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The versatility of pulses: Are consumption and consumer perception in different European countries related to the actual climate impact of different pulse types?

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A B S T R A C T

Pulses support sustainable production and consumption. Their culinary versatility creates a wide range of possibilities for new products, bridging consumers’ preparation barriers. However, this potential is often intangible for consumers who have little knowledge about plant-based foods. Based on an online survey in Denmark, Germany, Poland, Spain, and the United Kingdom (N = 4,226), this study aimed to investigate consumer utilization and perception of pulses as a versatile, low-carbon food relative to objective life cycle assessment (LCA) measures of 12 pulse types. The most popular pulse types, with specific preferences across countries, were lentils, kidney beans, and chickpeas, typically consumed at home and purchased in dried or canned form. Respondents associated pulses with being healthy and natural, but sustainability was not an essential attribute related to the perception of pulses. LCA revealed a low environmental impact caused by pulse production and consumption, with marginal variations between types and produce. Respondents were unaware of the nuances in the environmental impact of different pulse types, generally perceiving uncommon pulses to be relatively more sustainable than others. In conclusion, a low consumption combined with a misconception of pulses’ environmental impact may demand different promotional strategies including clear communication to inform consumers.

1. Introduction

Pulses are the dried edible seeds of leguminous plants, spanning across crops harvested solely for dry grain (FAO, 1994). Crops that are either harvested green, e.g., green beans, for oil extraction, e.g., soybeans, or sowing purposes, e.g., clover, are not included (Rebello et al., 2014). A lack of knowledge and inspiration in preparation or the association with gastrointestinal discomfort resulted in a neglect of pulses in the diet of Europeans (Didinger and Thompson, 2020; Henn et al., 2022). Pulses bear a rich repertoire with a range of different sub-types varying in, e.g., taste or preparation, whereby versatility and variety of plant-based foods have been attributed to ease the consumption of plant-based foods (Lea et al., 2005). The crops embody great benefits from both nutrition and sustainability perspectives if included in the daily diet. Their balanced profile of digestible protein, fiber, starch, and low amount of fat combined with the supply of vitamins, minerals, and bioactive compounds, has been associated with various health-protective effects (McCory et al., 2010; Mudryj et al., 2014). Consumption of pulses can, however, not only increase personal health but also contribute to climate change mitigation by lowering greenhouse gas (GHG) emissions associated with agricultural practices when replacing high-impact foods such as meat (Peoples et al., 2019). All leguminous plants live in a unique relationship with rhizobacteria which allows them to fix atmospheric nitrogen (Wang et al., 2018). Ultimately, the ability of pulses’ self-fertilization substantially reduces the use of additional synthetic fertilizers (Foyer et al., 2016). Following the versatility of pulse crops, some types, such as bambara beans, are extremely dry-tolerant (Didinger and Thompson, 2020; FAO/OCPP, 2016), which lowers water demand, and competition with plants nearby.

Today’s consumer has become more aware of environmental issues and demonstrates concern (Kim et al., 2016). However, most consumers are not capable of determining which behavior is worth changing to reduce the environmental impact caused by food consumption (Thøgersen, 2021). In general, consumers seem to overestimate the impact of plant-based foods or alternatives and highly underestimate the environmental harmfulness of meat (Hartmann et al., 2022).
Lazzarini et al., 2018, 2016; Lea and Worsley, 2008; Michel et al., 2021; Siegrist and Hartmann, 2019). An in-depth understanding of consumers’ drivers and barriers to food choice is needed to promote environmentally friendly consumption (Grunert, 2011; Lazzarini et al., 2018).

