Chapter

Perspective Chapter: Biaxial Extensional Viscosity in Wheat Doughs – Effect of the Use of Xylanases

Alán Pavlovich-Abril

Abstract

Extensional flow properties have long been recognized as important for understanding the dough performance, and the experimental measurement of these properties has been the topic of many studies. Agroindustry by-products have potential application as a source of fiber to wheat dough, bran composition, and their benefits to human physiology have been investigated, their technological role as an ingredient is still under study for a variety of cereal foodstuffs. This chapter provides an overview of functional properties and technological features concerning the breadmaking process. Knowledge of the structural characteristics of WE-AXs cereal bran is useful to explain the effects of cereal bran on dough properties. Also, lower arabinose/xylose substitution of WEAXs was in accordance with high intrinsic viscosity, and develop higher extensional viscosity. Therefore, is important to identify the nature of the interactions between various chemical compounds of fine bran throughout the process of changing the flow behavior. Biaxial extensional viscosity is a rheological parameter that determinates loaf volume and crumb firmness and is closely related to the fiber, protein, and starch content in the flour's bran blends. Thus, it reviews this subject to elucidate the potentialities of these methods providing the reader with a better understanding of the use of this technique.

Keywords: dough rheology, biaxial extension, wheat bran, viscoelastic behavior, bran dough

1. Introduction

The most important test for product formulation of baked goods is to attain an acceptable structure and texture [1]. Furthermore, enzymes that aim for the principal polymers in the flour, such as amylose, amylopectin, gluten, and arabinoxylans, can be used to influence dough and bread properties [2]. The arabinoxylans are characterized as water extractable (WE-AXs) or water unextractable (WU-AXs). The difference in their extractability accounts for various physicochemical properties. The AXs are an important component of dough because they bind water and contribute to viscosity. The WE-AXs play a more important structural role in dough and bread than the water un-extractable AXs [3]. At this point, it is worth mentioning that arabinoxylans are the main component of wheat bran, which is also used to increase the dietary fiber content in baked products. High content of arabinoxylans disturbs the protein network formation during dough development and could affect the dough properties.

Dough undergoes different stresses through the sequential stages of breadmaking in which it is subjected to different kinds of deformations, fluctuating between deformation from shear to elongation [4]. The governing deformation of dough matrix between expanding gas cells is a biaxial stretching flow [5] and is related to extensional viscosity information as attained from the biaxial extensional rheological test. Conceptual considerations by van Vliet et al. [6], on strain hardening of dough as a requirement for gas retention, have emphasized the interest in this type of deformation for breadmaking. Biaxial extensional viscosity has been reported as an important property for predicting loaf volume [7] and can be considered an indicator of the bread quality when flour-fine bran blends are used [8]. The rheological properties of dough and bread are importantly influenced by starch, protein, and cell-wall matrices. The network formation of the gelatinized starch molecules plays a vital role in crumb bread formation. Non-starch components in flour can also affect starch gelatinization properties [9], but these properties have been considered in only a minority of studies of flour-bran blends and bread quality [10].

Wheat bran enriched flour has an extended shelf life than whole wheat flour, yet wheat bran has a negative effect on gluten network structure and alters the secondary structure of glutenin changing the gluten network. This is due to changes in the physical structure and chemical bonds of dietary fibers and gluten. Deeper knowledge of the effects of these components on gluten protein should guide the development and production of improved flour products. In general, using wheat bran fractions can expand the application range and improve the market appeal of wheat bran-rich flour products [11].

2. Concepts of basic rheology

In essential rheology study the relation between forces applied to a material and the resulting deformation as a function of time. The forces are characterized by both size and direction; they are vectors. When stress is applied to a mechanically nonhomogeneous material, as many foods are, the ensuing relative deformation may vary over the product [12]. Therefore, the change in distance between two points in the material relative to the original distance should be taken as a quantitative measure of the local relative deformation. This ratio is called *strain*. Thus, a strain is a vector divided by a vector, resulting in a second-order tensor, and nine components are needed to describe it completely [12].

These tensorial characteristics of both stress and strain make it essential to perform rheological experiments in such a way that most of the stress and strain components can be neglected for the calculation of a specific characteristic parameter of the rheological behavior [13]. Although the rheology of wheat dough denotes mechanical behavior, this comportment is a function of the chemical composition and the spatial distribution of the components. Therefore, knowledge of a series of disciplines is required in order to fully understand the mechanical behavior of wheat dough. **Figure 1** depicted some of the scientific disciplines that are involved in dough rheology, including a short description of the issues that they attempt to resolve.

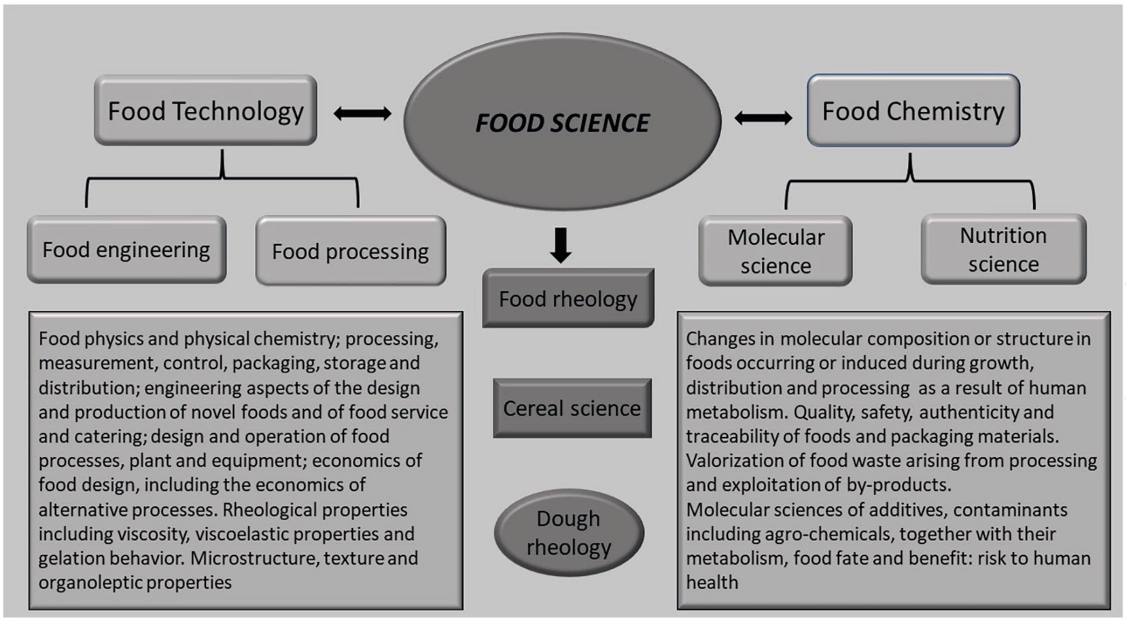

Figure 1.
Picture of the disciplines related to wheat dough rheology.

