Soybean quality: Adaptation to European needs

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Abstract: On the world-wide scale, soybean (*Glycine max* (L.) Merr.) is considered as an oilseed crop. In contrast, the primary interest of European soybean production is in its high protein content for providing a versatile raw material for livestock feed, food industry and traditional soy-food production. Thus, while oil compositional traits play a major role in North American soybean research, other seed traits appear to be relevant in Europe. Soybean genetic variation in seed compositional traits can therefore be utilized in plant breeding programs for fine-tuning seed characteristics to the specific needs of the industries and utilization patterns involved.

Key words: food-grade soybean, genetic diversity, seed protein content, soybean breeding

A glimpse of history of soy quality

Since the mid 19th century, soybean (*Glycine max* (L.) Merr.) had been termed the "Chinese oil pea" (*pois oleagineux*) particularly in France which takes into account its significant oil content unusual to most other legume crops. In the aftermath of the 1873 World Exhibition in Vienna, Austria, Friedrich Haberlandt did not only recognize the agronomic potential of soybean in a series of experiments across Central Europe, but he also reported on the high seed protein content of up to 40% and proposed a number of processing options based on the remarkable composition of the soybean seed. In 1880, however, Edmund von Blaskovics of Mosonmagyaróvár, Hungary, described a disappointing weight gain when feeding cattle with raw soybeans. Despite the high nutritional value of soybean, the limited feeding performance was due to antinutritional factors which were only overcome more than three decades later when Osborne and Mendel found out that steam cooking of soybeans greatly improved the digestibility of soy meals.

Soybean quality for feed and food

On average, the soybean seed contains about 40% protein and 20% oil. In contrast to other legumes, soybean is practically free of starch whereas is contains significant levels of soluble carbohydrates such as sucrose and glucose as well as the oligosaccharides raffinose and stachyose (3). In North America, soybean oil quality is of major interest: While linoleic and oleic acids are the predominant fatty acids in soybean oil, genotypes have been developed with reduced linolenic acid (C18:3) to avoid trans-fatty acid formation during oil processing (1). Other strains have been selected from mutant populations with either reduced or enhanced concentration of saturated fatty acids in order to better adapt soybean oil to particular health and processing needs.

In Europe, soybean is mainly grown for its high seed protein content, while vegetable oils are produced from oilseed rape, sunflower, olive and a number of regional specialty oil crops. Both genetic and environmental variation is high in soybean seed protein content when growing early maturity soybeans (maturity groups 000 to I) in Central Europe: Protein contents from below 30% to 48% have been reported (8). Low protein content might be due to unfavorable environmental conditions and reduced rates of biological di-nitrogen fixation. It has been estimated that only 40 to 52% of total nitrogen uptake of soybean is from symbiotic di-nitrogen fixation, while the remainder is from soil nitrate uptake (6). The comparatively low di-nitrogen fixation rate which has implications on seed quality and on the crop rotation value of soybean as compared to other legumes is well in agreement with a meta-analysis on soybean nitrogen fixation which revealed a negative nitrogen balance in 80% of cases across a high number of individual studies (4).

Over 90% of soybean is utilized in animal feeding rather than in human food production at present. For developing a soybean for on-farm utilization for livestock feeding, reductions in oil content and trypsin inhibitor activity are necessary. Germplasm carrying a null-allele at the Kunitz trypsin inhibitor locus has been utilized to develop a Kunitz trypsin inhibitor free soybean with a clearly reduced total trypsin inhibitor activity (9). However, genetic variation in a second inhibitor protein, the Bowman-Birk protease inhibitor has not been found so far which is limiting the progress towards developing a soybean for livestock feeding without the need for feed pre-processing. In addition, an oil content of 17-20% appears too high for full-fat soybean feeding in most applications, and low-oil soybean germplasm would be desirable for that purpose.

In countries such as Austria, a considerable amount of soybean harvested is utilized for soyfood production, as the consumption of soyfoods from GMO-free soybean has increased for a number of reasons. In soyfood production (e.g. soy milk, tofu, soy yoghurts, spreads, desserts, snack products, protein concentrates, meat substitutes etc.), food-grade soybeans are preferred as a starting material which have a yellow seed coat with a light hilum, larger seed size, higher seed protein and sugar content than standard soybean. An elevated seed protein

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content of at least 42-45% improves the nutritional value of food products, whereas a higher ratio of glycinin (11S) to beta-conglycinin (7S) globulin protein fractions as present in food-grade germplasm is important for characters such as tofu yield or structural properties of products (7). In addition, sucrose is influencing the taste of products and is therefore an important trait for improving consumer acceptance of soyfoods. Food-grade soybean populations reach sucrose contents from 6-8%, whereas conventional or high-protein populations are clearly lower in sucrose content (5).

Genetic variation in food safety characteristics may gain in relevance in the future as soyfood production is increasing. For instance, a reduction of the immunodominant soybean allergen protein P34 (Gly m Bd 30K) through introgression of a null allele is of particular interest, as soybean protein is increasingly utilized in many modern food applications raising the frequency of allergic reactions in sensitive consumers. As soybean production is expanding to new regions of Europe, uptake of heavy metals from contaminated soil is another concern in soyfoods. For cadmium, variation in a single gene coding for an ATPase mediating metal ion transport across cellular membranes in the root has a highly significant effect on seed cadmium concentration (10). A selection procedure based on a microsatellite marker closely associated with the cadmium uptake locus (Fig. 1) can easily be implemented for the identification of low cadmium accumulating genotypes contributing to food and feed safety.

Genetic diversity

Significant genetic diversity has been described in Central European soybean breeding materials (2) which is essential for further breeding progress. Variation is also available in various seed quality characters in soybean collections which needs to be introgressed into early maturity germplasm (see Fig. 2 for visual inspection of seed diversity). Thus, targeting of soybean quality to European requirements (i.e. protein production) could contribute to establishing domestic soybean production and to increase the range of options for profitable protein crop production in Central Europe.

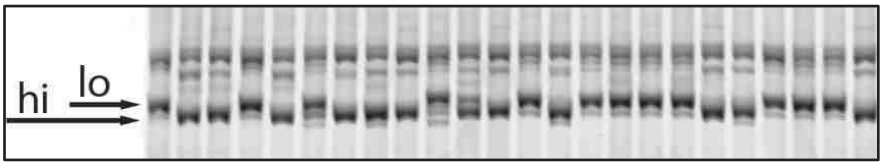

Figure 1. Differentiation between 24 soybean genotypes at the SacK149 SSR marker locus with alleles linked to either high (hi) or low (lo) seed cadmium accumulation (soybean *Cda1* gene)

Figure 2. Visual genetic diversity for soybean seed characteristics in conventional and specialty germplasm

Acknowledgements

J. Khudaykulov has been supported by the CASIA project of the Erasmus Mundus program.

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Issue 8 • July 2015