This study aimed to investigate consumer understanding of pulses as a versatile and sustainable food. Hence, the objectives included firstly to characterize the utilization of different pulse types and determine consumers’ underlying associations. Cross-national quantitative survey data, distributed to adult individuals in European countries, was collected to pursue consumer behavior. Secondly, the environmental impact of different pulse types based on protein content was estimated using life cycle assessment (LCA) while considering major parts of the supply chain. Thereby, the objective was to determine the boundaries of GHG emissions resulting from production and consumption of different pulse types, and consequently, resolve if the pulse commodity should be treated as one. Only a few researchers have previously performed similar LCA studies on pulses consumed in Europe (del Borghi et al., 2018; Tidåker et al., 2021). Most researchers investigated the role of pulses on the reduced burden in crop rotations (Costa et al., 2020). The third objective was built on evaluating consumers’ conception of the environmental impact of pulses by linking subjective measures on utilization and associations with objective LCA measures. By doing so, a novel bridge between consumer understanding and LCA measures is built.

2. Methodology

2.1. Quantitative pan-European consumer survey

A cross-cultural survey on pulses was developed based on focus group interviews and pre-testing in the respective countries. The countries included in the survey were Denmark, Germany, Poland, Spain, and the United Kingdom (UK). This choice was based on representing a geographical span throughout Europe with different cultures, cuisines, income levels, and consumption patterns (de Boer and Aiking, 2018; Elmadfa, 2009). Quantitative pan-European data (N = 5062) were collected in May and June 2020 through a large web-based survey. Questionnaire development and participant selection were performed as described by Henn et al. (2022). This paper considers only the questionnaire sections on participants’ consumption behavior regarding different pulse types. Thus, data management and analysis are based on the response of participants, who were classified to be familiar with pulses, i.e., could at least correctly associate one of the stated food products with the category “pulses” and consumed at least one pulse type in the past 12 months (“familiar consumers”, N = 4226). To investigate consumption frequency, participants who knew pulses but stated not to consume them (“familiar non-consumers”, n = 476) were added to the sample.

2.1.1. Responding procedure

Before beginning the survey, participants were informed about the study and asked to consent to participate. In the first part, participants answered questions about demographics, including age, gender, household situation and shopping, country of residence and origin, locality of residence, education, and dietary pattern.

Another part regarded the consumption of different pulse types. Participants could select between one to twelve different types (or none), carried throughout the subsequent questions. These questions considered frequency and place of consumption, the purchased form of pulses, combination with other foods or ingredients, and prepared dishes. The frequency of consumption was assessed with five ordered categories. Questions about form, combination, and preparation of pulses were presented as check-all-that-apply question matrices.

In a third step, participants were asked about their associations with different pulse types, whereby all 12 pulse types were presented regardless of whether participants indicated previous consumption or not. Thus, an opt-out category of “I do not know them” was added to the multiple-choice items. Participants could neither see the question numbers nor go back to a previous page throughout the survey. All data were collected anonymously without saving respondents’ IP addresses. The complete questionnaire can be found in supplementary material A.

2.1.2. Data management

Only fully completed questionnaires were included for further analysis. Participants who were identified as the worst-performing participants, as elaborated in detail by Henn et al. (2022), were removed, improving the overall quality of the data. The frequency of consumption ranging from “less than once a month” (1) to “(almost) every day” (5) was re-coded according to the frequency in days per month. Hence, to name an example, less than once a month was coded as 0.5 and once a week as 4. Additionally, non-consumers were included with 0 frequency, resulting in a range between 0 and 30 for this variable.

2.2. Life cycle assessment

A “cradle-to-grave” LCA was applied to quantify the environmental friendliness of individual pulse types represented by the carbon footprint. The functional unit of the LCA was defined as 1 kg protein, whereby protein contents of pulses were retrieved from literature (Henchion et al., 2017). The LCA was conducted according to the ISO standards 14,040 and 14,044 in SimaPro v9.1 (SimaPro, PRé Sustainability, Amersfoort, the Netherlands). The impact assessment method is based on IPCC emission factors (Pachauri and Meyer, 2014) with a time horizon of 100 years. Two forms of consumer products were considered, i.e., dry pulses and canned pulses. The system boundary for dry pulses covers farm production, transportation to consumers, household consumption (soaking and boiling), and end-of-life treatment of food and packaging waste (plastic). For canned pulses, the system boundary includes an additional step of industrial canning; the process inventory of the household consumption process (heating), and the end-of-life treatment process of packaging waste (aluminum cans) differ from that of dry pulses. Local farm production and onsite processing into consumer products were assumed for dry and canned pulses. Thus, the transportation distance from farms to the packaging facility is considered negligible. The final products are assumed to be sold to local consumers via road transport at an average distance of 25 km. Further details on each process within the system boundary including assumptions for the LCA can be reviewed in supplementary material B.

