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The quality of leguminous vegetables as influenced by preharvest factors

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ABSTRACT

The cultivation of most legumes, aims to the production of either dry seeds consumed by humans, also known as pulses, or animal fodder. However, some legumes are cultivated for fresh consumption either as pods or as immature seeds. The economically most important legumes consumed as vegetables are green pods of common bean, cowpea, faba bean, snow pea (mangetout) and green pea seeds. As a rule, the legume vegetables are consumed after cooking and in many countries, they may be used to cover primary nutritional needs, because their protein content is high in comparison with most other vegetables. Furthermore, the legume vegetables, which have distinct organoleptic properties when compared to pulses, are also considered important sources of carbohydrates, essential minerals, vitamins, several other antioxidants and health promoting compounds, and dietary fiber. On the other hand, legume vegetables constitute a low-fat foodstuff. Legume vegetables may contain some antinutritional factors, particularly lectins, phytic acid, saponins, oligosaccharides belonging to the raffinose-family, and vicin and convicin in faba bean, but the levels of most of them are lower than in dry pulses and generally do not constitute a constraint to their consumption. Breeding is one of the most efficient tools to reduce the concentrations of antinutritional factors and increase the levels of health promotic compounds and the taste in legume vegetables. Among the legume species frequently consumed as vegetables, a relatively large number of local accessions and landraces are available, which constitute a valuable genetic material for breeding programs aiming at improving their quality. Breeding of more resilient cultivars to combined stress conditions characterized by a higher nutritional value entails also a better understanding of the physiological mechanisms underlying the biosynthesis of health promoting and antinutritional compounds, as well as the plant adaptation to adverse environmental conditions. Last but not least, agronomical practices, such as crop establishment and plant density, fertilization, irrigation, weed control, and harvesting time and practices play a crucial role for the quality of legume vegetables and deserve special attention.

1. Introduction

Legumes are plants taxonomically classified under the family Fabaceae, formerly known as Leguminosae. The Fabaceae family comprises more than 650 genera and about 18,000 species, thereby constituting the third largest family of flowering plants (Polhill and Raven, 1981). From an economic point of view, Fabaceae represents the second most important family of cultivated plants after Poaceae (grass family), accounting for approximately 27% of the world's crop production (Graham and Vance, 2003). Legumes are characterized by their ability to grow in a symbiotic relationship with N_2-fixing bacteria, thereby contributing to a continuous input of atmospheric nitrogen to living organisms in the earth's biosphere. Many legume species, such as alfalfa (*Medicago sativa* L.), chickpea (*Cicer aretinum* L.), common bean (*Phaseolus vulgaris* L.), faba bean (*Vicia faba* L.), lentil (*Lens culinaris* Med.), peanut (*Arachis hypogaea* L.), peas (*Pisum sativum* L.), soybean (*Glycine max* L. Merr), etc., are important cultivated plants used either for food or for animal fodder or for both. Furthermore, many legume species are used as soil-enriching green manure due to their ability to fix atmospheric N_2 through rhizobia living symbiotically on their roots (Stagnari et al., 2017).

Most cultivated legumes used for food are consumed as grain seeds called pulses. However, the cultivation of some legume species is aimed at their consumption as vegetables. The most important legumes falling

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within this group are peas (*Pisum sativum* L.), faba bean referred to also as broad bean (*Vicia faba* L.), cowpea [*Vigna unguiculata* (L.) Walp. ssp. *unguiculata* cv.-gr. *unguiculata*], and yardlong bean [*Vigna unguiculata* (L.) Walp. ssp. *unguiculata* cv.-gr. *sesquipedalis*], which are grown in the open field, and common bean (*Phaseolus vulgaris* L.), which is grown both in open field and in greenhouses. Few more legume species may be locally grown for consumption as vegetables, such as soybean (*Glycine max* L. Merr, known as Edamame) (Konovsky et al., 1994; Mavlyanova, 2015), mungbean (*Vigna radiata* L. Wilczek) (Shanmugasundaram, 2007) and grass pea (*Lathyrus sativus* L.) (Kmiecik et al., 2004). Furthermore, legume sprouts, which are produced by forcing the seeds of some grain legumes to germinate and grow for a few days (Nnanna and Phillips, 1989; Lee et al., 2007), are also considered a vegetable food. Nevertheless, the quality of legume sprouts will not be addressed in the present review.

From a nutritional point of view, legumes are considered important sources of plant protein, carbohydrates, essential minerals, vitamins and several other antioxidants and health promoting compounds (Souci et al., 2000; Bouchenak and Lamri-Senhadji, 2013). Legumes consumed as vegetables contain more water and less proteins than those consumed as dry pulses. On the other hand, soluble carbohydrates are higher and starch content is lower in fresh vegetable legumes, which makes them more palatable than dry pulses. Moreover, vegetable legumes are richer sources of antioxidants and other health promoting compounds contained mainly or only in fresh plant biomass, such as carotenoids, phenolics, chlorophyll, vitamin A, and vitamin C (Bhattacharya and Malleshi, 2012). Consequently, their consumption is mainly intended to provide a more balanced nutrition full of healthy compounds rather than to serve as a primary protein source. Furthermore, vegetable legumes, which contain much more water than dry pulses, are short season crops which can be grown more than once a year being offered to the market as a fresh food with a limited shelf-life. Consequently, the quality characteristics of legume vegetables are different from those used to evaluate pulses. Another aspect to be considered when addressing the nutritional quality of legume vegetables is their content in antinutritional factors, i.e. compounds negatively affecting their taste and digestion by humans (Habiba, 2002; Wang et al., 2003).

