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Review

Fractionation of wheat and wheat flour into starch and gluten: overview of the main processes and the factors involved

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Abstract

The starch and gluten components of wheat flour or whole wheat kernels can be separated by a number of industrial processes. This review provides a summary of these processes from both starting materials. The wheat constituents of importance in the fractionation processes are briefly introduced, and the different fractionation processes described with emphasis on the parameters affecting the separation, such as flour composition, mixing and washing water, processing aids (with an emphasis on enzymes) and kernel pre-treatment (pearling) in the case of flour fractionation and steeping conditions and processing aids in the case of whole wheat. Although fractionation of flour is the basis for the current industrial processes, starch yields are impaired by starch damage as a result of milling and loss of starch to milling streams. On the other hand fractionation of whole kernels often leads to impaired gluten production as a result of harsh process conditions which 'devitalise' the gluten.

Keywords: Wheat starch/gluten separation; Review; Processing aids; Processing conditions; Wheat constituents

1. Introduction

The global wheat production in 2001 approached 600 million tons (FAO, 2003). A minor, but industrially very important and growing use of wheat is as a source of gluten and starch. This is related to the widespread industrial and food applications of wheat gluten and starch and its derivatives. World wheat starch production was ca. 4.1 million tons in 2000 (LMC International Ltd, 2002), originating from ca. 8 million tons of wheat.

In the context of this review, gluten is the fraction isolated from wheat, which is enriched in gluten proteins (i.e. gliadins and glutenins). Laboratory and industrially prepared wheat gluten contains both protein and non-protein material including lipids (ca. 3.5–6.8%), minerals (ca. 0.5–0.9%), and carbohydrate (ca. 7.0–16.0%, on an as-is basis), the latter being mainly starch and lesser amounts of non-starch polysaccharides (NSP) (Roels, 1997). If the isolated gluten is still able to form a network with viscoelastic properties, it is defined as 'vital gluten', implying that it still has functionality, e.g. in breadmaking.

In spite of the increasing importance of wet wheat processing, the literature on the subject is relatively scarce. This survey brings together and reviews the processes for starch-gluten separation from the two major starting materials (wheat flour or whole wheat kernels) and provides details on the effects of different factors on the recovery and drying of starch and gluten. First some basic information on the major components involved, i.e. proteins, starch, NSP and lipids is provided.

Abbreviations: AGP, arabinogalactan-peptides; AX, arabinoxylan(s); MW, molecular weight(s); NSP, non-starch polysaccharides; S-AX, solubilised arabinoxylan(s); WE-AX, water extractable arabinoxylan(s); WEF, water extractable fraction; WU-AX, water unextractable arabinoxylan(s); XAA, xylanase from *Aspergillus aculeatus*; XBS, xylanase from *Bacillus subtilis*.

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2. Components involved in the fractionation process

2.1. Proteins

Wheat grain contains about 12% proteins (Belitz and Grosch, 1999) which are found in the endosperm. The proteins can be divided in two main groups: the gluten

and non-gluten proteins. Non-gluten proteins (ca. 15–20% of total wheat protein) consist of albumins (soluble in water) and globulins (insoluble in water, soluble in dilute salt solutions) (Osborne, 1924). These are mainly monomeric proteins with molecular weights (MW) mostly lower than 25,000, although a significant proportion have MW between 60,000 and 70,000 (Veraverbeke and Delcour, 2002). Gluten proteins (ca. 80–85% of total wheat protein), the main storage proteins of wheat, are insoluble in water. Upon hydration and mixing, they form a strong, cohesive, viscoelastic network that allows the wheat flour dough to retain yeast fermentation gases and to produce a light, aerated baked product. Gluten proteins can be divided into gliadins and glutenins. Gliadins have MW between 30,000 and 80,000 (Veraverbeke and Delcour, 2002), are single-chained, and are extremely sticky when hydrated. They are rich in proline and glutamine and have a low level of charged amino acids. Intra-chain cystine disulphide bridges are present. Based on electrophoretic mobility at low pH, there are four types of gliadins, i.e. α-, β-, γ-, and ω-gliadins (Shewry, 2003). In dough formation, the gliadins act as 'plasticisers', promoting viscous flow and extensibility which are important rheological characteristics of dough. They may associate with one another or the glutenins through hydrophobic interactions and hydrogen bonds. Glutenins are multi-chained and vary in MW from about 80,000 to several million (Hoseney, 1994; Veraverbeke and Delcour, 2002). They apparently impart to dough its property of resistance to extension. The amino acid compositions of glutenins are very similar to those of gliadins, with high levels of glutamine and proline and low levels of charged amino acids. The glutenins are composed of subunits, linked through disulphide bridges. In addition to these inter-chain cystine bonds, glutenins, like gliadins, also contain intra-chain disulphide bridges. The glutenin subunits are released from glutenin by disulphide reducing agents such as β-mercaptoethanol or dithiothreitol. High MW glutenin subunits (MW between 65,000 and 90,000) and low MW glutenin subunits (MW between 30,000 and 60,000) can be distinguished (Goesaert et al., 2004; Veraverbeke and Delcour, 2002).