2.1 Rheological classification of foods

As an initial point of the classification of foods according to the rheological properties, we need to start mentioning the two ideal descriptions of the material, the viscous material and elastic material. Nonetheless, these two descriptions only serve as a point of reference, since many of the foods cannot be fully described as either viscous or elastic, but both, and a lot of confusion exists over the term elastic and viscous [13]. In many cases, materials are denoted elastic because of their high deformability/extensibility. Moreover, many food's reactions to stress or strain consist partly of a viscous contribution and partly of an elastic one; they behave *viscoelastically* [13]. And a liquid is considered more viscous upon the addition of a thickening agent, although after addition of a thickener the viscosity will have increased and officially often the material has become relatively more elastic. To make things more complicated, a material can be considered elastic or viscous depending on the time of observation. Also, the length of the time the material is stressed or strained may play a part, resulting in nonequilibrium behavior over short deformations time [14].

In the dough processing stages, such as mixing, sheeting, proofing, and baking, dough experiences different mechanical deformations including extension or compression. Extensional deformations mainly occur during the proofing and baking process; hence, the extensional properties of dough have been seen as an important factor to evaluate the dough baking performance [15]. Wheat dough is a non-Newtonian fluid, and its rheological behavior is heavily dependent on the type and strength of stress applied. Additional, thermal processing during baking change the flow behavior of the system [16].

2.2 The viscoelastic flow

A viscoelastic material presents a dual nature they have the properties of an elastic (solid-like) and viscous (liquid-like) fluid simultaneously. A partial recovery is obtained once the stress is removed. This flow behavior is also time-dependent and is not instantaneous [17]. Wheat flour doughs concurrently display features of a viscous liquid and of an elastic solid and hence are classed as viscoelastic materials. Fundamental characterization of dough viscoelasticity depends on techniques that apply small strains, such as dynamic (oscillatory) measurements (in shear or compression), to gain information on the structure of the material [18].

Nevertheless, while mechanical tests involving small deformations are very valuable for obtaining information on the structure of gluten and flour doughs, they barely show a clear relationship between the measured parameters and the functionality of wheat flour doughs throughout processing [19]. Through processing, data on dough behavior needs the use of rheological large deformations test. Stress relaxation and creep-recovery are suitable tools as their results may help to find links with empirical tests. Also, these tests do not require to be performed within the linearity range of the material, that is, at very low strain values [20]. Generally, dough presents many experimental and conceptual challenges to the rheologist [21]. Problems such as extended relaxation times and sample exposure to air make a consistent sample with good reproducibility and it is awfully problematic. The viscoelastic properties are also depended on the composition. Methods such as the water-correspondence principle and rectifications for rheological age are really convenient in making sense of the information collected from a series of different conditions [22].

As a polymeric material, the rheological properties of dough are the mechanical responses to externally applied deformation, which largely reflects the structural orientation and behavior of protein polymeric network [13]. The dough strength or dough extensibility is governed by the number of entanglements within glutenin molecules and the rate of gluten protein chain slippage [23]. Wheat flour dough also exhibits strain hardening under the extensional deformation, due to the formation of multi-branch structures in gluten network decreases the mobility of material components, leading to an increase in the stress during deformation, being extensional stress, the predominant deformation type occurring during fermentation and baking [24].

2.3 Bi-extensional flow

The leading deformation of dough matrix between expanding gas cells is a biaxial stretching flow [25] and is linked to extensional viscosity data as attained from the biaxial extensional rheological test. Theoretic considerations by van Vliet et al., on strain hardening of dough as a condition for gas retention, have highlighted the interest in this kind of deformation for breadmaking [6]. Among the various methods used for the determination of extensional properties of dough and polymeric materials, lubricated squeezing flow has certainly received the most attention. The original method involves uniaxial compression of a test piece between two circular plates at constant force (e.g. constant stress) [26]. In a later publication, data on bi-extensional viscosity of wheat flour doughs were related to loaf volume and crumb structure [27].

Currently, common extensional tests can be separated into two categories: uniaxial and biaxial extension tests. Devices of the uniaxial extension type include extensograph, Instrons, and other mechanical testing systems [28], although examples of biaxial extensional devices include alveographs, and squeeze flows that induce uniaxial compression [19].

It has been used to depict the behavior of polymeric liquids through the start-up of steady extensional flow when stress increases faster than calculated by use of the linear theory of viscoelasticity [29]. In the instance of wheat flour dough, “strain hardening” merely denotes an increase of stress with strain at a certain value of the strain rate, and there is not a reference to their linear viscoelastic behavior; generally undetermined, the value is purely descriptive and has no clear rheological meaning, even if the measurements were done at a constant strain rate because it depends, at least in part, on the transitory increase of stress due to the viscoelastic behavior of dough [30]. Furthermore, data are obtained in most cases in unstable conditions. Nevertheless, with this wide meaning, strain hardening is used in the dough rheology literature, and the "strain hardening" parameter has set up a widespread interest in relationship with dough behavior during proof and oven rise. The main idea is that rather homogeneous growing of gas bubbles in dough without premature rupture and coalescence should be favorable to maximum bread development [30]. In 2007, Abang Zaidel et al. reported that the extensibility parameters of gluten from strong flour provided higher values than from weak flour. The results are supported by the higher strain hardening properties of the strong flour gluten, which prevents early fracture of gluten samples [31].

