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Original Research Article

Anti-nutrient components and metabolites with health implications in seeds of 10 common bean (*Phaseolus vulgaris* L. and *Phaseolus lunatus* L.) landraces cultivated in southern Italy

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ABSTRACT

Common beans (*Phaseolus vulgaris* L.) provide an inexpensive food rich in macronutrients such as protein and starch, important micronutrients such as iron, and also a number of other stored bioactive compounds (phytates, polyphenols, tannins, raffinosaccharides, lectins, protease and α-amylase inhibitors, saponins, etc.) endowed with positive health implications through their antioxidant, anti-tumour or phyto-oestrogenic activity. They also produce negative dietary effects such as interference with micronutrient absorption, protein digestibility or glucose metabolism, or even direct toxic effects (lectins). Analysis of the levels of these compounds in seeds of local and underexploited common bean varieties and landraces may reveal traits of interest for promoting nutrition and preserving health, and in addition allow breeders to use them in genetic improvement programmes to modify the levels of specific compounds in new common bean varieties. In the present work, 10 bean populations belonging to 7 highly appreciated southern Italian landraces were analysed. The seeds of one of them, "Poverello di Rotonda AF", was found to accumulate remarkable levels of 4 health-promoting components such as quercetin (24.2 μg/g), genistein (21.6 μg/g), soysapogenin B (433 μg/g) and oleanolic acid (11.9 μg/g), while "Tabacchino" contained very high amounts of iron (131 μg/g) and three health-promoting components: kaempferol (61.0 μg/g), oleanolic acid (12.3 μg/g) and condensed tannins (2.36 mg/g). A level of variation high enough to be exploited for breeding purposes was found for 7 out of 15 biochemical parameters studied.

1. Introduction

The common bean (*Phaseolus vulgaris* L.) is a legume with outstanding importance for human nutrition throughout the world, especially in eastern and southern Africa and Central and South America, where people's diets lack animal protein and are largely based on beans and legumes to supply vegetable protein (Deshpande, 1992). Common bean seed contains high levels of important nutrients such as proteins, minerals, complex carbohydrates and some vitamins. In addition, although the potential health benefits of consuming common bean have so far been largely overlooked (Messina, 1999), some of the compounds present in bean grains possess relevant health-promoting activities. For instance, raffinosaccharides have been shown to be able to stimulate the growth and activity of beneficial bacteria or probiotics (Ricroft et al., 2001); phytate is now considered to be endowed with anticancer activity (Vucenik and Shamsuddin, 2006; Singh and Agarwal, 2005) and to possess certain health-beneficial properties, notably antioxidative and anticalcification (prevention of kidney stone formation) activities (Grases et al., 2007). Polyphenols such as the flavonols kaempferol and quercetin as well as condensed and hydrolysable tannins have been shown to exert effective antioxidant (Frossard et al., 2000; Park et al., 2006), anticarcinogenic (Chung et al., 1998) and antimutagenic (Cardador-Martınez et al., 2002) actions. The isoflavones daidzein and genistein possess phyto-oestrogenic activity, useful for treating a number of post-menopausal problems; in addition, similarly to kaempferol and quercetin, they are also involved in several important mechanisms related to anti-inflammatory effects (Hämäläinen et al., 2007). Finally saponins have been associated with various health beneficial and protective effects attributed to their antifungal and antibacterial activity, cholesterol-lowering action and most of all, to their ability to inhibit cancer cell growth (Jeon and Sung, 2000; Berhow et al., 2000).

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However, unfortunately, some of the these compounds, i.e. raffinosaccharides, phytates and some polyphenols, can as well exert negative antinutritional effects, particularly when beans are utilized as a staple food or included in the diet at high proportion for long time (Bollini et al., 1999; Raboy, 2001; Welch and Graham, 2004). Indeed, raffinosaccharides are undigestable compounds reaching the large intestine where very active bacteria utilize them as a carbon source, developing gases and causing flatulence. Another very relevant antinutritional effect is exerted by phytic acid through its ability, when forming phytate, to firmly bind cations, among which iron and zinc have primary nutritional significance, making them poorly available for absorption by the intestinal epithelium (Glahn et al., 2002; Bohn et al., 2008). The same effect is also exerted by polyphenols, particularly by tannins (Frossard et al., 2000; Guzman-Maldonado et al., 2000).

In most cases the prevalence of the nutritional or antinutritional effects on consumers depend on the extent of their bean intake. Furthermore, it is well known that beans contain protein factors which can directly affect the health of consumers, notably trypsin inhibitors, α-amylase inhibitors and phytohemagglutinins (lectins), of which the antinutritional and toxic effects are eliminated upon denaturation by cooking unless this is carried out poorly or improperly. Once our knowledge of all these bioactive compounds in bean seeds advances, programmes of genetic improvement may be undertaken to increase the amount of health-supporting metabolites, decrease the level of antinutritional compounds and increase the content of iron and possibly of protein in bean cultivars to be consumed by people of developing countries with mineral deficiency problems. Large genetic variation in the concentration of trypsin inhibitor (TI), tannins, phytate and lectins among common bean cultivars grown in Mexico and U.S.A. has previously been described (Barampana and Simard, 1993; Guzman-Maldonado et al., 1996; Muzquiz et al., 1999).