2.3. Statistical analysis

For questionnaire data, descriptive results are presented as proportions or mean values and standard error. Normality was determined using the Kolmogorov-Smirnov test. Non-parametric analyzes using a Kruskal-Wallis test were applied to determine differences across countries, as data were not normally distributed. Pearson correlation was carried out to measure the linear relationship between environmental impact and frequency of consumption as well as environmental impact and consumer perception of sustainability. Data used for correlation analysis, i.e., mean values for frequency of consumption, perception, and climate impact for the 12 pulse types, were normally distributed. All statistical analyzes were performed using IBM SPSS Statistics version 28 (SPSS Inc., Chicago, IL). Principal component analysis (PCA) explored binary variables of utilization and associations with different pulse types, with 26 and 10 variables respectively. Data for PCA was normalized according to the proportion of consumers and autoscaled (scaled so that each column has a variance of one). Due to considerable variation in sub-sample sizes for utilization of different pulse types resulting from a variation in eating behavior, resampling using 80% of

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1 n = 6 participants indicated to only eat pulses in a restaurant, hence neither buy nor prepare pulses, and were thus not included in the sample of familiar consumers.
3. Results

3.1. Utilization of pulses by European consumers

3.1.1. Consumption frequency

After scanning for the worst-performing participants, the sample size amounted to 4,916 responses, whereby 4,702 participants were characterized as “familiar consumers” (explained in 2.1). Across countries, the sample size of respondents being familiar with pulses amounted to 900 in Denmark, 947 in Germany, 959 in Poland, 972 in Spain, and 924 in the United Kingdom. Notably, the number of non-consumers was especially high in Denmark (n = 201) and low in Spain (n = 6). Table 3.1 shows differences in consumption behavior per country, as well as the proportion of participants who consumed a pulse type in the past 12 months and the mean consumption frequency of familiar participants. Groups of “popular” (>60%), “regular” (25–45%), and “exotic” (<10%) pulses were identified according to the proportion of consumers across countries. The first group of “popular” pulses consisted of lentils, kidney beans, and chickpeas. Spanish participants consumed lentils (M = 2.83) and chickpeas (M = 2.59) with a significantly higher frequency of about three times per month. Kidney beans were significantly more often used by Polish and UK participants compared to other European countries investigated. A group of “regular” frequently consumed pulses was built up of peas, faba beans, black beans, and lima beans. Thereby, regional differences in consumption frequency were observed, with more regular consumption of peas and faba beans in Poland, black beans in the UK, and lima beans in Spain. Cowpeas, lupines, mung beans, pigeon peas, and bambara beans were found to represent rather “exotic” pulses in Europe, as less than 10% of familiar participants indicated a consumption in the past 12 months. Again, Spain was the leading consumer segment of cowpeas and lupines, whereas pigeon peas and bambara beans were relatively more popular in Germany.