Large deformation of the dough can be studied under lubricated uniaxial compression, and the compression test is by far the most commonly used method that is relatively simple to perform. There is no need to grip the sample, which is a problem for a very soft solid, such as dough [32]. Yet, the drawback of the test is the presence of friction between the sample and the loading platens. For an incompressible material, such as wheat dough, tested under frictionless conditions is required, otherwise, such friction leads to a nonhomogeneous stress distribution and invalidates the data. Lubricants can be used to reduce friction but are difficult to completely eliminate, especially at larger strains [32].

Extensive knowledge of dough viscosity plays an important part in production control and equipment design. Dough viscosity is related to the quality of products and might control it in some cases [33]. Industrial processes of dough usually involve large strain rates in shear and extensional flows, and the viscosity of wheat flour dough may depend on the type and properties of used wheat flour, the combination of prepared dough, mixing conditions, and rest time. For instance, if the thickness of a dough wall between two adjoining bubbles is locally reduced at a point, the stress will be higher at this point and its deformation will increase much more than on the surroundings, inducing further thinning and premature rupture [30]. We can use a technique that simulate this phenomenon, consisting of the compression of a disk of wheat flour dough between two parallel plates under lubricated conditions—called lubricated squeezing flow (LSF)— can be used to characterize the rheology of wheat flour dough stressed by the breadmaking process [34]. The resultant deformation is a biaxial extension of the dough, which mimics the deformation of the dough between two adjacent bubbles, like those observed during the baking process. The test can be performed to a large strain provided the dough remains perfectly lubricated (perfect slippage) [35].

2.4 Mixing

It is a crucial operation during the production of wheat flour dough products. The quality of the dough has a great impact on the successive processing and the quality of the final products [36]. When dough is shaped, an exterior force from mixing is required so that interaction can be made between the flour and water. Optimal water level is essential to be used in developing a cohesive and viscoelastic dough with optimum gluten strength. During the development process, the dough is sheared and stretched by stirring blades. With the extension of mixing time and the continuous action of external forces, a gluten network gradually forms and then becomes destroyed [37]. The formation of dough is accompanied by the rupture and recombination of the gluten network [38]. Under different stress types (shearing, stretching, compression, etc.) and intensities, the dough undergoes a variety of interactions, resulting in extremely complicated stress-strain relationship, which seriously hinders the exploration of its mechanical behavior [39].

Through mixing a large number of air cells are incorporated into the dough. Thus, from a physical perspective, the dough can be studied as a foam. So, the stability of the gas cells in dough is mainly affected by two physical mechanisms: disproportionation and coalescence [14]. The amount to which these mechanisms affect the final bread structure powerfully depends on the mechanical properties of the dough films between the expanding gas cells. Subsequently, the large deformation and fracture properties of these dough films are crucial for the quality of bread, of which an even crumb structure and a high loaf volume are important value characteristics [14].

During the process of mixing, the dough is subjected to both large deformations, uniaxial and biaxial, thus a continuous protein network is formed [40]. Kneaders with spiral hooks incorporate mechanical energy typically by tension and compression, whereas shear rules in the rotating blades of high-speed mixers [41]. Generally, in kneading processes, such as dough, the resistance to extension increases, so the kneading energy increases and then, beyond a certain point, decreases [42]. Jekle et al. found that, once an optimal point is passed, there is a weakening of the entire system, because the mechanical input exceeds a certain limit, and the gluten network is stretched too much, resulting in a weakening of the gluten network [43]. Aljaafreh detected by stopping dough mixing nearby to the point of maximum resistance, that high-quality bread is attained. Thus, the rheological properties of the mixed material are related to the torque of the mixing machine [42, 44].

Cappelli et al., in a comprehensive review, conclude that enhancements to the kneading process must initiate with an exhaustive understanding of the key process parameters, followed by the implementation of a dedicated, real time control system that can regulate when kneading needs to end. The final step is to apply the most suitable improvement strategy, as a function of production needs [45].

3. Wheat bran dough rheology

The use of by-products, such as cereal bran, in particular, wheat bran, has a great potential to increase the dietary fiber content in breadmaking products because it is available in most flours' millers. It is relatively cheap and easy to use and almost does not require pretreatment before its incorporation into the flour dough. Two major strategies currently exist for adding dietary fiber to cereal food: extracting and purifying the non-starch polysaccharides that make up the fiber and compose an intrinsic part of cell walls in grain tissues, and directly adding grain fractions with high-fiber content to the product. The latter strategy is more practical and easier to instrument. Producing whole-grain products very similar to the original products and adjusting consumer habits to foster acceptance of the new products may result in consumer acceptance of whole-grain products that are high in fiber [46].

Using wheat bran in breadmaking process adds significant rheological problems, primarily linked to the addition of non-starch components of the caryopsis. These problems are due to the adverse impact of arabinoxylans, β-glucans, and other polysaccharides present when the development of the gluten network during the dough mixing process [47]. Arabinoxylans, in particular, affect dough rheology and bread characteristics by binding water, increasing viscosity, and disturbing the formation of the protein network during development [48]. Increased dough tenacity is the most remarkable rheological problem related to bran addition [49], followed by a subsequence rise in the viscosity [50].

Therefore, there are different strategies to limit the negative effects of adding bran to wheat flour. Numerous authors have studied the rheology of dough added with bran, proposed methods to improve dough rheology, and enhanced bread characteristics. There are several approaches to deal with these issues. Cappelli et al. 2018 relate the correct dosage of bran, middling, and dough water content [49] and the use of enzymes, such as xylanase, amylases, glucose oxidase, and phytase [51]. Cappelli et al. 2019 aimed to improve dough rheological parameters and bread characteristics [45]. In particular, they present a new procedure in which the addition of bran and middling's during kneading is delayed, and whether this modified procedure can enhance gluten development and improve wheat bran dough characteristics, both in technological and nutritional terms.

