

Grain Quality and Improvement in Wheat and Some Quality Aspect of Pasta Industries in Ethiopia: A Review

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Abstract: Depending on the intended use, quality can relate to a variety of physical and chemical characteristics of the product. Additionally, the standards for judging wheat grain quality attributes are as varied as their various applications. The impacts of some important genes for grain hardness, genes that code for storage proteins, etc., have been well documented. The development of DNA-based markers for desirable qualities is now possible because to the development of molecular biology. Therefore, DNA markers complement traditional breeding techniques, allowing for the quicker development of novel cultivars with desirable traits. Due to the low volume of durum wheat grain, Ethiopian pasta businesses still augment bread wheat flour with colorants and pasta zymes and are negatively impacted by the high import costs. Local farmers are increasing their durum wheat production and supplying high-quality durum wheat grain. Maintaining the grain quality of wheat under climate change is essential for human nutrition, end-use functional qualities, as well as commodity value, but the weak supply chain from the producer to the manufacturer is affecting both. Wheat yield can rise by up to 36% under conditions of high CO₂, however grain protein concentrations often decline and a change in composition results in fewer useful qualities. Crops that are post-anthesis can have a step-change drop in grain-set, grain size, and milling yield due to high temperatures. Wheat dough has lower viscoelasticity qualities because high temperature stress affects the glutenin/gliadin ratio and restricts the synthesis of the bigger sodium dodecyl sulfate (SDS)-insoluble glutenin polymers. The current understanding of the effects of high temperatures and elevated atmospheric CO₂ on the whole-grain and functional properties of wheat, as well as the recent development of molecular markers and their use in breeding programs, particularly to improve traits relating to wheat grain, are reviewed in this paper. Finally, a few aspects of the Ethiopian pasta industry are discussed.

Keywords: Wheat, Grain Quality, Molecular Markers, Heat Stress, Climate Change, Pasta

1. Introduction

To meet demand for the steadily rising global population (estimated at 9 billion people by 2050), wheat grain production must increase by 2% annually [1]. These wheat cultivars are the result of extensive selection by breeders to satisfy quality and agronomic requirements for the wide range of end products, including confectionery, biscuits, cakes, traditional pan, sponge and dough pan, flat or steamed breads, chapatti, frozen doughs, yellow alkaline or Udon style noodles, and high-quality pastas [2]. The most difficult task facing wheat breeders now is to improve grain quality for end products in order to fulfill the demands of the world's population, which is constantly growing [3]. As a result, improving wheat quality is a top priority in wheat breeding

programs for the global wheat trade [4].

It is crucial for human nutrition, end-use functional qualities, and commodity value that grain quality is maintained amid climate change. One of the important staple crops is wheat (*Triticum aestivum* L.), with 672 million tonnes produced worldwide in 2012 [5]. Climate change-related increased environmental stress on wheat production will have an impact on both the yield and quality of wheat output. Depending on the intended use, quality can relate to a variety of physical and chemical characteristics of the product. Physical and chemical qualities have been roughly categorized as the two kinds of parameters that affect wheat grain quality. The chemical characteristics are protein content, protein quality, and sedimentation test, whereas the physical characteristics include grain appearance score, kernel or grain hardness, vitreousness

of kernel, 1000-kernel weight, hectoliter weight (test weight), kernel size, and shape. Other tests that can estimate the viscoelastic or dough mixing qualities include the farinograph [6], extensograph [7], mixograph [8], and alveograph [9].

Environment, management, and genetics all have an impact on grain quality. Kernel properties like form, germ tissue, bran thickness, and crease traits are strongly influenced by genetics. However, the post-anthesis environment, including temperature and water availability, greatly affects seed size, making it crucial to define physical parameters like screens and milling yield [10]. Similar environmental factors, such as air CO₂ concentration and heat shock during the grain loading phase, affect the deposition of starch and proteins as well as functional qualities including dough rheology and baking quality [11].

2. Climate Change and Wheat Quality

The yield and quality of grain are seasonally changeable in Mediterranean-type environments when mature crops coincide with terminal drought due to low and unpredictable rainfall as well as the substantial risk of heat waves during the reproductive and grain-filling phases of crops. In many arable agricultural zones, growing-season rainfall is expected to decrease due to climate change, and the frequency of extreme weather events is predicted to increase (IPCC, 2012). Reduced output and poorer quality of staple grains are predicted to be the overall effects of a changing climate in semi-arid cropping regions [12]. While the whole-grain quality, protein quantity and composition, and a variety of functional features of wheat are the main emphasis of this review in relation to the environment and potential effects of climate change, yield implications are also taken into account. Higher leaf CO₂ absorption rates have the effect of lowering transpiration while stimulating photosynthesis and growth in C₃ plants [13]. This results in increased output and water use efficiency for grain crops [14].

The average yield increased by 36%, according to a meta-study of 430 yield observations of 37 plant species treated with CO₂ enrichment [14], with a 32% rise in yield of C3 grain crops. Other free-air carbon dioxide enrichment (FACE) experiments found that enhanced CO₂ content (eCO₂) increased wheat production by 10% [15], and by 26% (2.3 compared to 2.9 t/ha) in southern Australia [16]. eCO₂ is likely to improve production, although there is a varied but often negative impact on grain quality [15].

The ideal temperature for grain development is between 15 and 25°C [17], and while increasing temperature and photosynthesis increase the supply of assimilate, this does not fully make up for the shorter starch deposition time, which results in smaller grains when the temperature is generally higher. Between two wheat cultivars, persistent exposure to temperatures up to 30 °C from six days after anthesis (DAA) through maturity resulted in a 20–30% reduction in kernel weight [18]. These cultivars all experienced a similar decrease in kernel weight following a four-day heat shock treatment at 36 °C (6 DAA),

demonstrating that a heat shock reaction begins to develop at temperatures over 30 °C. Because the enzymes that catalyze starch synthesis are less active at temperatures above 30 °C, the rate of starch deposition reduces [19]. Although high temperatures where water supply is non-limiting have also been proven to produce a drop in single grain weight, adequate water availability to crops that are heat-stressed helps sustain grain-filling rate, length, and size [20]. The potential advantage of sufficient water in Mediterranean-style areas to reduce the impacts of heat stress on crops is probably limited because they often mature under terminal drought conditions. Future climates are also expected to experience an increase in the frequency of extreme weather events such as heat waves (IPCC, 2012), which can have a permanently negative influence on crop output potential.

Wheat growth is specifically impacted by heat shock during the reproductive phase by pollen sterility, tissue dryness, decreased CO₂ absorption, and increased photorespiration [21]. The period of exposure is a key factor in determining the impact since wheat is most susceptible to acute heat stress around blooming and becomes more tolerant of high temperatures during the grain filling phase [22]. Although critical thresholds can change depending on cultivar, a review of temperature effects on wheat growth [16], found that the maximum temperature (T_{max}) wheat could tolerate during the reproductive period was 31 °C during anthesis and that T_{max} increased to between 33 and 37 °C during the grain filling phase [23].

According to studies on the impact of heat stress on wheat growth, yields were lowered by 18–35% for a single day of heat stress at 35°C [24]. It is anticipated that hotter and drier circumstances during the grain filling phase will have a dominant impact on crop yield in a future climate, reducing the potential benefits of carbon fertilization. Furthermore, the consequences of high temperatures in a world with high CO₂ levels will have an additional detrimental effect on grain quality.