In the last ten years, the European Commission supported several research projects on legume crops, in recognition of their importance and in an attempt to increase both their production and their consumption in EU. Among them, EUROLEGUME (www.eurolegume.eu), which is scheduled to be completed by the end of 2017, payed special attention to legume vegetables, focusing mainly on pea, faba bean and cowpea. Legume vegetables represent a very small proportion of the total arable land covered by Fabaceae crops (Stagnari et al., 2017). Thus, the number of publications which address the quality of legume vegetables is small in comparison to papers addressing the quality of grain legumes. To our knowledge, a review paper focused on the quality of legume vegetables is currently missing in the international scientific literature. On the other hand, the consumption of vegetables is constantly expanding internationally due to increasing awareness of their importance for a balanced nutrition and their high content in health promoting compounds (Kader et al., 2004; Hounsome et al., 2008). Thus, a contribution on this topic summarizing current knowledge on all factors that determine the quality of legume vegetables, including the genotype, the cultivation environment, and the agronomic treatments, is timely. Recognizing this gap in knowledge, the present review paper was commissioned to provide a comprehensive overview of all aspects related to the quality of legume vegetables. The paper is based on all available sources of relevant information, including recent results from EUROLEGUME and other EU research projects dealing with legumes.

2. Quality attributes of legume vegetables

2.1. Nutritional quality of legume vegetables

2.1.1. Contribution of legume vegetables to human health

Legume vegetables are rich in protein, carbohydrates, and dietary fiber. In addition, they constitute an important source of essential micronutrients for humans, including vitamins and minerals, which contribute to maintenance of proper metabolic functions in cells and tissues due to their role as cofactors of metabolic reactions, coenzymes, regulators of gene transcription, and radical scavenging molecules (Bouchenak and Lamri-Senhadji, 2013; Septembre-Malaterre et al., 2017). Therefore, the consumption of legume vegetables has been associated with health promotion, particularly related with prevention of cardiovascular and metabolic diseases. Furthermore, many of these benefits have been related to the nutritional and phytochemical composition of hulls (Gutiérrez-Uribe et al., 2011), which is strongly dependent on the maturation stage (Basterrechea and Hicks, 1991).

The physiological effects of legume vegetables on the human organism vary according to their composition, as well as the relative proportion of hulls and seeds in pods. Therefore, given the growing trend to consume minimally processed foods, more attention should be paid to fresh pods, to assess their potential to be used in balanced diets. In addition to the nutritional properties, the sustainability of the dietary sources of essential nutrients represents another issue that should be taken into consideration. Providing the required nutrients according to the physiological needs of a continuously increasing population represents a serious constraint, given the limited resources available. Therefore, the consumption of fresh legume vegetables, which combine protein, fiber, minerals and bio-active compounds in a balanced composition, arises as a sustainable practice that would provide a valuable contribution to overwhelm this situation (Slavin and Lloyd, 2012).

2.1.2. Protein content

One of the most frequently used parameters when assessing the nutritional quality of legume vegetables is their protein content. Overall, pods and immature seeds of legumes contain less proteins than dry seeds of the same species (Karapanos et al., 2017; USDA-ARS, 2017). For instance, crude protein in fully ripened and dried cowpea pulses from different varieties and landraces ranged from 17.4 to 30.3% d.w. (Domínguez-Perles et al., 2016) and from 29.5 to 35.6% d.w. in immature fresh pods (Machado et al., 2017). However, in terms of fresh weight, the soluble protein content in immature cowpea pods is much lower, ranging between 1.6 to 3.3% f.w., i.e. 2.25% on average (Karapanos et al., 2017). Compared with cowpea pods, those of snap bean (*Phaseolus vulgaris* L.) contain significantly less proteins. Indeed, Fujihara et al. (2001) and Sánchez-Mata et al. (2003) reported a protein content of 1.55% and 1.64%, respectively, in fresh pods of snap bean, which is by about 25% less than that reported by Karapanos et al. (2017) for cowpea pods. Fujihara et al. (2001) reported a protein content of 2.01% f.w. in green pods of pea (*Pisum sativum* L.), which is slightly lower than that of cowpea pods. Nevertheless, the protein contents in immature seeds of pea and faba bean are substantially higher than in the entire immature pod. For instance, the protein content amounts to 5.4% f.w. in green pea seeds and 7.9% f.w. in immature faba bean seeds (Young and Pellett, 1994; USDA-ARS, 2017). An overview of the protein content in green pods and seeds consumed as vegetables is provided in Table 1.

The nutritional value of legume vegetables as protein sources depends not only on their protein content but also on the amino acid composition and the protein digestibility. Generally, the legume proteins are rich in lysine but poor in sulphur-containing essential amino acids, particularly methionine and cysteine (Yamauchi and Minamikawa, 1998). For instance, cowpea is an excellent source of lysine, but deficient in methionine and cysteine, while the tryptophan and threonine contents are also lower than the optimal levels