3.1 Mechanical properties of wheat dough

Rheological properties of dough are not exclusively governed by the protein composition or gluten protein network formation. The distribution of the starch granules within gluten protein network and the interaction between starch granules and protein branches could also impact the dough strength and dough extensibility [15]. Bran fractions have a major influence on final characteristics of rich-bran breads due to their effects on the development of the dough during mixing and fermentation. High fiber incorporation had a strong impact on dough extensibility and also demonstrate that water restriction (optimum amount for consistency white flour) can be used to obtain information useful for improving our understanding of the breadmaking quality of bran flours [52]. In addition, arabinoxylans structure has an influence on the extensional viscosity of bran dough, structural differences among fine bran WE-AXs are essential to explain the behavior of these molecules on dough behavior and bread characteristics [53].

Determining the effects of fiber addition is quite difficult, since handling dough containing soluble fiber is complicated, due to increased stickiness or because such measurements are less popular than small deformation measurements [54]. Large strain rheological measurements results, out of the linear viscoelastic range, can be related to process behavior by means of uniaxial compression test, Cavella et al. 2008 showed that dough elongational viscosity and strain hardening index decreased when adding up to 9% inulin, which suggests poor gas retention performance during dough fermentation and, subsequently, lower final bread volume [55].

There are diverse explanations of the effect of fiber on dough extensibility, and these effects may vary with the type and content of fiber. The extensibility of dough is mostly determined by the polymerization state of the gluten protein network [56]. Soluble dietary fiber mainly interacts with gluten protein noncovalently via hydrogen bonds and is dominated by the hydration level [56]. Flow properties are determined by the gliadins, and elongation testing revealed that glutenins contribute to the strength and elastic properties of dough [57], though the development of elasticity is fairly intricate. While helix/spiral structure can resist the intrinsic elasticity of high molecular weight glutenin subunits, our understanding of the subjacent secondary structure within the dough system elasticity is limited [57]. Belton, 1999 proposes "a loop and train model" that a higher degree of gluten hydration results in the formation of more ring regions governed by noncovalent molecular interaction (mostly hydrogen bonds) [58].

Some theories have been proposed to explain how wheat bran affects the rheology of dough; in general, dough rheology can be modified by wheat bran addition in numerous ways through complex mechanisms: a) bran itself is very hard and cannot be integrated with the gluten network; b) bran addition affects the structure of the gluten network and the hydration process of gluten protein; and c) wheat bran induces changes in the secondary structure of gluten protein, especially glutenin, resulting in more sheet-like structure and less spiral-like structure [11]. Dough extensibility predetermines the dough raising and, is an important quality parameter in breadmaking process. Wheat bran decreased dough extensibility and resistance to extension. Hence, the increased concentration of wheat bran in the dough formulation reduced the dough strength and extensibility characteristic [59].

Most of these effects are related to the chemical composition and the structure of the polysaccharides that constituted the caryopsis cell wall of wheat grain. Amongst the cell wall polysaccharides in wheat and rye, arabinoxylans have been widely studied, due to their effect on flour functionality and dough formation [60]. Often, arabinoxylans are distinguished into water-extractable (WE-AX) and water-unextractable (WU-AX). The WE-AX is supposed to be loosely bound at the cell wall surface, while WU-AX is associated with other arabinoxylans, proteins, or starch molecules [61, 62]. Degradation of WU-AX lowers viscosity and makes water available for gluten or starch [63].

3.2 Xylanase use in bran dough

As previously mentioned, the addition of wheat bran to dough carries with it certain negative effects, from a rheological perspective. However, it is a price that the industry is willing to pay, and finally, the consumer is also willing to do so, all this for the expectation of increasing the nutritional value of the product. The development of functional ingredients from wheat bran has been a key area of research for cereal scientists over the past 30 years, with a focus on the use of wheat bran to enrich products [11]. There is a rising awareness of the health benefits related to the consumption of dietary fiber products [11]. Recognizing this fact, different strategies have been developed to minimize these unwanted effects.

From a technological viewpoint, the existence of high amounts of arabinoxylans in wheat flour is inconvenient [60, 64], as they can obstruct gluten formation in wheat dough via several possible mechanisms. One of the proposed mechanisms is the restriction of water in the dough limiting gluten development since arabinoxylans compete for the water molecules [65]. Arabinoxylans from wheat bran has a high-water affinity and are efficient in binding water, with a water holding capacity of about five- to 10-fold higher than protein and starch [66]. It has been suggested that wheat bran water binding is to be the greatest significant factor affecting bread quality [67], additionally, insoluble fiber may interact with the gluten protein, which has detrimental effects on the gluten network [68].

Varied types of enzymes can be used as substitutes to the chemical improving ingredients, that is, some hydrocolloids and emulsifiers, and those types used in bakery applications can be acknowledged by the single word "enzymes," a term which many consumers perceive as natural and clean label compared to additives named by their

Flour type	Aim/objective of work	Dough rheology properties	Main conclusion	Reference
White	Explain dough behavior and bread quality to make a contribution to the knowledge of enzyme mechanism in foodstuffs.	Dough-mixing properties. uniaxial extensibility	The increase of soluble pentosans promoted by xylanase, increased dough viscosity and extensibility, improved bread quality.	Steffolani ME, et al. 2010 [73]
Bran flour	Produce AXOS enriched breads using xylanase technology without impairing dough manageability and final loaf volume.	Dough stickiness. The force (g) required for separating the probe from the dough surface was recorded.	The breadmaking process can be used to introduce AXOS in the diet since AX are naturally present in the traditional bread raw materials.	Damen B, et al. 2012 [74]
Bran flour	Study the different enzyme labels and its effect on wheat bran on breadmaking by using the properties and functionality of different wheat milling by-products.	Mixing properties using Farinograph.	By-products can strongly differ in chemical composition, enzyme activity levels and physical properties, inducing clear changes in dough behavior.	Hemdane S, et al. 2015 [67]
Bran flour	Investigate the effects of lactic acid bacteria fermentation and enzymatic treatment on AX solubility and technological characteristics of dough and bread.	Biaxial extension using the alveograph.	Enzyme treatment exerted a positive influence on AX solubility in the dough, allowing a better distribution of the water.	Messia MC, et al. 2016 [75]
Whole wheat flour	Investigate the effect of xylanase extracted from *Penicillium citrinum* on the rheological properties of whole wheat dough and its effect on flow behavior of dough under small and large deformations.	Shear stress and uniaxial extensibility.	Xylanase containing bread exhibited greater extensibility and less resistance to extension as compared to control samples, and makes the dough softer.	Ghosha G, et al. 2017 [76]
Bran dough	The effect of α-amylase, xylanase and cellulase on the rheological properties of the bread dough with 15% content of wheat bran compared to regular bread dough without wheat bran	Mixing properties by Mixolab, extension test using textural analyzer Kieffer test. Dough stickiness Chen-Hoseney's method	The combination of enzymes had a synergetic effect on the dough rheology due to the interactions among enzyme activities and their coupled reactions.	Liu W, et al. 2017 [77]
Bran flour	Wheat bran modification by semi solid-state fermentation and enzymatic hydrolysis. Effects of treatment on the nutritional value of wheat bran, thermomechanical properties of dough and thiol disulfide bonds (SS) contents	thermomechanical properties were obtained from the results of Mixolab.	The modified treatment effectively alleviated the damage of wheat bran to the gluten network. However, the modification did not improve the thermal stability of gluten.	Zhang H, et al. 2018 [78]