2.1. Whole-Grain Quality Characteristics

The physical traits of grain, such as milling yield, screens, and test weight, which are influenced by both genotype and environment, are included in the category of whole-grain quality. The latter is the subject of this review. The amount of flour that can be produced from grains is known as milling yield, which depends on the mature kernel's endosperm content (75-83%), which is compared to the embryo (germ), aleurone, and seed coat (bran), as well as grain hardness [25]. A reduced milling yield is often produced by the higher proportion of bran compared to endosperm, which also occurs for small and shrivelled grains [26]. Additionally, the depth of the crease plays a significant role in determining milling output, with shallower creased kernels having a larger milling yield [27].

Wheat screenings are measured by the weight of grain that passes through a 2 mm slotted screen and are classified as either small, non-shrivelled kernels or pinched kernels. They are affected by the cultivar, the season, and management

practices like when to sow and how much nitrogen fertilizer to use [11]. Sharma and Anderson, showed that screens percentage was proportionate to plant population and grain set but inversely related to post-anthesis rainfall and associated drought stress [28]. Additionally, the water and nitrogen status before to anthesis had a significant impact on grain-set.

High nitrogen availability generally increased screening %, albeit cultivar had an impact on this pattern. Small pinched grains are screened, while small non-shrivelled grains have preferable milling and other end-use qualities [29]. Small kernels do not directly affect milling yield, but the removal of pinched and small grain before milling has an impact on the economics of milling because of the substantial losses involved in the refining process. As a result, the measurement of screens offers crucial commercial data on milling-related losses. Similar to screens, grain size heterogeneity—the percentage of grain that falls into different size classes—is a crucial sign of milling yield. For instance, grain that is not screened and is skewed toward small grain size is likely to have a lower milling yield. Test weight, which indicates the bulk density of grain, is the weight of a measured volume of grain stated in kilograms per hectolitre. While low test weights are linked to either undersized and/or pinched kernels or weather-damaged grain with a high water content, higher test weights indicate larger, higher quality grain.

2.1.1. Elevated CO₂ Levels (Concentration) in the Atmosphere

The impact of eCO₂ on milling yield for a variety of FACE experiments has been inconsistent, either increasing [11] or having no effect [30]. Similar to the FACE experiment, there was no impact of eCO₂ on grain milling yield for three commercial types of wheat in southern Australia [31]. In contrast, the growing season had a substantial impact on milling output, demonstrating that water stress had a greater impact than atmospheric CO₂ levels. Test weight responded to milling yield in a consistent manner. Hoky et al., found that the effect of elevated CO₂ on kernel size was negative [15], Hoky and Fangmeier, found no effect [32], and Panozzo *et al.*, found an increase [31], which may be related to the effects of temperature and post-anthesis water availability on defining grain size when grain number and yield potential have increased as a result of elevated CO₂ concentration. There may also be a change in sink-source ratios brought on by eCO₂.

2.1.2. Heat Exhaustion (Stress) and High Temperatures

Increased warmth accelerates crop development, which reduces the length of the grain filling period, raises the screening percentage, and causes starch production and deposition that results in small grains [33]. A single grain's weight has been seen to decrease by as much as 4% for every 1°C increase in temperature above 18°C, despite water not being a limiting factor. This suggests that the effects of high temperatures may operate independently of crop water availability [13]. The heterogeneity in grain size within a

crop is also likely to grow as a result of high temperature impacts during the grain filling phase. Spikelets and florets often fill in a specific order according on where they are on a developing wheat spike [34]. When compared to the kernel on distal spikelets and florets, the central spikelets and proximal florets have the advantage of flowering earlier and gaining priority allocation of assimilates, leading to bigger grain size. Abiotic stress will often cause upper and lower spikelets and distal florets to either abort or produce tiny grains, such as high temperatures that limit the availability of starch for deposition [35]. There is also a relationship between the spikelet's position and the variation in N supply and variation in grain nitrogen content [34]. For a variety of wheat cultivars, macro- and micronutrient contents drop at grain locations farther from the rachis [36]. So, in addition to reducing grain set, water and temperature stress will also result in greater grain size variation in the crop, which will increase screens, a change in distribution toward smaller grain size, and a consequent decline in milling yield. Given environmental conditions during grain filling, such intra-head variation in grain size and N-concentration resulting from how assimilate is distributed to forming kernels may hold a key to modeling physical grain properties and the extent of N-dilution.

2.2. Functional Characteristics and Grain Chemistry

According to Ferreira et al., the viscoelastic properties of dough are controlled by the ratio of the storage proteins glutenin and gliadin and the size distribution of the former, and are influenced by genetics and environment [33]. Functional properties of wheat are related to grain hardness, protein content (percentage), and composition [37]. Wheat dough's diverse viscoelastic qualities apply to final products including bread, cakes, biscuits, noodles, and pasta. When grain filling is defined by three sequential stages, grain protein concentration is the ultimate result of independent starch and protein increase in the grain (Vos, 1981).

The first 7–14 days following anthesis are a lag period when the rate of starch accumulation is slow and is connected to the definition of the caryopsis structure. The majority of carbohydrates and protein accumulate in the grain at a steady rate during the second (linear) phase. Starch deposition stops during the third phase, although protein accumulation lasts longer and ends closer to maturity. When the post-anthesis environment is non-limiting and the early rapid linear phase is present during the grain filling period, the rate and deposition of carbohydrates are sink-limited. The N reserves accumulated in the leaves and stems during the pre-anthesis period are used to support protein deposition, which is primarily source-limited [38]. Genetic variables also affect the amount of protein in the grain through variations in plant-N accumulation and the efficiency of starch and N transfer during grain filling.

The monomeric and polymeric prolamins known as gliadins and glutenins, respectively, are the grain storage proteins that give dough its viscoelastic qualities [39]. The elasticity (resistance) features of dough are provided by the

polymeric complexes of glutenin, which are crucial in determining the dough strength [40]. Together, the glutenin low molecular weight (LMW) and high molecular weight (HMW) subunits explained 70% of the difference in the measured elasticity [41]. The elasticity of the dough is correlated with the monomeric gliadin proteins. The viscoelasticity of the dough and end-use quality are influenced by the balance between the elasticity (resistance) and extensibility conferred by the relative concentrations of glutenins to gliadins and size distribution of the HMW subunits of glutenin [33].

2.2.1. Elevated CO₂ Levels in the Atmosphere

Chemical composition changes when CO₂ levels are high, especially when it comes to C₃ plants' increased C/N ratios and decreased leaf N concentrations [42]. Numerous theories have been put forth to explain such reductions in leaf N under eCO₂, including dilution mechanisms (increased carbon assimilation under eCO₂ may 'dilute' all other minerals relative to C in biomass), but also more focused theories involving CO₂-effects on N uptake, allocation (such as decreased N allocation to RuBisCo, a significant leaf N pool), or biochemical assimilation, with some or all of them potentially contributing to varying degrees [43]. Consistently lowering atmospheric CO₂ concentration increases Decreases in leaf N concentrations will affect the amount of N that is available for remobilization because N concentrations in cereal grains are the result of significant remobilization of N from leaves. However, any eCO₂-induced changes in timing and rate of N remobilisation during leaf senescence and grain filling may also contribute to the decline in grain protein [44]. In a review of plant CO₂ response, compared the average relative effect of elevated CO₂ (380 vs 550 ppm) on grain protein concentration and found that for open top chambers, closed top chambers, and FACE experiments, respectively, there was a 4.2, 3.9, and 2.3% reduction in grain protein concentration due to elevated CO₂ [32].