3.1.2. Utilization of pulses - purchase, preparation, and consumption behavior

Utilization of different pulse types, including form of purchase, place of consumption, preparation, and combination with other foods, was determined using PCA. As no significant country-effect was found for this utilization, PCA was applied for the total sample. Four components were retained, explaining a cumulative variance of 81.2%. PC1 vs PC2 and PC3 vs PC4 are shown, as this, in principle, shows how the pulses and the variables are changing with all four principal components. Fig. 3.1 shows a separation between two major groups of pulses on the first principal component, whereby a first group of bambara beans, mung beans, pigeon peas, and lupines was negatively related to PC1, explained by the place of consumption being typically in a restaurant or “on the go”. Lupines also correlate negatively with the second principal component, which could be explained by the consumption “on the go”, purchase in processed, sprouted, or fermented form, processing other than a stew. In contrast to this first group, other pulses clustered together on the positive axis of PC1, which is driven by consumption at home. The component revealed further positive associations with practices such as purchasing dried or canned form, preparation as stews, and combination with bread, vegetables, or pork. The third and fourth principal components indicate a separation of pulse types according to consumption in either dried or canned form. Kidney beans as well as chickpeas, lupines and black beans were characterized by purchase in canned produce, while cowpeas, bambara beans, lentils, and lima beans were utilized in dried form.

3.2. The European mindset of consumers towards pulses

3.2.1. Consumer association with different pulse types

Consumers associated pulse types with different attributes, whereby the first four principal components resulting from a PCA are shown in Fig. 3.2. The first two principal components show distinct differentiation in how participants perceived the pulse types. Most pulse types were associated with being versatile, healthy, boiling, filling, natural, and sustainable, with a few exemptions. Bambara beans being negatively correlated with PC1 were associated with being inconvenient and having a bland taste. Furthermore, faba beans, lima beans, and lupines seemed to be perceived as more local and appealing compared to other pulse types, according to a negative correlation with the second component.
The third and fourth components added an association of cowpeas being inconvenient but natural and peas being local. Additional Pearson’s correlation analysis showed strong correlations between consumers’ associations. Healthiness perception was positively correlated with naturalness perception ($r = 0.76$, $p = 0.004$). The perception of being sustainable was not significantly correlated with any other association.

3.3. Environmental impact of pulses

Cradle-to-grave carbon footprint accounting of pulses is shown in Fig. 3.3. The carbon footprint of dry pulses varied across pulse varieties, ranging from 4.1 kg CO₂eq to 21.5 kg CO₂eq per kg protein. The carbon footprint of canned pulses in the functional unit of 1 kg protein ranged from 12.4 kg CO₂eq to 33.4 kg CO₂eq. Farm production was a hotspot for the carbon footprint of both dried and canned pulses. For canned pulses, significant contributions came from processing ranging between 9.6 and 19.9 kg CO₂eq for different pulses and accounting for 56.3–79.1% of the total carbon footprint. In contrast, the consumption stage, i.e., home preparation, accounted for 50.9–91.3% of the cradle-grave carbon footprint for dry pulses. The carbon footprint also varied for the different pulse types depending on the form of purchase. Thereby, the most remarkable change was observed for lentils and pea, with the former experiencing a quadrupled carbon footprint when the form of consumption is changed from dry to canned pulses. The footprint of the other pulse types commonly had an approximately onefold increase.

Among all pulse types, bambara beans had the highest carbon footprint per kilogram of consumer product, primarily due to the significantly higher contributions from the farming stage compared to other pulse types. Black beans, faba beans, chickpeas, kidney beans, and lima beans performed similarly in both product forms with a carbon footprint of around 12.0 and 25.1 kg CO₂eq per kg protein in dry and canned pulses, respectively. The lowest carbon footprint of dry pulses was determined for lentils, followed by peas, mainly as a result of reduced cooking time compared to other types as well as relatively emissions during farm production. Lupine ranked third due to its comparably high protein content.

3.3.1. Relationship between consumption frequency and environmental impact

No significant correlation ($r = -0.52$, $p = 0.086$; $r = -0.07$, $p = 0.842$) was observed between the consumption frequency and the environmental impact of dried and canned pulses, respectively. A scatterplot of environmental impact versus consumption frequency with corresponding product-moment correlation coefficients visualizes the distribution (Fig. 3.4). The plot shows that those pulse types with a low environmental impact were not necessarily consumed the most, such as lupines and mung beans. However, lentils were found to have a low environmental impact, if not the lowest for dried pulses, and were consumed most frequently by the participants. In comparison, participants consumed bambara beans with the lowest frequency, while LCA data revealed a relatively higher environmental impact of these pulses.