Flour type	Aim/objective of work	Dough rheology properties	Main conclusion	Reference
Bran flour	Investigating the dry fractionation process to extract arabinoxylans-enriched fractions evaluating the bread baking performance of the dry-fractionated bran fractions using xylanase on bread quality.	Mixing properties using the farinograph.	The study shows the potential of AX-enriched fractions to be supplemented to bread to improved nutritional value, while maintaining high quality.	Zhang L, et al. 2019 [79]
Bran flour	Investigates the effect of xylanase and arabinofuranosidase on the rheological properties of the bread dough with 15% content of wheat bran and their textural and sensory properties of final steamed bread.	The dough extensibility test was conducted using an extender JMLD150, measure dough resistance to extension.	That cocktail enzymes can be used as more efficient enzymatic improver that can enhance the nutritional and technological functionality of WB for improving the quality of WB rich products	Xue Y, et al. 2020 [80]
Whole wheat flour	Evaluate the influence of different micronized whole wheat flour particle sizes and different xylanase contents on dough properties and breadmaking by using response surface methodology.	Dough extensional properties by textural analyzer.	Xylanase must be implemented carefully, the improvement in fiber-rich bread texture is necessary to expand consumer acceptance of nutritional and functional foods	Both J, et al. 2021 [81]
White-rye flours	That enzymatic hydrolysis of WE-AX and/or WU-AX influences the linear and nonlinear extensional rheology of white flours dough and mixed doughs prepared from various blends of white and rye flour.	Uniaxial extensional viscosity using an ARES-G2 rheometer.	doughs prepared with a modified water content supported the hypothesis that the observed decrease in dough extensional viscosity values resulted from release of water previously bound by AX.	Meus Y, et al. 2021 [81]

Table 1.
Xylanase use on wheat dough, effects on arabinoxylans and dough rheology.

chemical composition. As consumers demand bakery products with more natural-sounding ingredients, the commercial use of enzymes has increased in recent years [51].

An enzyme that catalyzes the hydrolysis of any non-starch polysaccharides can be called hemicellulases, and xylanases are being used for some time now. Xylanase is widely known to improve the dough and properties of flour, with beneficial effects, such as softening the dough, increasing loaf volume, improving crumb structure, and decreasing staling rate. Of these enzymes, endoxylanases are commonly used in breadmaking [69]. Additionally, there are some efforts with the combination of enzymes, for example, Laurikainen et al. (1998) studied the effect of three enzymes (hemicellulolytic culture filtrate, xylanase, and a-amylase) on breads added with 5% rye bran. They found a significant improvement in the bran bread with the enzymes compared with its contra part not treated. The improvement in baking quality was attributed to changes in the cell wall polysaccharides caused by the enzymes [70]. Also, Katina et al. (2006) study the effects of sourdough and enzymes (a-amylase, xylanase, and lipase) on bread added with 20% wheat bran. Sourdough and enzymes combination results in loaves with crumb texture similar to the control, and also showed the lowest rate of staling. The outcomes were attributed to degradation of cell wall components that results in an enhanced gluten network, changes in the water migration during staling, and reduced starch retrogradation [71].

Nowadays, there are many strategists with different approaches to address the challenges of the bran addition to the flour dough and, the foods technologies, cereal industry, and researchers have to tackle these issues. Thus, preprocessing treatment, extraction method, and processing parameters affect AX properties and functionality, so differences in the raw materials and methods used in different studies make it difficult to draw solid conclusions, and more research is required around the interactions between processing, molecular structure, and functionality of arabinoxylans from the cell walls of wheat bran [72].

In the past decade, there are many efforts to dilucidated the importance of arabinoxylans in bread making and its effects on dough rheology, with an increased tendency to add cereal bran and its fractions to the dough. **Table 1** summarizes several works that related the use of enzymes, xylanase in particular, with the dough rheology added with cereal bran.

All these efforts are focused on solving the problems associated with the addition of bran to wheat dough, in order to obtain products that are as similar as possible to the original product, which is white bread. However, the consumer is willing to sacrifice some attributes, with the expectation of obtaining a healthier product, since the presence of cereals bran increase the fiber content.

4. Conclusion

The chapter examines the current research status on the cereal industry on this matter, mostly from a food technology perspective. Extensional viscosity is a valuable tool for evaluating the rheological properties of bran dough and can provide useful data for investigations to improve the process. With the gradual increase in the consumption of bran added to bread, it is to be expected that the cereal industry will look for new ways to increase the offer of new products and, it is here that the use of enhancers such as enzymes, especially xylanases, can gain relevance in the development of new products rich in wheat bran and, maintaining as much as possible, the characteristics of a refined product. Nevertheless, even with the growing evidence of the beneficial effects on health of the consumption of dietary fiber and, therefore its use in the cereal industry, is important to be prudent in the claims made with respect if the potential health benefit of the consumption of the high fiber products. The reason for this, from the writer´s view, is because scientific terminology is not understood entirely by the consumer and, the food industry may abuse this lack of communication to abuse in advertising and, often put in front profit before consumer wellness.