Additional FACE studies conducted in Germany and Australia discovered a decrease in grain protein percentage caused by increased CO₂ of 7.4% and 3.7%, respectively [31]. Along with a reduction in absolute grain protein as a result of increased CO₂, a shift in protein composition (glutenins/gliadins ratio) has also been noted, which will change the rheological and mixing properties of dough. In the German FACE, gliadins were significantly lower than glutenins, which resulted in a modest (non-significant) rise in the glutenin/gliadin ratio [15]. Similarly, Blumenthal *et al.* (1996) discovered that the glutenin/gliadin ratio remained steady despite an overall decrease in protein %, whereas Wieser *et al.*, noticed an increase in the glutenin/gliadin ratio [42]. The functional characteristics of dough and bread are often impacted by both a decrease in grain protein percentage and a changed protein composition [30]. Currently, a protein content of around 11.5% is needed to produce bread with an acceptable level of quality [32]. Therefore, in a CO₂-rich environment, a global decrease in grain protein may result in an increase in wheat whose protein content is below the

minimum requirement for making bread. However, if the bread-making process could be adjusted to accommodate wheat with lower protein levels, this protein threshold might be lowered.

In experiments, the effects of eCO₂ on dough rheology resulted in a 34% significant reduction in dough resistance, a non-significant increase in extensibility, and a 9% significant reduction in loaf volume [15]. Similar to this, across three growing seasons, a FACE experiment on wheat in southern Australia showed a persistent and significant decrease in loaf volume of between 6 to 10%. For two of the three seasons examined, dough extensibility considerably decreased under eCO₂, while dough strength was unaffected by CO₂ concentration [31]. The effects of eCO₂ on industrial processes and functional qualities are probably varied and less significant than variations in the absolute concentration of grain protein. The impetus for creating adaptation methods through agronomic and breeding solutions to reduce the impact on human nutrition and the market value of staple grains in a high CO₂ future comes from a decline in grain quality caused by worldwide increases in atmospheric CO₂.

2.2.2. Heat Exhaustion and High Temperatures

The characteristics of dough are greatly weakened by heat stress [45]. Protein content and dough strength increase when temperature is raised to a certain point during grain filling, but prolonged high temperatures (up to 30 °C) and heat shock (greater than 30 °C) change the ratio of protein to starch in the grain, which has a negative impact on end-use properties like dough strength, extensibility, and loaf volume. Protein content is seen to rise at high temperatures during the grain filling process [40]. The rate of protein accumulation is mainly unaltered at temperatures above 30°C, whereas the rate of starch accumulation reduces [12], leading to greater grain protein content. Similarly, DuPont *et al.* (2006) showed that grain protein accumulation translated to a compensation of starch accumulation under shorter length of grain development associated with high temperature, as opposed to starch, and that grain protein concentration increased under rising temperature.

Although the amount of protein in grains increases at high temperatures, both the composition and the functional characteristics of both starch and protein are also changed [21]. Two kinds of polymers, amylose and amylopectin, which are made up of straight-chained and highly branched molecules, respectively, make up starch. When grainfilling is subjected to heat stress (>30°C), the amylose/amylopectin ratio rises, which lowers the elasticity of the dough. Temperature also affects how evenly the starch granules are distributed in size [46]. The ability to model the distribution of starch granule sizes and estimate emergent properties like grain milling, starch digestibility, and dough viscoelastic proteins is made possible by an understanding of the relationship between temperature during the grain filling phase and the deposition of starch granules.

Although in one study a reduction in glutenin due to post-anthesis heat stress translated to greater dough strength, in

most cases high post-anthesis temperatures, which cause a heat-shock response, translate to a reduction in dough strength that is linked with a reduction in the HMW glutenin subunits [40, 47]. Typically, during the grain filling phase, high temperatures ($>30^{\circ}\text{C}$) for even brief periods (a few days) reduce the synthesis of glutenin or result in a relative drop in the glutenin/gliadin ratio [40]. According to Stone and Nicolas, cultivar variation in protein composition can make it difficult to assess the precise consequences of heat stress [23].

Blumenthal *et al.*, have put out a number of suggestions to explain the alteration in dough-protein function brought on by heat stress during grain filling [47]. Briefly these include (i) the reduction in the glutenin/gliadin ratio due to gliadin synthesis being maintained while glutenin synthesis decreased, during heat stress, translates to weaker dough properties, (ii) the proportion of larger sized glutenin polymers in the mature grain, which is correlated with dough strength, are reduced due to heat stress limiting enzymes supporting the disulphide bonding and glutenin polymer size accordingly, (iii) the synthesis of heat shock proteins (HSP), which could prevail in the mature grain, weakens the dough structure, and (iv) the polymerization process of gluten proteins is disrupted due to HSP inducing disaggregation and hydrolysing of proteins under heat stress conditions. The size distribution of glutenin polymers, as determined by the proportion of sodium dodecyl sulfate (SDS) insoluble polymers within the glutenin protein fraction, is considered an important determinant of dough visco-elasticity [33].

SDS-insoluble glutenin polymers decreased as a result of heat shock conditions (several days over 32°C at 6 DAA) as well as chronically high temperatures during the grain filling process that reached up to 30°C [18]. Additionally, this study found that the tested wheat cultivars responded differently, suggesting a chance to improve the stability of grain quality under temperature stress. For durum wheat, SDS-insoluble glutenin polymer synthesis seemed to start early in the grain filling phase (as early as 7 DAA), where insolubilization of glutenin polymers occurred in concert with the continuous dehydration of the grain [48]. Overall, the protein polymerization process and the emerging size distribution of glutenin protein polymers can be used to link the high temperature impacts during the grain filling phase with the functional qualities of wheat flour.

2.3. Combined Effect of High Temperature and Levels CO_2 on Grain Quality

The maintenance of grain production and the quality of staple crops around the world is significantly hampered by rising atmospheric CO_2 concentration, increase in average temperature, limited water supply, and increased frequency of heat waves in Mediterranean-type environments, where the grain filling phase of temperate crops typically coincides with high temperatures and terminal drought. The potential for greater pre-anthesis growth and yield under elevated CO_2 and an intensifying terminal drought may result in conditions known as "haying off", where in incomplete grain fill becomes more frequent [49].

As a result, the grain would have a lower milling yield and greater screening losses. In order to improve baking quality, heat shock may increase the gliadin/glutenin ratio while increased CO_2 decreases gliadin synthesis [15]. These two effects may work against one another. However, the overall drop in protein content brought on by rising CO_2 and high temperature, which limits the production of glutenin protein polymers, is expected to have a disproportionately large impact on the bread's baking characteristics. While the change in other abiotic stresses like temperature and rainfall patterns will be localized, the rise in atmospheric carbon dioxide is a worldwide event. As a result, if effective mitigating techniques are not found, the global output and quality of staple grains is likely to become more variable and could even drop. Crop biophysical models offer one way to study the intricate relationship between climate and weather on crop growth and offer a theoretical framework for agronomic or genetic adaptive methods.