In this study, we determined the amounts of the compounds cited above in flours obtained from seeds of 10 bean populations (nine *P. vulgaris* and one *Phaseolus lunatus* L.), belonging to 7 different landraces grown at various locations in southern Italy (Sicilia, Basilicata, Campania). Although these landraces are very old and rather susceptible to all major bean diseases widespread in Italy (common bacterial and halo blight, bean common mosaic virus, anthracnose, etc.), they are still cultivated to produce beans of high culinary quality. Due to the particular geographical position and orography in southern Italy, these territories present many different environments. In each one of them, different bean materials (most probably originated from South America) had been selected by local farmers during the past three centuries. This long selection activity has produced, in each environment, a small number of selected local cultivars, the characteristics of which are unique. Moreover, as the environments are rather different from each other, it is difficult to cultivate these local cultivars (landraces) outside of their location because their characteristics, especially productivity and culinary quality, become modified, in general with a decrease in quality. Thus, when examining many different landraces in just one geographical area, with each one coming from a slightly different environment, there is the risk that only one or two of them will exhibit the normal behaviour and characteristics of product, while the others will show a distorted response. For this reason we preferred to examine their response in their own environment (taken to be the ideal environment, because it is the one in which the landrace evolved its traits), which is the result of the interaction "environment × genetic background", especially as this demonstrates single ecosystem advantages.

In summary, the main aims of this study are: (a) to characterize 10 landraces for the content of the bioactive substances; and (b) to identify the possible occurrence of extremely high/low content (or absence) of some of these compounds in order to make use of the new findings for breeding purposes. Once these data have been established, these 10 landraces could be used for clinical or laboratory studies.

2. Materials and methods

2.1. Chemicals

All chemicals, where not specified, were purchased from Sigma Chemical Company (St. Louis, MO, USA).

2.2. Plant material

The origins and main agronomic and visible traits of all plant materials examined are summarized in Table 1. Three different populations of "Poverello di Rotonda" (PH18, PH19 and PH20), two of "Badda bianco" (PH05 and PH08), and one for each of the other landraces, "Bianco di Rotonda", "Monaco Mussu Niuru", "Badda nero", "Tabacchino", "Fagiolo a Formella" were examined. "Poverello di Rotonda" [Fig. S-1 and S-1b] and "Bianco di Rotonda" [Fig. S-2] are cultivated in the area of the town of Rotonda (Potenza province, Basilicata region), "Badda bianco" [Fig. S-3 and S-3b] and "Badda nero" [Fig. S-4 and S-4b] are cultivated in the area of the town of Polizzi Generosa (Palermo province, Sicilia region), "Monaco Mussu Niuru" [Fig. S-5] in the area of the towns of Sinagra and Raccuia (Messina province, Sicilia region), "Tabacchino" [Fig. S-6] in the area of the town of Sarconi (Potenza

Table 1
Traits of the examined bean landraces.

Sample	Landrace[a]	Traits				
		Plant growth habit[b]	Plant growth duration[c]	Average seed weight (mg)	Seed coat colour	Origin
PH05	Badda bianco FRM	Climber type IV	120	560	White + orange-brown eye	Sicilia
PH08	Badda bianco SG	Climber type IV	120	520	White + orange-brown eye	Sicilia
PH13	Badda nero SG	Climber type IV	120	590	White + black-purple eye	Sicilia
PH14	Monaco Mussu Niuru	Climber type IV	130	600	White + dark mottled eye	Sicilia
PH18	Poverello di Rotonda S	Climber type IV	125	505	Ivory	Basilicata
PH19	Poverello di Rotonda AF	Climber type IV	125	550	Ivory	Basilicata
PH20	Poverello di Rotonda BT	Climber type IV	125	520	Ivory	Basilicata
PH22	Tabacchino	Determinate bush type Ia	100	520	Brown-yellow	Basilicata
PH29	Fagiolo a Formella	Determinate bush type Ia	–	430	Ivory	Campania
PH32	Bianco di Rotonda TL	Determinate bush type Ia	125	650	Ivory	Basilicata

The standard deviations of the means of plant growth duration and seed weight did not exceed 15%.
[a] "Fagiolo a Formella" is a *P. lunatus* whereas all other are *P. vulgaris*.
[b] Plant habit according to Singh (1982).
[c] No. of days from sowing date to harvest.