IntechOpen

Author details

Alán Pavlovich-Abril
Department of Research and Graduate Studies in Food, University of Sonora, Sonora, Mexico

*Address all correspondence to: alan.pavlovich@unison.mx

References

[1] Delcour JA, Joye IJ, Pareyt B, Wilderjans E, Brijs K, Lagrain B. Wheat gluten functionality as a quality determinant in cereal-based food products. Annual Review in Food Science and Technology. 2012;**3**:469-492

[2] Karunaratne DN, Pamunuwa G. Food Additives [Internet]. London: IntechOpen; 2017. p. 176. DOI: 10.5772/65204. Available from: https://www.intechopen.com/books/5766

[3] Gudmundsson M, Eliasson A-C. The effects of water soluble arabinoxylan on gelatinization and retrogradation of starch. Starch – Stärke. 1991;**43**(1):5-10

[4] Bloksma AH. Rheology of the breadmaking process. Cereal Foods World. 1990;**35**:228-236

[5] Bloksma AH, Nieman W. The effect of temperature on some rheological properties of wheat flour doughs. Journal of Texture Studies. 1975;**6**:343-361

[6] van Vliet T, Janssen AM, Bloksma AH, Walstra P. Strain hardening of dough as a requirement for gas retention. Journal of Texture Studies. 1992;**23**:439-460

[7] Ktenioudaki A, O'Shea N, Gallagher E. Rheological properties of wheat dough supplemented with functional by-products of food processing: Brewer's spent grain and apple pomace. Journal of Food Engineering. 2013;**116**:362-368

[8] Rouzaud-Sández O, Pavlovich-Abril A, Salazar-García MG, Robles-Sánchez RM, Vidal-Quintanar RL. Multivariate analysis to select chemical compounds and rheological parameters as predictors of bread quality: Interaction of wheat genotype and particle size of fine bran. Journal of Food Science and Technology. 2021;**59**(7):2694-2704

[9] Li E, Dhital S, Hasjim J. Effects of grain milling on starch structures and flour/starch properties. Starch/stärke. 2014;**66**:15-27

[10] Kim B-K, Cho A-R, Chun Y-G. Park D-J Effect of microparticulated wheat bran on the physical properties of bread. International Journal of Food Sciences and Nutrition. 2013;**64**:122-129

[11] Ma S, Wang Z, Liu H, et al. Supplementation of wheat flour products with wheat bran dietary fiber: Purpose, mechanisms, and challenges. Trends in Food Science and Technology. 2022;**123**:281-289

[12] van Vliet T. Rheological classification of foods and instrumental techniques for their study. In: Rosenthal AJ, editor. Food Texture: Measurement and Percaption. Gaithersburg, Maryland: Aspen Publishers; 1999. pp. 65-98. ISBN 0-8342-1238-2

[13] Watanabe H, Matsumiya Y, Chen Q, Yu W. Rheological characterization of polymeric liquids. Polymer Science: A Comprehensive Reference. 2012;**10**(2):683-722. DOI: 10.1016/B978-0-444-53349-4.00053-4

[14] Sliwinski EL. Large-deformation Properties of Wheat Flour and Gluten Dough. Wageningen, The Netherlands: Wageningen University; 2003

[15] McCann TH, Le Gall M, Day L. Extensional dough rheology - Impact of flour composition and extension speed. Journal of Cereal Science. 2016;**69**:228-237

[16] Alpers T, Olma J, Jekle M, Becker T. Relation between polymer transitions and the extensional viscosity of dough systems during thermal stabilization assessed by lubricated squeezing flow. Food Chemistry. 2022;**389**:133048

[17] Ramaswamy H, Marcotte M. Background and basics. In: Ramaswamy H, Marcotte M, editors. Food Processing: Principles and Applications. Boca Raton, FL: CRC Press Taylor & Francis Group; 2006. pp. 7-63. ISBN 1-58716-008-0

[18] Smith JR, Smith TL, Tschoegl NW. Rheological properties of wheat flour doughs. III. Dynamic shear modulus and its dependence on amplitude, frequency, and dough composition. Rheologica Acta. 1970;**9**:239-252

[19] Dobraszczyk BJ, Morgenstern MP. Review: Rheology and the breadmaking process. Journal of Cereal Science. 2003;**38**:229-245

[20] Campos DT, Steffe JF, Ng PKW. Rheological behavior of undeveloped and developed wheat dough. Cereal Chemistry. 1997;**74**:489-494

[21] Bagley EB, Dintzis FR, Chakrabarti S. Experimental and conceptual problems in the rheological characterization of wheat flour doughs. Rheologica Acta. 1998;**37**(6):556-565

[22] Trevor SK, McKinley GH. Linear to non-linear rheology of wheat flour dough. In: Plenary paper presented at the International Symposium on Food Rheology and Structure (ISFRS2006). ETH, Zurich; 2006

[23] Singh H, MacRitchie F. Application of polymers science to properties of gluten. Journal of Cereal Science. 2001;**33**(3):231-243

[24] Polakowski NH, Ripling EJ. Tensile Properties. Strength and Structure of Engineering Material. Englewood Cliffs N.J: Prentice Hall; 1966. pp. 265-292

[25] Stojceska V, Butler F, Gallagher E, Keehan D. A comparison of the ability of several small and large deformation rheological measurements of wheat dough to predict baking behaviour. Journal of Food Engineering. 2007;**83**:475-482

[26] Chatraei SH, Macosko CW, Winter HH. Lubricated squeezing flow: A new biaxial extensional rheometer. Journal of Rheology. 1981;**25**:433-443

[27] Janssen AM, van Vliet T, Vereijken JM. Fundamental and empirical rheological behaviour of wheat flour doughs and comparison with bread making performance. Journal of Cereal Science. 1996;**23**:43-54

[28] Sliwinski EL, Kolster P, van Vliet T. On the relationship between large-deformation properties of wheat flour dough and baking quality. Journal of Cereal Science. 2004;**39**(2):231-245

[29] Dealy JM. Do polymeric liquids exhibit strain hardening? Journal of Rheology. 1990;**34**:1133-1147