3. Approaches for Enhancing Grain Quality Parameters

3.1. Breeding for Quality

In traditional plant breeding, the goal is to create populations of plants with superior quality attributes by producing variety through sexual crosses between chosen genotypes, frequently with contrasting qualities. In recent years, breeders have created some varieties with high-quality traits using traditional plant breeding techniques, and wheat production has been steadily rising. However, there are numerous breeding limitations that affect the genetic enhancement of wheat quality [50]. Schmidt *et al.*, noted that the loaf volume reflects environmental variables. It is a potent barrier to breeding improvements in wheat quality [51]. Wheat protein in lines developed from a hybrid between Atlas 66 and Naphal was improved by [52]. These lines produced grain with a higher protein content than parent cultivars as a result of transgressive segregants. Using *Hordeum chilense* as a donor, created durum wheat with high yellow pigment [53].

3.1.1. Glutenin and Gliadin's Role in Enhancing Wheat Grain Quality

Wheat stands out among the grains because its flour is the only one that can create dough with the rheological characteristics needed for a larger variety of dishes. The majority of proteins in dough are transformed into gluten complex. The primary contributors to the rheological and end product producing qualities of wheat flour are the storage proteins from wheat, specifically gliadin and glutenin. With molecular weights of nearly a million daltons, glutenin proteins are among the biggest protein molecules in nature, according to research on flow fractionation and gel filtration [54, 55]. Based on their mobility on SDS-PAGE, the high molecular weight (HMW) and low molecular weight (LMW) glutenin subunits have been identified as the two main

classes of glutenin subunits in wheat endosperm [54]. Because they are parts of the glutenin polymer, high molecular weight glutenin subunits (HMW-GS) are crucial in determining the distinct visco-elastic characteristics of wheat dough [56]. The HMW-GS are encoded at the Glu-1 loci, also known as Glu-1A, Glu-1B, and Glu-1D, on the long arms of group 1 chromosomes (1A, 1B, and 1D, respectively).

3.1.2. Traditional Methods' Drawbacks

Simple qualities can be improved quickly and easily through breeding, such as plant height and grain count. But when it comes to quality characteristics, evaluation of the finished product is necessary. As a result, only a certain amount of lines can be examined. A considerable number of grain samples are needed for direct estimation through milling and baking, which is expensive, time-consuming, and typically not possible in early breeding generations [4]. In order to solve this issue, indirect tests like the alveograph, mixograph, and SDS sedimentation volume have been created to assess the capacity of former generations to produce finished goods. However, the breeder's resources are severely constrained by how time-consuming these methods are [57].

Wheat breeders face significant challenges in enhancing grain quality through breeding and indirect tests; as a result, wheat storage Protein indicators, such as glutenin and gliadin, offer a viable option for enhancing grain quality attributes. By comparing the relative migration of glutenins (HMW and LMW glutenin subunits) and gliadins on Sodium dodecyl sulphate polyacrylamide gel electrophoresis (SDS-PAGE) and Acid Polyacrylamide gel electrophoresis (ACID-PAGE), respectively, it is typically possible to identify the allelic pairs present in a genotype. SDS-PAGE has been widely utilized to pinpoint the HMW and LMW glutenin subunit alleles and investigate how they affect the quality of bread [58, 59]. The technique's downside, though, is that various glutenin subunits can occasionally appear to have the same relative mobility, leading to the inaccurate identification of some HMW-GS alleles that are functionally unique [60]. For wheat breeders, the availability and usage of multiple quality-based markers met the intended goal and made the selection of the required trait relatively simple.

3.2. DNA Indicators for Quality Attributes as of Right Now

Plant breeders primarily use three types of markers: morphological, biochemical, and DNA markers (Collard *et al.*, 2005). Wheat breeding uses morphological and biochemical markers extensively [2]. The main drawbacks of morphological and biochemical markers are their scarcity and susceptibility to environmental influences [61]. Due to their availability and genome coverage, DNA markers are the most popular sort of markers. They result from a variety of DNA alterations, including point mutations, insertions, inversions, duplications, deletions, translocations, and mistakes made during the replication of tandemly repeated DNA [62]. For marker-assisted selection (MAS) in wheat breeding, breeders are currently paying more attention to

DNA markers [63, 64].

3.3. Issues and Upcoming Prospects

In vitro tissue culture, gene transfer, and the use of DNA markers are just a few of the biotechnological techniques that have emerged as potent tools to supplement traditional methods of breeding. These techniques create the genetic variability required for desirable traits and shorten the time it takes to create cultivars with improved traits. Particle bombardment has been a popular technique for developing wheat transformation systems that are incredibly effective [65, 66]. The integration and expression of particular HMW-GS genes may enhance the quality of wheat used to make bread, according to studies on gene dosage [67, 68]. The goal of wheat quality enhancement studies is to increase bread-making quality, hence efforts have been undertaken to modify the fraction of HMW-GS that is related with optimal bread-making quality. Breeding programs can benefit greatly from the DNA markers for desirable features. For screening a large population of segregating progenies for simple features, PCR, which only needs a little amount of DNA, is becoming increasingly useful. Through MAS, undesirable alleles can be completely eradicated or significantly reduced in the early phases of plant development [69].

The expense of developing and analyzing current DNA marker technologies is rather significant, and they also have low throughput and a requirement for sequence data. In order to quickly and cheaply find and screen a large number of markers for modern wheat breeding's rapid and accurate analysis of germplasm, mapping, and MAS, novel marker systems of high throughput analysis are needed. In conclusion, the last 20 years have seen a revolution in biological and agricultural science due to the creation of numerous DNA-based markers. When it comes to early generation screening and testing, DNA markers are particularly effective for genotype screening in wheat breeding projects aimed at improving quality. However, there are still a number of obstacles facing MAS in crop breeding, and the achievement of practical benefits is taking longer than anticipated. The poor quality of markers and high prices of DNA assays are the primary causes of this delay [70]. Multiple markers can be scored in a single reaction due to the durability and robustness of the PCR-used markers.

4. Overview of Pasta Industries in Ethiopia

4.1. General Perspective

Durum wheat is primarily delivered for producing pasta and macaroni, whereas bread wheat is primarily delivered for making bread. Despite the fact that statistics in Ethiopia don't seem to distinguish between bread and durum wheat, both types of wheat are grown, research is being done to advance both types of wheat's varieties, and over 40 durum and 60 bread wheat varieties have been made available in Ethiopia

over the past seven decades. Even though some of the more ancient kinds are no longer grown because of stem rot races, newer releases have far higher levels of resistance and are still used in farming. Durum wheat produced and released in Ethiopia isn't well taken by businesses due to passive value chain. Subsequently, the pasta makers have invested a lot for under-quality grain, colorants and pastazymes.

Ethiopia now has more than 20 pasta-making industries. The weak supply chain from the producer to the factory, in the opinion of the pasta factory's proprietors, hurts both

producers. The acceptable quality of wheat by some pasta-making industries in Ethiopia, including Kaliti Food Complex, K. O. J. J. Food Processing Complex PLC, Ahwan Food Complex PLC, Asteco Food Complex PLC, Booze and Kebrone Flour Factory and Food Complex, Adea Food Complex PLC, and Ahfan Food Complex PLC, has been found to be important. Other factors include impurity, hectoliter weight, protein content, gluten content, ash content, moisture content (table 1).

Table 1. Pasta making quality parameters required by industries [71].

