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Assessment of some quality parameters of organic and conventional wheat flour

BACHELOR'S THESIS

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Declaration

I hereby declare that I have done this thesis entitled 'Assessment of some quality parameters of organic and conventional wheat flour' independently, all texts in this thesis are original, and all the sources have been quoted and acknowledged by means of complete references and according to the Citation rules of the FTA.

In Prague, 2023

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Abstract

Common wheat (*Triticum aestivum*) is a grass widely used for its grain, which has many versatile uses when processed into flour. The composition of the wheat grain as well as the composition of the flour affects the rheological properties of the dough. The thesis aimed to compare the quality parameters of organic and conventional flours and doughs and to monitor changes in the parameters throughout the year. Each month samples of organic and conventional flour were analysed in the laboratory. Flour properties were examined through analyses of moisture content, gluten index and falling number. The rheological properties of the dough were then studied using Mixolab. The results of flour properties showed differences in moisture content, where organic flour mostly did not reach the requirements. Similarly, in wet gluten content, organic flour usually contained less wet gluten than desired unlike conventional flour, which in few of the measurements contained even more than necessary. This suggested that conventional flour was better suited for baking. Nonetheless, the results acquired from Mixolab did not show significant differences between organic and conventional flours throughout most of the year. Only in the last four months starting in October 2022, changes began to occur, although, they were believed to be influenced by the environment, rather than the flour origin, as they occurred in the months following the wheat harvest. Overall, it remained inconclusive whether organic or conventional flour performed better during baking as their differences were not confirmed to significantly affect the finished product.

Keywords: gluten index, Glutomatic, falling number, Mixolab, moisture content

Abstrakt

Pšenice setá (*Triticum aestivum*) je tráva, která se nejvíce používá pro zrno, které má v podobě mouky obrovské množství využití. Složení pšeničného zrna a stejně tak složení mouky ovlivňuje vlastnosti těsta. Cílem práce bylo porovnat kvalitativní parametry mouky a těsta u bio a konvenční mouky a zároveň pozorovat jejich změny během roku. Každý měsíc byly v laboratoři analyzovány vzorky bio a konvenční mouky. Vlastnosti mouky byly pozorovány za pomoci parametrů: vlhkost mouky, gluten index a pádové číslo. Vlastnosti těsta byly zkoumány přístrojem Mixolab. Výsledky vlastností mouky ukázaly rozdíly ve vlhkosti mouky, kde pro bio mouku vlhkost ve většině případů nedosahovala požadovaných hodnot. Podobně tomu bylo u množství mokrého lepku, kde bylo většinou v bio mouce méně mokrého lepku, než je žádáno. Oproti tomu v konvenční mouce bylo v několika pozorováních mokrého lepku dokonce více, než bylo třeba. Tyto výsledky nabízely odpověď, že konvenční mouka měla lepší pekařskou jakost. Ovšem výsledky z Mixolabu neukázaly významné rozdíly mezi bio a konvenční moukou během většiny roku. Až v posledních pár měsících, počínaje říjnem 2022, se ukázaly změny, avšak tyto změny byly připisovány spíše vlivu prostředí než vlivu původu mouky. Bylo tomu tak, protože změny se objevily až v měsících následujících sklizeň. Celkově zůstalo nezodpovězeno, zda měla při pečení lepší vlastnosti bio či konvenční mouka, protože nebyl prokázán významný vliv jejich rozdílných vlastností na finální produkt.

Klíčová slova: gluten index, Glutomatic, pádové číslo, Mixolab, vlhkost mouky

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CD – coeliac disease

FN – falling number

GI – gluten index

HMW – high-molecular weight

LMW – low-molecular weight

SD – standard deviation

1. Introduction

Wheat (*Triticum*) is a grass that has been cultivated since around ten thousand years ago. It has evolved many times over the years into the form that we are currently most familiar with, the common wheat (*Triticum aestivum*). It is a staple food for the majority of the global population, as it is one of the most produced cereals in the world. The most important part of the plant is its seed, a cereal grain, for which it gets cultivated. The reason for such a huge success of wheat over other crops is the large variety of products that can be made from wheat flour (Shewry 2009).

