of providing some nutrients, such as high-quality protein and bioavailable iron. However, the logistics of implementing these nutritional strategies need careful consideration. Data from the FAO demonstrates that, compared with rice, cereals, and pulses, meat represents a relatively minor source of energy in these regions.<sup>88</sup> Infrastructure and economic inputs required for establishing increased reliance on livestock agriculture as a source of food may not be viable in areas where resources are already scarce.<sup>89,90</sup> For example, in Kenya, where water scarcity is a concern, a recent study demonstrated that the increase in meat and milk consumption increased the water footprint of these foods by factors of 2.3 and 4.2, respectively.<sup>91</sup> Furthermore, sustainability of food systems should be integrated into strategies when dietary interventions are used to address a broad range of food-related issues, including food insecurity, malnutrition, and overnutrition, as international conversations around climate change continue to escalate. In developed and developing regions, pulses could be used as a nutrient-dense food source that, in combination with other inputs, could help address some of these issues.

It is also recognized that the 100-g recommendation for cooked pulses is based on dietary guidance for adults and that 100-g portions could be difficult for children to consume in a single serving. Nevertheless, 100 g of cooked pulses is a relatively small amount that could be either incorporated into the dietary patterns of some children without difficulty or appropriately adjusted to smaller amounts that still provide nutritional benefits.

Although pulses are nutrient-dense foods, they are well known for containing components identified as “antinutritional factors” that can reduce the bioavailability of macro- and micronutrients. Examples of such factors include trypsin inhibitors and tannins that affect protein digestion, as well as oxalate and phytate that decrease absorption of calcium, iron, and zinc.<sup>92,93</sup> Various forms of household and commercial processing methods (including soaking, boiling/thermal processing, and canning), commonly practiced prior to the consumption of pulses, have been shown to substantially decrease the levels and activities of antinutritional factors.<sup>93–97</sup> However, in regions where this is

insufficient to address macro- and micronutrient shortfalls, emphasis on dietary variety, alongside food fortification and supplementation with macro- and micronutrients, may be required to ensure nutritional adequacy. Furthermore, ongoing breeding efforts to biofortify pulses and other plant-based foods may help address common nutritional deficiencies, such as iron-deficiency anemia, in developed and developing regions.<sup>67,98</sup>

In some regions, it is likely that multiple strategies will be needed to increase the proportion of people consuming pulses at the 100-g serving level. This is especially true in regions such as Australia, Canada, and the United States, where the majority of individuals do not consume pulses regularly. In countries such as Canada and the United States, if pulses were consumed approximately 2 days per week in amounts of approximately 100 g, one would expect a per capita consumption of approximately 30 g/d ( $2 \times 100 \text{ g} = 200 \text{ g}$  per 7 days  $\approx 30 \text{ g}$ ). Or alternately, on any given day, two-sevenths ( $\approx 30\%$ ) of the population would consume pulses. The United Nation’s designation of 2016 as the International Year of Pulses already serves as a platform for a global concerted effort toward communicating the benefits of pulses for nutrition adequacy and sustainable agriculture. Other strategies will include increased promotion and prominence of pulses in regional dietary guidelines. As indicated by dietary guidelines for Australia, Nordic countries, the United Kingdom, and the United States, pulses can be promoted across vegetable and protein-rich food groups, given their nutritional composition. Furthermore, the nutrient composition and methods of consumption of pulses also suggest that beans, lentils, chickpeas, and peas could also be promoted within carbohydrate-based food groups that typically include cereal grains. Programs and educational campaigns that advocate for partial replacement of cereals with pulses can bolster the nutritional density of staple meals, especially in developing regions where meals or diets are highly cereal-based and, at times, lack variety. Similar strategies may also prove efficacious in regions where dietary patterns are of lower quality and comprise foods of high energy and low nutrient density, which are associated with nutrition-related ailments such as increased cardiometabolic risk, including obesity.<sup>99–101</sup>

Healthy dietary patterns are acknowledged to carry a higher cost than diets of lower quality.<sup>102,103</sup> However, Drewnowski and Rehm<sup>103</sup> demonstrated that, across 46 vegetables consumed in the United States, pulses are among plant-based foods with the highest nutritional value per dollar and the lowest cost per gram.<sup>103</sup> Similar associations for beans, legumes, seeds, and nuts, when compared as a single group with other food groups, have been shown when the cost per 100 kcal was

expressed as a function of nutrient density per 100 kcal.<sup>104</sup> In regions where pulse consumption remains low, the 100-g recommendation suggested here, when used in conjunction with appropriate promotional strategies, will help to reposition pulses as mainstream dietary constituents and address global nutrition and food-related challenges. It is hoped that consensus regarding the use of 100 g of cooked pulses as a target serving size will encourage unified global messages that advocate for increased consumption of pulses to improve dietary quality.

It is important to emphasize that the recommended serving size of cooked pulses is based on the nutritional contribution of pulses to diets and does not imply therapeutic benefits. In addition, this amount of pulses (100 g) is proposed in the context of a balanced diet. For example, given that pulses can have lower levels of essential sulfur-containing amino acids, it is assumed that pulses will be eaten as a complement to other plant-based or animal protein sources that contain higher levels of methionine and cysteine. Accordingly, consumption of any healthy food should be underscored by dietary variety.

## CONCLUSION

In conclusion, 100 g (0.5 metric cup or 125 mL) of cooked beans, lentils, chickpeas, or peas is a reasonable minimum serving size that can contribute to improving the nutrient density of healthy diets. The use of this amount as a serving size would harmonize international strategies for communicating the nutritional benefits of pulses on the basis of their important contribution to the nutrient density of healthy diets. The frequency of consumption of the standard serving could then be adjusted to suit local needs and cuisine characteristics.

## Acknowledgments

*Author contributions.* All authors contributed to conceiving and conceptualizing the study question. C.M. and J.C. wrote the manuscript. All authors interpreted and discussed the information put forward as well as read and approved the manuscript.

*Funding/support.* No external funds supported this work.

*Declaration of interest.* C.M. and J.C. are employed by Pulse Canada. C.M. was previously employed by Kellogg Canada. J.S. has received research funding from the American Pulse Association and is on the editorial

board of Dry Bean Quarterly. L.T. has received research funding from the Australian Grains and Legumes Research Council. The Pathfinders Research and Management Ltd (C.A.P.) has undertaken research for Pulse Canada.

## Supporting Information

The following Supporting Information is available through the online version of this article at the publisher's website.

*Table S1 Nutrition composition summary for whole cooked pulses (per 100 g) for select nutrients*

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