Physico-chemical quality	Acceptable by pasta making industries						
	Kaliti	Booze	Asteco	Ahwan	Ahfa	K. O. J. J	Adea
Impurity	≤10%	≤10%	≤9%	≤10%	≤10%	≤10%	≤10%
HLW	72-78%	72-80	76-78%	76-83%	72-76%	72-81%	70-78
Protein	10-12%	12%	10%	10-12%	10-12%	10-12%	>10
Gluten	>25%	32%	26-28%	30-40%	29-33%	27%	>26%-32
Ash	0.5-1%	<1%	1%	1%	<1%	1%	1%
Moisture%	12%	11.5%	12.5%	<12%	12%	<12%	<12%
Falling number	>300 sec.	280-350 sec	>300 sec.	>280 sec.	>300 sec.	>250 sec.	>300 sec.

4.2. Some Challenges and Opportunities Related to Pasta Industries in Ethiopia

Facts that are holding back the growth of Ethiopian pasta industry, from the perspective of research and pasta manufacturers are as follow;

4.2.1. Brokers

Brokers are the primary market system generators in Ethiopia. Grain was purchased by industries through middlemen (brokers). They constantly have suspicions that they might be lying. Brokers occasionally "skim" extra earnings off the price that they actually get in the market rather than the price that they represent to the industries, it should be added. In general, brokers have been establishing a strong connection with producers in a variety of areas, such as in religion, Ekub, family, and various social norms. This has been a source of conflict between industries and brokers, or generally speaking, every region of the country. It is consistent with the existence of broader social norms that direct economic relations that informal mediation is frequently used instead of legal action. They are well off financially. Therefore, before crop harvest, brokers supply capital and production inputs. Industries find it challenging to engage in direct trade with an unidentified partner because of the unlawful or oral nature of contracts and the lack of legal enforcement of contracts. Mixing low-quality (soft and shriveled grain) with high-quality grain, introducing contaminants (stone, nails, soils, and others), and increasing moisture level are all examples of adulteration (adding water).

4.2.2. Unions and Cooperatives in Agriculture

The establishment of agricultural cooperatives and unions in Ethiopia is closely related to and accountable for resolving the issues that individual farmers were unable to handle on their own. According to Proclamation No. 47/1998,

cooperative groups should coordinate their expertise, resources, and labor in order to tackle social and economic problems [72]. The Ethiopian government has also made efforts for the growth of cooperatives and unions, which are opportunities. Studies revealed that the rise of cooperatives is accelerating across the nation. Industries assert that the goal of unionization was to facilitate the market system by providing high-quality inputs (grains) at competitive prices. However, some of the agricultural unions have been converted to flour mills due to confusing regulations and proclamations. This objectively measurable growth and improvement is for both individuals and the benefit of the nation's industrialization-driven policies. The market system and authorization, however, have been disturbed and dissuaded for pasta producers. Interferences in cooperative decision-making by the government, brokers, and other development partners; unlawful incursions and the use of cooperatives for political ends by local governments; lack of a defined exit strategy by cooperative initiators; and provision of grains at a premium price.

4.2.3. The Market for Durum Wheat Is Not Part of Ethiopia's Commodity Exchange

Every industry that produces pasta was concerned about the problem. In order to ensure the development of an effective modern trading system that would safeguard buyers, sellers, and intermediaries, the wheat market system should be operated under Ethiopian commodity exchange (ECX), just like coffee, chickpeas, and other commodities. This is due to the large share of Ethiopian wheat product and role to the large society. Smallholder farmers in particular stand to gain from ECX's strategies for improving financial and other logistics, promoting traceability in the trading system for private traders, setting up a regulatory framework for policing the system's brokers, and empowering cooperative unions to participate in the value chain.

There is a low supply of durum wheat grains on the market,

which increases the chance of fraud. Since the majority of the wheat grain market has no owners, the government is unable to levy taxes on such a substantial resource. Additionally, ECX created a brand-new technique of exchange and a marketing system that protects both parties to the deal while coordinating better links and faster. In contrast to the previous trading system, it is a modern trading system based on standard crop contracts that defines standard specifications for commodity grades, transactions, size, payment and delivery, and trade order matching [73].

4.2.4. Pasta Made Using Bread Wheat Flour

High-quality raw materials are the foundation of any good pasta product. Due to its distinctive qualities, such as a relatively high yellow color concentration, low lipoxigenase activity, and a high protein level appropriate for optimum cooking quality, durum wheat (*Triticum durum*) is best suited for pasta (Aalami et al., 2007). The dough prepared from durum wheat semolina is perfect for the production of pasta. For pasta to cook well, it is vital to consider the quantity, type, and strength of the proteins, in particular the gluten. Bread wheat has progressively replaced the durum wheat that had been grown in Ethiopia for thousands of years. However,

there has been a consistent increase in pasta demand. It is anticipated that the pasta factories need between 1000 and 1500 quintals of product every day. According to Ethio-Italy project unpublished report (March 2019), in three Zones of Oromia (Bale, West Arsi, and Arsi), small- and large-scale farmers could be able to produce 2.3 million quintals main production season [71]. This ensured that Ethiopia can export durum wheat to the world market.

The survey result depicted that; few pasta makers are seeking bread wheat flour for pasta making due to; (1) In the milling process durum wheat takes long conditioning time (24 hours) than bread wheat (17 hours). (2) Intervention of new technologies (enzymes), some pasta makers are using new enzymes which enabled pasta makers to make pasta only from bread wheat flour (soft wheat). (3) Soft wheat relatively has a low price. (4) No national policy or rules which enforce pasta makers to make pasta only from durum wheat. (5) Limited awareness of customers about quality products; industries have high market demand; they can sell both high quality and poor quality at the same price. This has been a challenge for the durum wheat value chain and value through the above-mentioned reasons.

Table 2. Some pasta making industries profile and potential wheat supplier areas for pasta makers in Ethiopia [71].

Some Ethiopian pasta making industries profile					
Name of Factory	Year of establishment	Address	Product Name	Output (Qt/day)	Customer
Kaliti food complex S. C	1930	Addis Ababa	Ceralia & Knick knack	1500	Organizations and Retailers
Asteco food complex L. C	2004	Addis Ababa	Tena, Altan & Shafe luka	1200	
K. O. J. J food complex L. C	1994	Addis Ababa	K. O. J. J	1400	
Kebrone complex L. C	2001	Addis Ababa	Booze	1000	
Booze food complex L. C	2001	Addis Ababa	Booze	1000	
Ahfa food complex L. C	NA	Addis Ababa	Oche	250	
Adea food complec	NA	Debre zeit	Adea	NA	
Ahwan food complex L. C	2001	Adama	Ahwan	NA	
Potential wheat supplier areas, quality property and impurity level					
Area	Quality property		Impurity level	Remark	
Arsi	Good protein and Hard		<10%	Very good	
West Arsi	Good protein and Hard		<10%	Very good	
Bale	Good protein and Hard		<10%	Very good	
Minjar	Very hard and high protein		<2%	Excellent	
Ejere	Good protein and Hard		<10%	Some pocket areas	
Arsi Negele	Good protein and very hard		<10%	Belg season wheat does not have good quality.	
Western Hararge	Good protein and Hard		<10%	Excellent	
Northern Somali	Very hard and high protein		<5%	Excellent	
East Gojam	Hard and good protein		10-15%	Red color of soil has bad effect on the pasta quality	
North Shewa	Hard and good protein		10-15%	Dust (threshed on traditional 'awudma ')	
Meskan/Mareko	Very hard and high protein		<10%	Very good	
Area	Qualitv prperty		Impuritv level	Remark	

4.2.5. Color Additives as a Colorant

Any dye, pigment, or other ingredient that, when added to or applied to pasta, imparts color to meet customer expectations is considered a yellow color additive (yellow pasta). One of the most important elements that directly influences consumers' food preferences and appetites is color. Color additives are employed in foods for a variety of reasons and may have an impact on the real and perceived nutritional content of food through influencing flavor recognition and product desirability (Martins et al., 2016). Therefore, to manufacture yellow pasta, a

small number of Ethiopian pasta makers use colorants on bread wheat flour. However, colorants can result in reactions like digestive issues like diarrhea and colicky pains, nervous issues like hyperactivity, insomnia, and irritability, respiratory issues like asthma and rhinitis, sinusitis, and hives, itching, rashes, and swelling, and skin issues like hives, itching, rashes, and swelling (<https://www.betterhealth.vic.gov.au/health/conditionsandtreatments/food-additives>).