The time of sowing and harvest depends on the climate conditions of the region where wheat is grown. In most of Central Europe, harvesting is done at the end of summer, in August (Wrigley 2009). However, flour is made throughout the year, so there is a possibility that for example, storage conditions may influence the quality of flour made from older wheat grains.

Another possible determinant of flour quality can be the cultivation method of wheat grains. Wheat produced in conventional farming can reach higher yields due to the use of nitrogen fertilisers and chemical treatments against diseases. In organic farming, only natural forms of enhancing growth and protection from pests and diseases can be used, which might result in lower yield and consequently a higher price (Wrigley 2009). But ultimately for some customers, flour from organically grown wheat might be the preferred option as this method is less invasive for the environment and is believed to be the healthier option.

To assess if there are significant differences between these two types of flour throughout the year, a series of analyses that describe flour quality were carried out.

2. Literature Review

2.1. Wheat grain

Wheat grain is the most important and useful part of wheat. In length, it usually reaches around 5 mm. Its standard colour is dark (orange to brown) or light (yellow). The grain consists of the following main parts: bran, endosperm, and germ (Belderok 2000).

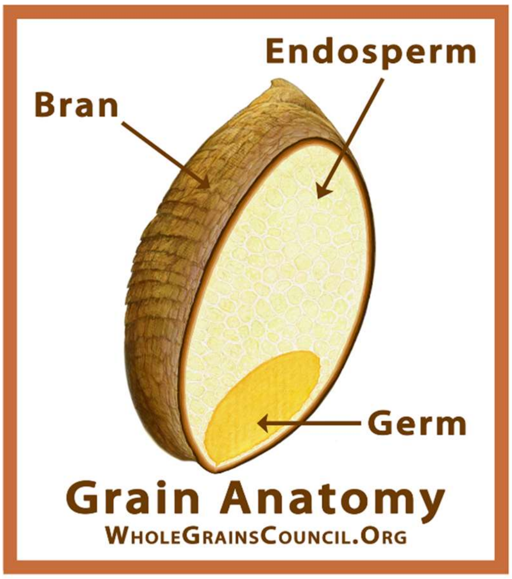

Figure 1 - Wheat grain anatomy

Bran is the combination of the pericarp, seed coat and the aleurone layer. The aleurone layer makes up the outer part of the endosperm. Endosperm which has this layer removed is called starchy endosperm. Germ has three parts: scutellum, rudimentary stem and leaves, and rudimentary primary root. Together they create the future plant. On a dry matter basis, the germ takes up 2-3% of the wheat grain, the bran 13-17% and the largest part belongs to the starchy endosperm at 80-85% (Belderok 2000).

2.1.1. Nutritional value

As described by Wrigley (2009): 'Wheat is recognised as an important source of essential nutrients, providing energy, fibre, carbohydrate, protein, B vitamins, iron, calcium, phosphorus, zinc, potassium and magnesium.'

It provides nutrition for most of the population. Due to a high content of starch, which in white flour makes up about 65-75%, it is often perceived as a mere calorie intake.

Even though it may seem like the nutritional value of wheat is not so significant considering its relatively low protein content, not reaching over 15%, in low-income economies, where wheat products supply a large part of the population's diet, wheat represents a good source of nutrition (Shewry 2009).

Wheat offers a generous amount of complex carbohydrates, such as starch, which are notably better for the organism than simple carbohydrates (sugars) due to their low glycaemic index. This means that after consumption, the energy acquired from a wheat product is released continuously for a longer period of time, thus providing the organism with energy better than sugars would (Cornell 2012).