[30] Launay B, Michon C. Biaxial extension of wheat flour doughs: Lubricated squeezing flow and stress relaxation properties. Journal of Texture Studies. 2008;**39**:496-529

[31] Abang Zaidel DN, Chin NA, Abdul Rahman R, Karim R. Rheological characterisation of gluten from extensibility measurement. Journal of Food Engineering. 2008;**86**(4):549-556

[32] Charalambides MN, Wanigasooriya L, Williams JG, Go SM, Chakrabarti S. Large deformation extensional rheology of bread dough. Rheologica Acta. 2006;**46**:239-248

[33] Sharma N, Hanna MA, Chen YR. Flow behaviour of wheat flour-water dough using a capillary rheometer, I Effect of capillary geometry. Cereal Chemistry. 1993;**70**(1):59-63

[34] Kouassi-Koffi JD, Davidou S, Launay B, Kouamé LP, Michon C. Lubricated squeezing flow of thin slabs of wheat flour dough: Comparison of results at constant plate speed and constant extension rates. Rheologica Acta. 2010;**2010**(49):275-283

[35] Vanina FM, Lucasa T, Trystram G, Michon C. Biaxial extensional viscosity in wheat flour dough during baking. Journal of Food Engineering. 2018;**236**:29-35

[36] Kansou K, Chiron H, Della Valle G, Ndiaye A, Roussel P. Predicting the quality of wheat flour dough at mixing using an expert system. Food Research International. 2014;**64**:772-782

[37] Zheng H, Morgenstern MP, Campanella OH, Larsen NG. Rheological properties of dough during mechanical dough development. Journal of Cereal Science. 2000;**32**(3):293-306

[38] Ortolan F, Steel CJ. Protein characteristics that affect the quality of vital wheat gluten to be used in baking: A review. Comprehensive Reviews in Food Science and Food Safety. 2017;**16**(3):369-381

[39] Peighambardoust SH, van der Goot AJ, van Vliet T, Hamer RJ, Boom MR. Microstructure formation and rheological behaviour of dough under simple shear flow. Journal of Cereal Science. 2006;**43**(2):183-197

[40] Preedy V, Watson R, Patel V. Flour and Breads and their Fortification in Health and Disease Prevention. Elsevier Inc.; 2011. DOI: 10.1016/C2009-0-30556-5

[41] Tietze S, Jekle M, Becker T. Advances in the development of wheat dough and bread by means of shearing. Journal of Food Engineering. 2019;**247**:136-143

[42] Aljaafreh A. Agitation and mixing processes automation using current sensing and reinforcement learning. Journal of Food Engineering. 2017;**203**:53-57

[43] Jekle M, Necula A, Jekle M, Becker T. Concentration dependent rate constants of sodium substitute functionalities during wheat dough development. Food Research International. 2019;**116**:346-353

[44] Asaithambi N, Fontaine J, Lancelo E, Rebillard A, et al. Evaluation of bread dough aeration during kneading by an air-jet impulse system. Journal of Food Engineering. 2020;**278**:109931

[45] Cappelli A, Guerrini L, Cini E, Parenti A. Improving whole wheat dough tenacity and extensibility: A new kneading process. Journal of Cereal Science. 2019;**90**:102852

[46] Pavlovich-Abril A, Rouzaud-Sández O, Torres P, Robles-Sánchez RM. Cereal bran and wholegrain as a source of dietary fibre: Technological and health aspects. International Journal of Food Science and Nutrition. 2012;**63**(7):882-889

[47] Boita ER, Oro T, Bressiani J, Santett GS, Bertoli TE, Gutkoski LC. Rheological properties of wheat flour dough and pan bread with wheat bran. Journal of Cereal Science. 2016;**71**:177-182

[48] Shewry PR, America AHP, Lovegrove A, Wood AJ, Plummer A, Evans J, et al. Comparative compositions of metabolites and dietary fibre components in doughs and breads produced from bread wheat, emmer

and spelt and using yeast and sourdough processes. Food Chemistry. 2022;**374**:131710

[49] Cappelli A, Cini E, Guerrini L, Masella P, Angeloni G, Parenti A. Predictive models of the rheological properties and optimal water content in doughs: An application to ancient grain flours with different degrees of refining. Journal of Cereal Science. 2018;**83**:229-235

[50] Le Bleis F, Chaunier L, Chiron H, Della Valle G, Saulnier L. Rheological properties of wheat flour dough and French bread enriched with wheat bran. Journal of Cereal Science. 2015;**65**:167-174

[51] Tebben L, Shen Y, Li Y. Improvers and functional ingredients in whole wheat bread: A review of their effects on dough properties and bread quality. Trends in Food Science and Technology. 2018;**81**:10-24

[52] Pavlovich-Abril A, Rouzaud-Sandez O, Romero-Baranzini AL, Vidal-Quintanar RL, Salazar-García MG. Relationships between chemical composition and quality-related characteristics in bread making with wheat four-fine bran blends. Journal of Food Quality. 2015;**2015**(38):30-39

[53] Pavlovich-Abril A, Rouzaud-Sandez O, Carvajal-Millan E, Navarro RE, Robles Sanchez RM, Barron-Hoyos JM. Molecular characterization of water extractable arabinoxylans isolated from wheat fine bran and their effect on dough viscosity. LWT - Food Science and Technology. 2016;**74**:484-492

[54] Arufe S, Chiron H, Doré J, Savary-Auzeloux I, Saulnier L, Della VG. Processing & rheological properties of wheat flour dough and bread containing high levels of soluble dietary fibres blends. Food Research International. 2017;**97**:123-132

[55] Cavella S, Romano A, Giancone T, Masi P. The influence of dietary fibres on bubble development during bread making. In: Campbell GM, Scanlon MG, Pyle DL, editors. Bubbles in Food 2 - Novelty, Health and Luxury. St Paul, USA: Eagan Press; 2008. pp. 311-322

[56] Nawrocka A, Krekora M, Niewiadomski Z, et al. Effect of moisturizing pre-treatment of dietary fibre preparations on formation of gluten network during model dough mixing–A study with application of FT-IR and FT-Raman spectroscopy. LWT - Food Science and Technology. 2020;**121**:108959