4.2.6. Using Pastazym to Improve Quality

Economically speaking, soft wheat flour might be used to

make pasta; but, due to the inferior sensory characteristics and cooking quality of such goods, durum semolina must be used instead. In order to improve the inferior quality of unconventional pasta, chemicals and enzymes have been predominantly used [74]. Soft wheat farina pasta's hardness increased, according to Haber et al. in 1978. The cooking quality, color, and sensory properties of high-temperature dried soft wheat pasta supplemented with cowpea were estimated in trials [74]. Starch and protein compete with one another for water when pasta is cooking (Pagani, 1986). Also, starch granules enlarge and gelatinize more quickly when less protein surrounds them. It is therefore hypothesized that adding legumes, with their higher protein content, causes slower starch swelling and, as a result, a longer time period for gelatinization to take place, resulting in a longer cooking time. Pasta zymes' drawbacks include the following: (1) Affects the protein profile of allergens; (2) Low immune reactivity; (3) Lower sensory characteristics; and (4) Low firmness, cream color, and flavor.

5. Conclusion

Ethiopian industries still rely on soft and hard bread wheat flour by employing pastazymes and colorants due to the low volume of durum wheat output there. Brokers, improper use of cooperatives and unions, market structures, and the use of pricey additives were the main obstacles that hindered the expansion of the Ethiopian pasta sector. The wheat cultivars are the outcome of thorough selection by breeders to satisfy both quality and agronomic requirements for the wide range of end products, including confectionery, biscuits, cakes, and premium pastas. Other end products include traditional pan, sponge and dough pan, flat or steamed breads, chapatti, frozen doughs, yellow alkaline or Udon style noodles, and frozen doughs. The relationship between grain functional characteristics, glutenin polymer production, and grain temperature during the grain filling phase may offer a conceptual framework for modeling wheat's post-anthesis environment. In particular, if the interactive effects of higher CO₂, high temperature, and trait testing have been taken into consideration, grain quality data from FACE experimental programmes are expected to be of substantial use in the creation and testing of grain quality models. Overall, the development of crop models that take into account expanded functional, whole-grain, and end-use characteristics will give researchers a strong tool for creating agronomic and breeding adaptation strategies to counteract the effects of climate change on the production and quality of grain.

References

- [1] Rosegrant, MW, Agcoili M (2010). Global food demand, supply and food prospects. International food policy research Institute, Washington, D. C., USA.
- [2] Gale KR (2005). Diagnostic DNA markers for quality traits in wheat. *J Cereal Sci.* 41: 181-192.
- [3] Duveiller E, Singh RP, Nicol JM (2007). The challenges of maintaining wheat productivity: pests, diseases, and potential epidemics. *Euphytica.* 157: 417-430.
- [4] Gross C, Bervas E, Chanliaud G, Charmet G (2007). Genetic analysis of bread making quality scores in bread wheat using a recombinant inbred line population *Theor Appl Genet.* 115: 313-323.
- [5] FAOSTAT, 2014. Agricultural Data. Food and Agriculture Organisation of the United Nations, Rome, Online at <http://faostat.fao.org/>.
- [6] Md Zaidul IS, Abd Karim A, Manan DMA, Ariffin A, Nik Norulaini, NA, Mohd Omar AK (2004) farinograph study on the viscoelastic properties of sago/wheat flour dough systems. *J Sci Food and Agric.* 84: 616-622.
- [7] Abbasi H, Ardabili SMS, Emam-Djomeh Z, Mohammadifar MA, Zekri M, Aghagholizadeh R (2012) Prediction of Extensograph properties of wheat-flour dough: Artificial neural networks and a genetic algorithm approach. *J Texture Studies.* DOI: 10.1111/j.1745-4603.2011.00342.x.
- [8] Martinant JP, Nicolasa Y, Bouguennec A, Popineaub Y, Saulnier L, Branlard G (1998) Relationships between mixograph parameters and indices of wheat grain quality. *J Cereal Sci.* 27: 179-189.
- [9] Codina GG, Mironeasa S, Mironeasa C, Popa CN, Tamba Berehoiu R (2012) Wheat flour dough Alveograph characteristics predicted by Mixolab regression models. *J Sci Food and Agric.* 92: 638-644.
- [10] Guttieri, M. J., Stark, J. C., O'Brien, K., Souza, E., 2001. Relative sensitivity of spring wheat grain yield and quality parameters to moisture deficits. *Crop Sci.* 41, 327-335.
- [11] Fernando, N., Panozzo, J., Tausz, M., Norton, R., Fitzgerald, G., Seneweera, S., 2012. Rising atmospheric CO₂ concentration affects mineral nutrient and protein concentration of wheat grain. *Food Chem.* 133, 1307-1311.
- [12] Asseng, S., Ewert, F., Martre, P., Rotter, R. P., Lobell, D. B., Cammarano, D., Kimball, B. A., Ottman, M. J., Wall, G. W., White, J. W., Reynolds, M. P., Alderman, P. D., Prasad, P. V. V., Aggarwal, P. K., Anothai, J., Bass, B., Biernath, C., Challinor, A. J., De Sanctis, G., Doltra, J., Fereres, E., Garcia-Vila, M., Gayler, S., Hoogenboom, G., Hunt, L. A., Izaurralde, R. C., Jabloun, M., Jones, C. D., Kersebaum, K. C., Koehler, A. K., Muller, C., Naresh Kumar, S., Nendel, C., O'Leary, G. J., Olesen, J. E., Palosuo, T., Priesack, E., Eyshi Rezaei, E., Ruane, A. C., Semenov, M. A., Shcherbak, I., Stockle, C., Stratonovitch, P., Streck, T., Supit, I., Tao, F., Thorburn, P. J., Waha, K., Wang, E., Wallach, D., Wolf, J., Zhao, Z., Zhu, Y., 2015. Rising temperatures reduce global wheat production. *Nat. Clim. Change* 5, 143-147.
- [13] Conroy, J. P., Seneweera, S., Basra, A. S., Rogers, G., Nissen-Wooller, B., 1994. Influence of rising atmospheric CO₂ concentrations and temperature on growth, yield and grain quality of cereal crops. *Aust. J. Plant Physiol.* 21, 741-758.
- [14] Kimball, B. A., Idso, S. B., 1983. Increasing atmospheric CO₂: effects on crop yield, water use and climate. *Agric. Water Manage.* 7, 55-72.
- [15] Hogg, P., Wieser, H., Kohler, P., Schwadorf, K., Breuer, J., Franzaring, J., Muntifer, R., Fangmeier, A., 2009. Effects of elevated CO₂ on grain yield and quality of wheat: results from a 3-year free-air CO₂ enrichment experiment. *Plant Biol.* 11, 60-69.