3.3.2. Relationship between sustainability perception and environmental impact

The correlation analysis of consumer perception of sustainability and objective environmental impact of dry and canned pulses was not statistically significant, respectively ($r = 0.02$, $p = 0.963$; $r = -0.06$, $p = 0.859$). The scatterplots depicted in Fig. 3.5 indicate an overestimation of the environmental friendliness of relatively unknown pulse types such as bambara bean and pigeon pea compared to familiar types. However, consumer perception and climate impact showed a good fit for the case of lentils and peas if purchased in dry form. Interestingly, frequency and perception were not correlated either ($r = -0.34$, $p = 0.288$). Hence, participants did not attach greater importance to consuming perceived sustainable pulse types more often.

4. Discussion

4.1. Sustainable consumption of pulses

Investigations of consumers showed that lentils, kidney beans, and chickpeas were most frequently consumed among European participants of this study. Regarding the popularity of certain pulse types, individual
preferences in the five countries could be uncovered. These regional differences could result from traditional recipes as well as the availability in local supermarkets. Foremost in the Mediterranean diet, pulses are still anchored and traditionally served with olive oil, herbs, and vegetables and complemented with bread (Dilis and Trichopoulou, 2009). For the analysis, distinctions were made between the proportion of participants consuming the pulses and the respective frequency of consumption per month of these selected participants. Results indicated that this distinction is essential as it showed that even though some pulses are consumed by many, they are used very infrequently per month.

The PCA highlighted differences in the utilization of the pulse types. A significant variance in the PCA was explained by the consumption at home in dried or canned form versus eating in a restaurant or on the go in other forms. Pulses are commonly found in dry or canned produce in European markets. In other cultures, pulses are often consumed in sprouted form, mainly mung beans, which improves nutritional quality, as sprouting increases the content of vitamins and minerals but decreases the content of anti-nutrient factors (ANF) (Abu-Ghannam and Gowen, 2011). Furthermore, fermented pulses benefit from enriched quality and taste, as the typical bean flavor and aroma are reduced after fermentation (Michaels, 2004). Fermentation is mainly applied to soybeans and less frequently to mung beans and chickpeas (Abu-Ghannam and Gowen, 2011). Pasta, snacks, or bakery products integrating pulses with cereals could help bridge barriers such as the old-fashioned image as food for the poor (Magrini et al., 2018). Hence, different consumption patterns were identified across European countries, with a general low frequency of consumption and low diversity in consumption. The consumption was below the nutritional guidelines indicating the need to promote pulse consumption across European countries. The diversity in pulse varieties may be a driver for future promotion.

The boundaries of the LCA showed that pulses can be treated as one commodity with regards to their environmental impact, with overall low GHG emissions caused during production and consumption. These low emissions might be premised on the self-fertilization ability of leguminous plants, which do not require additional nitrogen fertilizer. Synthetic fertilizers do not only account for 12% of the GHG emissions associated with agriculture (Peoples et al., 2019) but also contribute to soil acidification and toxicity (Ferreira et al., 2021). Pulses stimulate soil fertility through nitrogen fixation and nitrogen release, enhancing yields of mixed crops and with less environmental impact (Burgess et al., 2012; Ferreira et al., 2021). Growing pulses additionally fosters a re-

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**Fig. 3.2.** Principal component analysis of the first four components of consumers’ associations (X) with pulses.
Fig. 3.3. Cradle-to-grave carbon footprint of pulse products purchased as dry (A) and canned (B) pulses expressed as kg CO$_2$-equivalents per kg protein.