[57] Bonilla JC, Erturk MY, Kokini JL. Understanding the role of gluten subunits (LMW, HMW glutenins and gliadin) in the networking behavior of a weak soft wheat dough and a strong semolina wheat flour dough and the relationship with linear and non-linear rheology. Food Hydrocolloids. 2020;**108**:106002

[58] Belton PS. Mini review: On the elasticity of wheat gluten. Journal of Cereal Science. 1999;**29**(2):103-107

[59] Packkia-Doss PP, Chevallier S, Pare A, Le-Bail A. Effect of supplementation of wheat bran on dough aeration and final bread volume. Journal of Food Engineering. 2019;**252**:28-35

[60] Kweon M, Slade L, Levine H. Solvent retention capacity (SRC) testing of wheat flour: Principles and value in predicting flour functionality in different wheat-based food processes, as well as in wheat breeding—A review. Cereal Chemistry. 2011;**88**(6):537-552

[61] Courtin C, Delcour J. Arabinoxylans and endoxylanases in wheat flour bread-making. Journal of Cereal Science. 2002;**5**:225-243

[62] Verwimp T, Van Craeyveld V, Courtin CM, Delcour JA. Variability in the structure of rye flour alkali-extractable arabinoxylans. Journal of Agricultural and Food Chemistry. 2007;**55**:1985-1992

[63] Leys S, De Bondt Y, Bosmans G, Courtin CM. Assessing the impact of xylanase activity on the water distribution in wheat dough: A 1 H NMR study. Food Chemistry. 2020;**325**:126828

[64] Levine H, Slade L. Influence of hydrocolloids in low-moisture foods – A food polymer science approach. In: Phillips GO, Williams PA, editors. Gums and Stabilisers for the Food Industry 12. The Royal Society of Chemistry; 2004. pp. 423-436. DOI: 10.1039/9781847551214-00423. ISBN = 978-0-85404-891-5

[65] Wang MW, Hamer RJ, van Vliet T, Grppen H, Marseill H, Weegels PL. Effect of water unextractable solids on gluten formation and properties: Mechanistic consideration. Journal of Cereal Science. 2003;**37**:55-64

[66] Wang M, Zhao Z, Niu M, Zhao S, Jia C, Wu Y. Thermomechanical behaviors and protein polymerization in bread dough modified by bran components and transglutaminase. LWT - Food Science and Technology. 2020;**133**:109894

[67] Hemdane S, Leys S, Jacobs PJ, Dornez E, Delcour JA, Courtin CM. Wheat milling by-products and their impact on bread making. Food Chemistry. 2015;**187**:280-289

[68] Noort MWJ, van Haaster D, Hemery Y, Schols HA, Hamer RJ. The effect of particle size wheat bran fractions on bread quality – evidence for fibre-protein interactions. Journal of Cereal Science. 2010;**52**:59-64

[69] Jiang Z, Li X, Yang S, Li L, Tan S. Improvement of the breadmaking quality of wheat flour by the hyperthermophilic xylanase B from *Thermotoga maritima*. Food Research International. 2005;**38**(1):37-43

[70] Laurikainen T, Harkonen H, Autio K, Poutanen K. Effects of enzymes in fibre-enriched baking. Journal of the Science of Food and Agriculture. 1998;**76**:239-249

[71] Katina K, Salmenkallio-Marttila M, Partanen R, Forssell P, Autio K. Effects of sourdough and enzymes on staling of high-fibre wheat bread. LWT - Food Science and Technology. 2006;**39**:479-491

[72] Pietiainen S, Moldin A, Ström A, Malmberg C, Langton M. Effect of physicochemical properties, pre-processing, and extraction on the functionality of wheat bran arabinoxylans in breadmaking – A review. Food Chemistry. 2022;**383**:132584

[73] Steffolani ME, Ribotta PD, Pérez GT, León AE. Effect of glucose oxidase, transglutaminase, and pentosanase on wheat proteins: Relationship with dough properties and bread-making quality. Journal of Cereal Science. 2010;**51**:366-373

[74] Damen B, Pollet A, Dornez E, Broekaert WF, Van Haesendonck I, Trogh I, et al. Xylanase-mediated in situ production of arabinoxylan oligosaccharides with prebiotic potential in whole meal breads and breads enriched with arabinoxylan rich materials. Food Chemistry. 2012;**131**:111-118

[75] Messia MC, Reale A, Maiuro L, Candigliota T, Sorrentino E, Marconi E. Effects of pre-fermented wheat bran on dough and bread characteristics. Journal of Cereal Science. 2016;**69**:138-144

[76] Ghoshal G, Shivhare US, Banerjee UC. Rheological properties and

microstructure of xylanase containing whole wheat bread dough. Journal of Food Science and Technology. 2017;**54**(7):1928-1937

[77] Liu W, Brennan MA, Serventi L, Brennan CS. Effect of cellulase, xylanase and a-amylase combinations on the rheological properties of Chinese steamed bread dough enriched in wheat bran. Food Chemistry. 2017;**234**:93-102

[78] Zhang H, Zhang X, Cao XR, Iftikhar M, Wang J. Semi-solid state fermentation and enzymatic hydrolysis impeded the destroy of wheat bran on gluten polymerization. LWT - Food Science and Technology. 2018;**98**:306-313

[79] Zhang L, van Bovena A, Mulder J, Grandia J, Chen XD, Boom RM, et al. Arabinoxylans-enriched fractions: From dry fractionation of wheat bran to the investigation on bread baking performance. Journal of Cereal Science. 2019;**87**:1-18

[80] Xue Y, Cui X, Zhang Z, Zhou T, Gao R, Li Y, et al. Effect of β-endoxylanase and α-arabinofuranosidase enzymatic hydrolysis on nutritional and technological properties of wheat brans. Food Chemistry. 2020;**302**:125332

[81] Meeus Y, Janssen F, Wouters AGB, Delcour JA, Moldenaers P. The role of arabinoxylan in determining the non-linear and linear rheology of bread doughs made from blends of wheat (Triticum aestivum L.) and rye (Secale cereale L.) flour. Food Hydrocollogy. 2021;**120**:106990