- [16] O'Leary, G. J., Christy, B., Nuttall, J. G., Huth, N. I., Cammarano, D., Stockle, C., Basso, B., Shcherbak, I., Fitzgerald, G., Luo, Q., Farre-Codina, I., Palta, J. A., Asseng, S., 2014. Response of wheat growth, grain yield and water use to elevated CO₂ under a free air CO₂ enrichment (FACE) experiment and modelling in a semi-arid environment. *Global Change Biol.*, <http://dx.doi.org/10.1111/gcb.12830>, in review.
- [17] Porter, J. R., Gawith, M., 1999. Temperatures and the growth and development of wheat: a review. *Eur. J. Agron.* 10, 23–36.
- [18] Wardlaw, I. F., Blumenthal, C. S., Larroque, O., Wrigley, C. W., 2002. Contrasting effects of chronic heat stress and heat shock on kernel weight and flour quality in wheat. *Funct. Plant Biol.* 29, 25–34.
- [19] Jenner, C. F., 1994. Starch synthesis in the kernel of wheat under high temperature conditions. *Aust. J. Plant Physiol.* 21, 791–806.
- [20] McDonald, G. K., Sutton, B. G., Ellison, F. W., 1983. The effect of time of sowing on the grain yield of irrigated wheat in the Namoi Valley, New South Wales. *Aust. J. Agric. Res.* 34, 229–240.
- [21] Farooq, M., Bramley, H., Palta, J. A., Siddique, K. H. M., 2011. Heat stress in wheat during reproductive and grain-filling phases. *Crit. Rev. Plant Sci.* 30, 1–17.
- [22] Tashiro, T., Wardlaw, I. F., 1990. The response to high temperature shock and humidity prior to and during the early stages of grain development in wheat. *Aust. J. Plant Physiol.* 17, 551–561.
- [23] Stone, P. J., Nicolas, M. E., 1994. Wheat cultivars vary widely in their responses of grain yield and quality to short periods of post-anthesis heat stress. *Aust. J. Plant Physiol.* 21, 887–900.
- [24] Talukder, A., Gill, G., McDonald, G., Hayman, P., Alexander, B., 2010. Field evaluation of sensitivity of wheat to high temperature stress near flowering and early grain set. In: Dove, H., Culvenor, R. (Eds.), 15th Australian Agronomy Conference. Christchurch, New Zealand <http://www.agronomy.org.au/>.
- [25] Hammermeister, A., 2008. The Anatomy of Cereal Seed: Optimizing Grain Quality Involves Getting the Right Proportions within the Seed. Organic Agriculture Centre of Canada.
- [26] Marshall, D. R., Ellison, F. W., Mares, D. J., 1984. Effects of grain shape and size on milling yield in wheat. I Theoretical analysis based on simple geometric models. *Aust. J. Agric. Res.* 35, 619–630.
- [27] Mabilbe, F., Abecassis, J., 2003. Parametric modelling of wheat grain morphology: a new perspective. *J. Cereal Sci.* 37, 43–53.
- [28] Sharma, D. L., Anderson, W. K., 2004. Small grain screenings in wheat: interactions of cultivars with season, site, and management. *Aust. J. Agric. Res.* 55, 797–809. Shewry, P. R., 2009. Wheat. *J. Exp. Bot.* 60, 1537–1553.
- [29] Gaines, C. S., Finney, P. L., Andrews, L. C., 1997. Influence of kernel size and shrivelling on soft wheat milling and baking quality. *Cereal Chem.* 74, 700–704. Gupta, R. B., Batey, I. L., MacRitchie, F., 1992. Relationships between protein and functional properties of wheat flours. *Cereal Chem.* 69, 125–131.
- [30] Kimball, B. A., Morris, C. F., Pinter Jr., P. J., Wall, G. W., Hunsaker, D. J., Adamsen, F. J., LaMorte, R. L., Leavitt, S. W., Thompson, T. L., Matthias, A. D., Brooks, T. J., 2001. Elevated CO₂, drought and soil nitrogen effects on wheat grain quality. *New Phytol.* 150, 295–303.
- [31] Panozzo, J., Walker, C. K., Partington, D. L., Neumann, N. C., Tausz, M., Seneweera, S., Fitzgerald, G. L., 2014. Elevated carbon dioxide changes grain protein concentration and composition and compromises baking quality. A FACE study. *J. Cereal Sci.* 60 (3), 461–470.
- [32] Hogg, P., Fangmeier, A., 2008. Effects of elevated atmospheric CO₂ on grain quality of wheat. *J. Cereal Sci.* 48, 580–591.
- [33] Ferreira, M. S. L., Martre, P., Mangavel, C., Girousse, C., Rosa, N. N., Samson, M., Morel, M., 2012. Physicochemical control of durum wheat grain filling and glutenin polymer assembly under different temperature regimes. *J. Cereal Sci.* 56, 58–66.
- [34] Stoddard, F. L., 1999. Variation on grain mass, grain nitrogen, and starch B-granule content within wheat heads. *Cereal Chem.* 76, 139–144.
- [35] Bremner, P. M., 1972. Accumulation of dry matter and nitrogen by grains in different positions of the wheat ear as influenced by shading and defoliation. *Aust. J. Biol. Sci.* 25, 657–668.
- [36] Calderini, D. F., Ortiz-Monasterio, I., 2003. Grain position affects grain macronutrient and micronutrient concentration in wheat. *Crop Sci.* 43, 141–151.
- [37] Johansson, E., Prieto-Linde, M. L., Jonsson, J. O., 2001. Effects of wheat cultivar and nitrogen application on storage protein composition and breadmaking quality. *Cereal Chem.* 78, 19–25.
- [38] Jenner, C. F., Ugalde, T. D., Aspinall, D., 1991. The physiology of starch and protein deposition in the endosperm of wheat. *Aust. J. Plant Physiol.* 18 (3), 211–226.
- [39] Shewry, P. R., 2009. Wheat. *J. Exp. Bot.* 60, 1537–1553.
- [40] Panozzo, J., Eagles, H. A., 2000. Cultivar and environmental effects on quality characters in wheat. II protein. *Aust. J. Agric. Res.* 51, 629–636.
- [41] Gupta, R. B., Batey, I. L., MacRitchie, F., 1992. Relationships between protein and functional properties of wheat flours. *Cereal Chem.* 69, 125–131.
- [42] Wieser, H., Manderscheid, R., Martin, E., Weigel, H. J., 2008. Effects of elevated atmospheric CO₂ concentrations on the quantitative protein composition of wheat grain. *J. Agric. Food Chem.* 56, 6531–6535.
- [43] Buchner, P., Tausz, M., Ford, R., Leo, A., Fitzgerald, G. J., Hawkesford, M. J., Tausz-Posch, S., 2015. Expression patterns of C- and N- metabolism related genes in wheat are changed during senescence under elevated CO₂ in dry-land agriculture. *Plant Sci.* 236, 239–249.
- [44] Taub, D. R., Miller, B., Allen, H., 2008. Effects of elevated CO₂ on the protein concentration of food crops: a meta-analysis. *Global Change Biol.* 14, 565–575.
- [45] Wardlaw, I. F., Wrigley, C. W., 1994. Heat tolerance in temperate cereals: an overview. *Aust. J. Plant Physiol.* 21, 695–703.

