ELSEVIER

Trends in Food Science & Technology xx (2015) 1–11

TRENDS IN FOOD SCIENCE & TECHNOLOGY

Dry fractionation for sustainable production of functional legume protein concentrates

M.A.I. Schutyser*, P.J.M. Pelgrom, A.J. van der Goot and R.M. Boom

Wageningen University, Food Process Engineering Group, Bornse Weilanden 9, 6708 WG, Wageningen, The Netherlands (P.O. Box 17, 6700 AA Wageningen, The Netherlands. Tel.: +31 317 488629; fax: +31 317 482237; e-mail: maarten.schutyser@wur.nl)

Plant proteins gain increasing interest as part of a sustainable diet. Because plant materials not only contain protein, they are generally isolated via an energy intensive wet fractionation. This review discusses dry fractionation as an alternative and more sustainable route for producing functional legume protein-enriched fractions. Increasing protein purity of dry-enriched fractions is discussed by identification of relationships between legume morphology and ability for separation in the dry state. Finally, functionality and nutritional properties of legume protein fractions and their application in high protein beverage and meat like structures are reviewed.

Introduction

The global protein demand is expected to double in the coming decades due to the increasing prosperity and world population. To keep up with the demand, the transition from an animal to a plant-based protein supply is desirable from long-term economic and environmental perspectives (Jayasena, Chih, & Nasar-Abbas, 2010; Lqari, Vioque, Pedroche, & Millan, 2002; Schutyser & van der Goot, 2011), as the production of animal protein imposes a severe burden on the available arable land, water and fossil fuels. Unfortunately, replacing animal based ingredients and components is not trivial. Animal-derived products have widespread preference because of their excellent taste, which is partly due to the microstructure of meat, but also due to its different composition. Plant materials can contain significant amount of carbohydrates and other components, which strongly influence the taste and nutritional profile. This explains the increased interest in fractionation methods.

The conventional route to obtain plant protein ingredients is wet extraction (Fig. 1). Legumes are an interesting source of plant proteins as they have high initial protein content (>20 g protein/100 g dry matter (Table 1)), dietary fibre content, contain a variety of micronutrients and phytochemicals and have a low level of fat (Messina, 1999) and at the same time they are able to fixate nitrogen. Legumes can be divided into those that use starch for energy storage, and those that store oil for this. Starch-rich legumes, such as peas and many beans are fractionated through dispersing the legumes into water to dissolve the protein and suspend the starch granules. Subsequently, the slurry is treated in a hydrocyclone to separate the proteins from the starch granules. Oil-rich legumes, such as soy and lupine, are subjected to solvent extraction to isolate the oil first. The defatted legume flour is mostly used as feed, but can also be further processed to obtain a protein isolate. Then, the defatted flour is suspended in water and a suspension of protein and fibre is obtained. For both types of legume (starch rich and oil rich) the solubilised proteins are separated from insoluble fibres at pH 9. Soluble fibres are separated by precipitating the proteins at their iso-electric point (pH 4.5–4.8). Subsequently, the pH is readjusted to 7 and a dry protein isolate is obtained after a final drying step (75–90 g protein/100 g dry matter) (Berghout, Pelgrom, Schutyser, Boom, & van der Goot, 2015; Boye, Zare, & Pletch, 2010). This wet process involves the use of large amounts water and chemicals (e.g. for acidification and neutralisation). Typically, the production of lupine protein isolate from the lupine seed requires, more than 80 kg water/kg protein isolate, 22.4 kg hexane/kg protein isolate, 40 g NaOH and 40 g HCl per kg protein isolate (Berghout *et al.*, 2015).

* Corresponding author.

http://dx.doi.org/10.1016/j.tifs.2015.04.013

Please cite this article in press as: Schutyser, M. A. I., et al., Dry fractionation for sustainable production of functional legume protein concentrates, Trends in Food Science & Technology (2015), http://dx.doi.org/10.1016/j.tifs.2015.04.013