Fig. 3.4. Environmental impact (kg CO$_2$eq per kg protein) for dried (left) and canned (right) pulse types plotted against consumption frequency (days per month) of each type. Red and green frames and arrows indicate a possible shift of pulse consumption to optimize environmental impact.

Fig. 3.5. Environmental impact (kg CO$_2$eq per kg protein) for dried (left) and canned (right) pulse types plotted against consumer perception of sustainability (%). The red frame indicates the misconception between consumer perception and actual environmental impact of pulses.
sistant and resilient ecosystem, building on the activity of microbes in the soil (FAO/OCPCP, 2016). Thus, pulses not only reduce agricultural GHG emissions but also increase biodiversity by benefitting neighboring plants, cropping and soil ecosystems, and the habitats for species considered critical for nature conservation (Peoples et al., 2019). Consequently, pulses render great effects on a more climate-friendly food production with positive impacts on soil ecosystem health and services (Thomsen et al., 2012).

Food production and consumption have been accounted to contribute one third of the household’s environmental impact in the Western world (Tubelli et al., 2021). There is consensus that a shift from Western diets high in meat to a more plant-based diet can relieve environmental pressure (Karlsson Potter and Röös, 2021). LCA of the pulse types evidenced an increase of environmental impact when purchasing canned produce instead of dried forms, mainly due to energy used during the canning process. Thus, a minimized CO2 footprint would be assured by purchasing dried, locally produced pulses. However, pulse consumption does not evolve around optimizing but around providing an alternative to the current consumption of animal-based foods. Dried pulses are less convenient, and a realistic increase in consumption frequency by the general population can only be realized by offering appropriate alternatives. Canned pulses are a way to promote convenient products and are still more sustainable than animal-based food production, which causes an approximately 10-fold higher emission of greenhouse gases. The benefits of local production and dried forms are hence comparatively of secondary order of importance, as increasing the general pulse consumption as alternative to animal-based foods will have a greater impact on reduction climate and environmental impacts food consumption. For example, beef production, differentiating between dairy and beef herds, was measured to emit 169 to 499 kg CO2eq per kg protein (Ritchie and Roper, 2020), respectively, compared to 12–33 kg CO2eq per kg protein for canned pulses. The effect of meat consumption on GHG emissions, water, and land use, regardless of the efficiency of animal feed production, is more significant than even the most inefficient production of foods of plant-based origin, such as pulses (Aschemann-Witzel et al., 2020). Pulses are a suitable replacer for animal-based foods as they contain comparable amounts of digestible protein (Dillis and Tri-chopoulou, 2009). Nevertheless, in comparison to animal-based products, pulses yet lack a complete set of essential amino acids and need to be complemented with cereals or rice. Future LCAs could thus evaluate the climate impact of a complement of cereals and pulses, which is nutritionally appropriate to substitute meat products.

4.2. Correspondence of consumer perception and objective measures

Consumers associated the pulse types with different attributes. PCA showed that lima beans, faba beans, and lupines were associated with being local and appealing pulse types. Previous research indicated that locally produced food is perceived as of higher quality, particularly in terms of freshness and taste (Chambers et al., 2007). Besides these observations, no significant correlation between the attributes of locally produced foods and perceptions such as sustainable, natural, or appealing could be evidenced. However, most of the attributes which consumers associated with pulses were correlated. While perceived healthiness and naturalness were linked, no significant relation towards the attribute of being sustainable was found. However, it was previously suggested that the sustainability of foods is typically associated with naturalness (Verhoog et al., 2007). In this case, the association with healthiness seemed to be more prominent. In general, sustainability perception was not correlated with other attributes. Interestingly, participants who found pulses to be filling and bloating did not perceive inconvenience, indicated by a significant negative correlation. This finding suggests that consumers utilizing convenient forms of pulses, i.e., canned pulses, might have noticed abdominal discomfort such as bloating and feeling full more frequently than consumers using dry (inconvenient) forms of pulses.