- [46] Hurkman, W. J., McCue, K. F., Altenbach, S. B., Korn, A., Tanaka, C. K., Kothari, K. M., Johnson, E. L., Bechtel, D. B., Wilson, J. D., Anderson, O. D., DuPont, F. M., 2003. Effect of high temperature expansion of genes encoding enzymes for starch biosynthesis in developing wheat endosperm. *Elsevier journal of plant science* 164 (5), 873-881. [http://dio.org/10.1016/S0168-9452\(03\)00076-1](http://dio.org/10.1016/S0168-9452(03)00076-1)
- [47] Blumenthal, C. S., Stone, P. J., Gras, P. W., Bekes, F., Clarke, B., Barlow, E. W. R., Appels, R., Wrigley, C. W., 1998. Heat-shock protein 70 and dough-quality changes resulting from heat stress during grain filling in wheat. *Cereal Chem.* 75, 43–50.
- [48] Ferrise, R., Bindi, M., Martre, P., 2015. Grain filling duration and glutenin polymerization under variable nitrogen supply and environmental conditions for durum wheat. *Field Crops Res.* 171, 23–31.
- [49] Nuttall, J. G., O’Leary, G. J., Khimashia, N., Asseng, S., Fitzgerald, G., Norton, R., 2012a. ‘Haying-off’ in wheat is predicted to increase under a future climate in south-eastern Australia. *Crop Pasture Sci.* 63, 593–605.
- [50] Kadar R, Moldovan V, Tianu M, Marca V (1999) Cercetaqri privind calitatea de panificatie a graului de toamma-In: Contributii ale Cercetaqrii stiintifice la dezvoltarea agriculturii, Tipografia Boema Turda, Vol. VI, 25-34.
- [51] Schmidt JW, Mattern PJ, Johnson VA, Morris R (1974) Investigations of the genetics of bread wheat baking quality. *Genetics Lectures*, Vol. III: 83-101.
- [52] Johnson VA, Mattern PJ, Patterson CJ, Kuhr SL (1985) Improvement of Wheat protein by traditional breeding and genetic techniques. *Cereal Chem.* 62: 350-355.
- [53] Alvarez JB, Martin LM, Martin A (1999) Genetic variation for the carotenoid pigments content in the amphiploid *Hordeum chilense* × *Triticum trugidum* conv. durum. *Plant Breed.* 118: 187-189.
- [54] Huebner FR, Wall JS (1976) Fractionation and quantitative differences of glutenin from wheat varieties varying in baking quality. *Cereal Chem.* 53: 258-269.
- [55] Wahlund KG, Gustavsson M, MacRitchie F, Nylander T, Wannerberger L (1996). Size characterization of wheat proteins, particularly glutenin, by asymmetrical flow field-flow fractionation. *J Cereal Sci.* 23: 113-119.
- [56] Nieto-Taladriz MT, Perretant MR, Rousset M (1994). Effect of gliadins and HMW and LMW subunits of glutenin on dough properties in the F6 recombinant inbred lines from a bread wheat cross. *Theo Appl Genet.* 88: 81–88.
- [57] Howitt CA, Gale KR Juhasz A (2007). Diagnostic markers for quality. In: Wrigley C, Bekes F, Bushuk W (eds) *Gliadin and Glutenin: The unique balance of wheat quality*, AACC International, U.S.A.
- [58] Afshan S, Naqvi FN (2011). Allelic variation in high molecular weight glutenin subunits in Pakistani bread wheat genotypes. *Cereal R. es Commu.* 39: 109-119.
- [59] Ribeiro M, Carvalho C, Carnide V, Guedes-Pinto H, Igrejas G (2011). Towards allelic diversity in the storage proteins of old and currently growing tetraploid and hexaploid wheats in Portugal. *Genet Resour Crop Evol.* 58: 1051-1073.
- [60] Butow BJ, Gale KR, Ikea J, Juhasz A, Bedo Z, Tamas L, Gianibelli MC (2004). Diversity and dissemination of Bx7 glutenin subunits revealed by novel PCR markers and RP-HPLC. *Theor Appl Genet.* 109: 1525-1535.
- [61] Winter P, Kahl G (1995) Molecular marker technologies for plant improvement. *World J Microbio Biotechnol.* 11: 438–448.
- [62] Paterson AH (1996). Making genetic maps. In: Paterson A H (ed) R. G. Landes Company, San Diego, California; Academic Press, Austin, Texas.
- [63] Collard BCY, Mackill DJ (2008). Marker-assisted selection: an approach for precision plant breeding in the twenty-first century. *Phil Trans R Soc B.* 363: 557-572.
- [64] Gupta PK, Landridge P, Mir RR (2010). Marker-assisted wheat breeding: present status and future possibilities. *Molecular Breed.* 26: 145-161.
- [65] Vasil V, Srivastava V, Castillo AM, Fromm ME, Vasil IK (1993). Rapid production of transgenic wheat plants by direct bombardment of cultured immature embryos. *Biotechnology.* 11: 1553–1558.
- [66] Altpeter F, Vasil V, Srivastava V, Vasil IK (1996). Integration and expression of the high-molecular-weight glutenin subunit 1Ax1 into wheat. *Nat Biotechnol.* 14: 1155–1159.
- [67] Flavell RB, Goldsbrough AP, Robert LS, Schnick D, Thompson RD (1989). Genetic variation in wheat HMW glutenin subunits and the molecular basis of bread-making quality. *Biotechnology.* 7: 1281-1285.
- [68] Shewry PR, Tatham AS, Barro F, Barcelo P and Lazzeri P (1995). Biotechnology of breadmaking: unrevealing and manipulating the multi-protein gluten complex. *Biotechnology.* 13: 1185-1190.
- [69] Landjeva S, Korzun V, Börner A (2007). Molecular markers: actual and potential contributions to wheat genome characterization and breeding. *Euphytica.* 156: 271-296.
- [70] Bonnett DG, Rebetzke GJ and Spielmeyer W (2005). Strategies for efficient implementation of molecular markers in wheat breeding. *Mol Breed.* 15: 75–85.
- [71] Mekuria Temtme, Negash Geleta and Tamirat Kore, 2022. Pasta industries in Ethiopia, challenge and Opportunities. *Global scientific journal.* Volume 10, 1954-1962.
- [72] Federal Democratic Republic of Ethiopia (FDRE). 1998. Establishment of Cooperative Societies, Proclamation No. 147/1998. Addis Ababa: Federal Negarit Gazeta.
- [73] Dejen Debeb and Mathews Haile., 2016. Agricultural Cooperatives, Opportunities and Challenges, the Case of Bench Maji Zone, Ethiopia. *Journal of Poverty, Investment and Development.*
- [74] Bergman, C. J., Gilberto, D. G., and Weber, C. W. (1994). Development of a high- temperature – dried soft wheat pasta supplemented with cowpea (*Vigna unguiculata*, IL. Walp). Cooking quality, color, and sensory evaluation. *Cereal Chem.* 71: 523–527.