During grain development, wheat storage proteins are deposited as protein bodies which as the grain matures, lose their distinct structure and form a continuous matrix within the endosperm cells, in which starch granules are imbedded.

2.2. Starch

Starch is the most abundant component (ca. 63–72%) of wheat (Lineback and Rasper, 1988) and is present in the endosperm. It consists of the glucose polymers, amylose and amylopectin. Amylose is essentially linear, consisting of (1→4)-α-linked D-glucopyranosyl units with MW in the range $10^5 - 10^6$ (Lineback and Rasper, 1988). In contrast, amylopectin is highly branched and consists of chains (1→4)-α-linked D-glucopyranosyl units joined through (1→6)-α-linkages. Branch points occur at approximately every 20–25 glucopyranose residues. Amylopectin has one of the highest MW ($>10^8$) among naturally occurring polymers. Typical levels of amylose and amylopectin are 25–28% and 72–75%, respectively (Colonna and Buléon, 1992).

Wheat starch granules are of two sizes; large, lenticular A-type granules ca. 15–40 μm (mean diameter of ca. 20 μm), and small, spherical B-type granules ca. 1–10 μm (mean diameter 5 μm) (Karlsson et al., 1983; Lineback and Rasper, 1988; Moon and Giddings, 1993). When viewed in polarised light, native starch granules are birefringent and exhibit a Maltese cross pattern, indicating an orderly arrangement of the starch molecules. The characteristic X-ray pattern and NMR spectra of starch granules is due to the orderly packing of adjacent branches of the amylopectin components.

2.2.1. Damaged starch

During milling a small, but significant proportion (5–8%) of starch granules in flour are physically damaged. Granule fragments produced during milling are not birefringent (Hoseney, 1994). The level of starch damage varies with the severity of grinding and the hardness of the wheat. The rate of water absorption during dough making and enzymic degradation of starch increases with increasing damage.

2.3. Non-starch polysaccharides (NSP)

Wheat contains polysaccharides other than starch. NSP are present in the walls of cells of the endosperm and bran tissues which are composed of arabinoxylans (AX) (1→3,1→4)-β-glucans, cellulose and arabinogalactan-peptides (AGP). AX are the most abundant (1.5–2.5% in flour) and are water extractable (WE-AX, typically 0.5% in flour) or water unextractable (WU-AX, typically 1.5% in flour). AX are made up of (1→4)-β-linked D-xylopyranosyl residues, substituted at the C(O)3 and/or the C(O)2 position with α-L-arabinofuranosyl units (Izydorczyk and Biliaderis, 1995; Perlin, 1951a,b). The C(O)5 of some arabinofuranosyl units may be esterified with ferulic acid (Fausch et al., 1963; Izydorczyk and Biliaderis, 1995).

Wheat arabinogalactan-peptides (AGP) consist of large polysaccharide moieties (92–94%) covalently linked to a 15 amino acid peptide (6–8%) (Van den Bulck et al., 2002). The polysaccharide is built up of highly branched backbone of D-galactopyranosyl residues which are (1→3)-β- or (1→6)-β-linked. This galactan backbone is substituted with single arabinofuranosyl residues (Fincher et al., 1974).

2.3.1. Viscosity and water binding capacity

WE-AX and solubilised AX (S-AX) (obtained by xylanase hydrolysis of WU-AX or by alkali treatment of WU-AX) yield highly viscous solutions. Their viscosity depends mainly on AX chain length (Dervilly-Pinel et al., 2001; Picout and Ross-Murphy, 2002). WU-AX have