Perceived sustainability was low, as only 30–40% of respondents affiliated the attribute with pulses. Most of all, pigeon peas, bambara beans, both relatively uncommon pulse types, and lentils were evaluated to be more sustainable. Especially kidney beans were perceived to be less sustainable. Pulse types such as kidney beans, chickpeas, black beans, and lupines are predominantly consumed in canned form, suggesting an association between canned produce and environmental harm. It was previously advised that consumers do not have sufficient knowledge about food production and often misjudge processed foods to have more significant environmental harm and negative consequences on health (Lea and Worsley, 2008; Tobler et al., 2011). In general, consumers seem to underestimate the sustainability and environmental impact of pulses and rate plant-based foods to be more harmful than foods from an animal base (Hartmann et al., 2022; Lazzarini et al., 2018). Overall, consumers appear to not know about the climate impact of foods, comparing meat with other protein-rich foods (Hartmann et al., 2022). Previous studies showed that conscious plant-based consumption is driven by health benefits, though not yet associated with environmental reasons (Henn et al., 2022; Lea et al., 2005).

The aim of this study was to investigate consumer perception of pulses as low-carbon foods. A correlation between consumers’ evaluation of pulses’ sustainability and their actual climate impact was determined. A negative correlation was expected, i.e., the lower the environmental impact, the higher the perception of a respective pulse to be sustainable. However, consumer ranking of sustainability for dry pulses and climate data were not correlated. Consumption frequency and environmental impact showed a strong negative correlation, meaning that pulse types with a low impact are consumed the most, yet this correlation was insignificant. Nevertheless, information on the environmental impact of pulses is not widely available, and consumers cannot acquire knowledge, making them able to differentiate. Notably, frequency of consumption and consumers’ perception of sustainability weren’t correlated either. In other words, consumers found certain pulse types to be marginally more sustainable than others but did not realize this in their consumption behavior. However, the differences in sustainability perception were minor, so other factors, such as preparation skills or availability, might have played a predominant role in consuming pulses. In general, the sustainability and environmental beneficial aspects of pulse consumption were not reflected in the consumer motives for pulse consumption. Hence, there is a need of informing European consumers about the benefits of pulse consumption for the environment and climate footprint.

5. Conclusion

Consumption of pulses was occurring at low frequencies, with lentils, kidney beans, and chickpeas representing the most popular pulse types in the investigated European countries. Relatively uncommon pulse types, among them bambara beans, pigeon peas, mung beans, and lupines, were typically consumed in a restaurant or on the go, often in processed, sprouted, or fermented form. Those pulse types purchased in cans, i.e., chickpeas, kidney beans, lupines, and black beans, were perceived as comparably less sustainable. LCA of different pulse types yet highlighted pulses’ low climate impact. Thereby, the form of consumption, i.e., dried, or canned, and the pulse type played a minor role in associated GHG emissions compared to meat products. This underlines the notion of promoting pulse consumption irrespective of form or type instead of guiding consumers towards choosing the most sustainable option among pulse-based foods. Furthermore, consumers’ knowledge about the sustainability of pulses was low. Firstly, a link between the low environmental impact and sustainability perception was missing, whereby consumers evaluated the sustainability of the commodity without further differentiations per pulse type. Secondly, pulses were not necessarily associated with sustainability, regarding the importance of healthy, natural, versatile, appealing, and filling attributes. This little knowledge introduces the need to seek new strategies to promote
pulses’ sustainability. Clear communication to consumers about pulses as representative of low-carbon foods is essential to advance sustainable choices.

Ethical statement

The research aim of the study was explained to participants in the online questionnaire. Participants were informed that all data are anonymous and will be stored confidentially. Only participants who acknowledged an informed consent statement were included in the study. Participants were able to withdraw from the survey at any time without giving a reason. They were financially compensated for their participation.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The data used for the tables and figures can be accessed at 10.5281/zenodo.7300307.

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Supplementary materials

Supplementary material associated with this article can be found in the online version, at doi:10.1016/j.fufo.2022.100202.

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