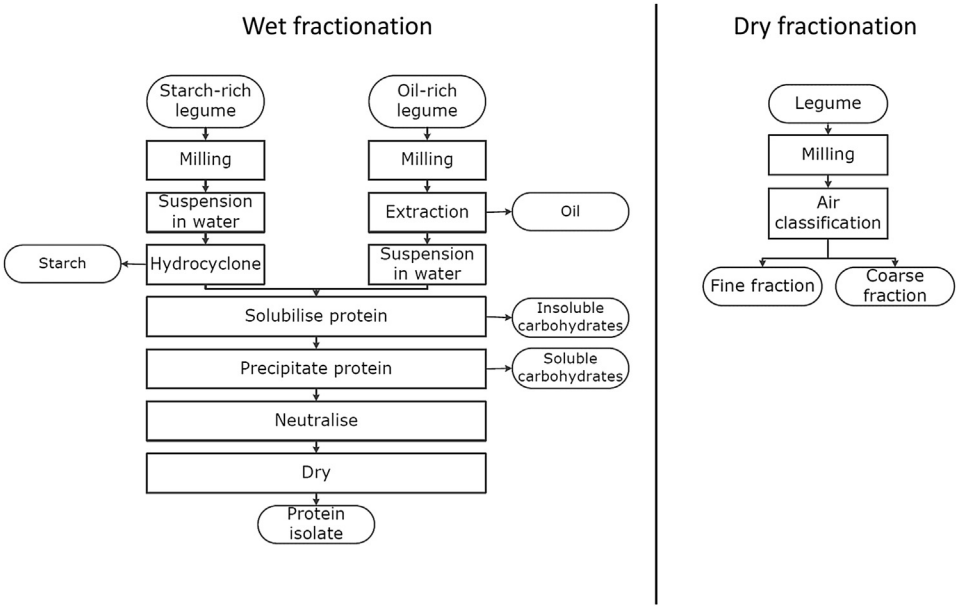

Fig. 1. Schematic illustration of wet (left) and dry (right) fractionation process.

A more sustainable alternative to obtain protein-enriched fractions from legumes is dry fractionation (Fig. 1), which employs milling and air classification. Air classification of legumes has been investigated in the 1970s but since then received less attention (Vose, 1978). Major reasons for the renewed interest into dry fractionation are the wish to establish plant protein extraction routes that are less energy and resource-intensive and that can deliver functional protein fractions for preparing attractive and healthy foods. The improved sustainability originates from the fact that dry fractionation does not require the addition of water and thus no energy intensive dehydration (Berghout *et al.*, 2015). Another advantage is that the absence of a drying step together with the absence of the exposure to chemicals retains the native functionality of components. Moreover, air classification is accredited for organic food production and the declaration of its products does not require E-numbers. The major drawback of dry fractionation is the relatively modest enrichment in protein content that can be obtained relative to wet extraction, but it can be expected high purity might not be necessary for most food applications (Schutyser & van der Goot, 2011). Related to the modest enrichment and the absence of heating is the presence of higher amounts of components such as oil, fibres and anti-nutritional components in dry-enriched protein fractions. This has implications in terms of functional and nutritional properties. For example, on the one hand higher amounts of oil are less desired in relation to foaming behaviour, but on the other hand presence of more water binding fibres improves gelling behaviour of the protein fractions. Overall, it can be concluded that dry fractionation is promising for the novel design of processes were the full legume is used in a more integrated and efficient way, while attention should be paid to the increased variability in composition of the fractions (Abecassis, de Vries, & Rouau, 2014).

This paper reviews the dry fractionation process and the properties of products made through this process. In addition, an evaluation is given of recent developments

Table 1. Protein enrichment by air classification of wheat and several legumes ± absolute deviation.

Legume/ grain	Initial protein content (g/ 100 g dry matter)	Protein content fine fraction (g/100 g dry matter)
Wheat	12.3 ± 1.8	28.3 ± 4.0
Lima bean	23.7 ± 0.4	48.9 ± 0.8
Cowpea	27.2 ± 0.0	50.9 ± 0.2
Common bean	26.3 ± 1.6	54.7 ± 2.2
Navy bean	27.2 ± 1.6	56.7 ± 6.8
Lentil	23.7 ± 2.1	57.6 ± 4.1
Pea	23.8 ± 1.2	58.5 ± 3.0
Mung bean	27.2 ± 0.4	62.3 ± 1.2
Faba bean	31.0 ± 0.8	69.9 ± 5.2
Lupine	40.4 ± 0.6	59.4 ± 0.6

(Aguilera, Lusas, Uebersax, & Zabik, 1982; Bergthaller, Dijkink, Langelaan, & Vereijken, 2001; Cloutt *et al.*, 1987; Elkowicz & Sosulski, 1982; Jones & Halton, 1959; Kent, 1965; Patel, Bedford, & Youngs, 1980; Pelgrom, Berghout, van der Goot, Boom, & Schutyser, 2014; Pelgrom, Boom, & Schutyser, 2015a; Poel van der, Aarts, & Stolp, 1989; Sosulski & Youngs, 1979; Stringfellow, Wall, Donaldson, & Anderson, 1976; Tyler *et al.*, 1981; Vose, Basterrechea, Gorin, Finlayson, & Youngs, 1976; Wright *et al.*, 1984; Wu & Nichols, 2005; Wu, Stringfellow, 1992).

Please cite this article in press as: Schutyser, M. A. I., et al., Dry fractionation for sustainable production of functional legume protein concentrates, Trends in Food Science & Technology (2015), http://dx.doi.org/10.1016/j.tifs.2015.04.013