Dietary fibre holds a high importance in the human diet, due to its health benefits mainly connected with digestion (Lafiandra et al. 2014). The total dietary fibre content of wheat, which includes soluble and insoluble fibre, goes through a significant change due to milling. Its original content in the grain varies from 11.0-12.7% and after removing the bran during milling the fibre content of the flour is only 2.0-2.5% (Carson & Edwards 2009).

2.1.2. Carbohydrates

Carbohydrates consist of three elements: carbon, hydrogen, and oxygen, that together form molecules. In the whole wheat grain, there is around 68% of carbohydrates (Belderok 2000). They can be divided into classes based on their molecular size and degree of polymerisation. Each class is then further divided corresponding to composition and number of monosaccharide units. The categories are sugars (mono- and disaccharides), oligosaccharides, starch (amylose and amylopectin) and non-starch polysaccharides (Lafiandra et al. 2014). The carbohydrates are mostly stored in the starchy endosperm, taking up 85% of the wheat grain. Starch makes up ~80% of those carbohydrates (Stone & Morell 2009).

Mono-, di- and oligosaccharides in wheat are represented mainly by sucrose, which is present in the highest amount. In minor amounts are also present: glucose, fructose, maltose and raffinose. These carbohydrates are significant mainly during grain development and as the grain matures their content decreases (Stone 1996).

Glucan polymers, amylose and amylopectin, form starch. These polymers differ in their level of branching with amylopectin being highly branched, while amylose is fundamentally linear, however, they are both formed of α-D-glucose (Jeon et al. 2010). Starch influences the colour and texture of the finished product as well as retrogradation, which affects shelf life. During milling, starch gets slightly damaged, which is necessary for fermentation and regulation of water absorption (Carson & Edwards 2009). Nonetheless, in the case of too much starch damage, reactions with enzymes worsen the quality of the finished product, as further described in 2.1.5.

Arabinoxylans belong to the non-starch polysaccharides category, and they are one of the major cell wall components (Stone & Morell 2009). Cellulose is another major cell wall component (Stone 1996). Analysis of the effect of arabinoxylans on rheological properties was performed using different concentrations of low-molecular weight (LMW) and high-molecular weight (HMW) arabinoxylans. An increase in loaf volume upon the addition of HMW and LMW arabinoxylans was observed, but after adding even more, the loaf volume decreased, hinting at an optimal value of arabinoxylans that should not be passed. The LMW arabinoxylans required a higher concentration to reach the optimum than HMW arabinoxylans. It was established that to enhance loaf volume a smaller amount of HMW arabinoxylans is needed and it is therefore a better method of improving the flour properties (Biliaderis et al. 1995).

It was also found that mainly HMW arabinoxylans affect water absorption, increasing its value, which also enables a higher moisture content of products. This might consequently influence the firmness of the crumb, which was found to be lower with increasing amounts of HMW arabinoxylans (Biliaderis et al. 1995).

2.1.3. Protein

Proteins are usually composed of twenty amino acids, of which ten cannot be synthesised by organisms and must be acquired through food, making them essential in this sense. All essential amino acids except for lysine, have been found in sufficient amounts in the wheat grain and some even in noticeably higher amounts than the recommended levels for an adult. The levels are higher in whole wheat grain, although flour is not far behind (Shewry 2009). The whole grain contains around 10-17% protein with the largest amount found in germ and bran but due to the small size of these particles, their protein content is almost insignificant compared to protein in the endosperm (Sluková et al. 2017). Even with the loss of some protein due to the removal of bran and germ during milling, the content of protein in white flour remains similar to that of wheat grain. Nevertheless, it is important to note that white flour may have up to 4% fewer proteins than whole wheat flour (Sluková et al. 2017). Overall protein content in wheat flour can vary depending on the level of nitrogen fertilisation during growth, which then helps to determine the flour's best use, as different products prefer different amounts of protein (Shewry & Jones 2012).

Through proteomic analysis performed on the endosperm of a mature wheat grain it was found that there are approximately 1125 individual proteins expressed (Skylas et al. 2000). In the endosperm, there are various proteins with four distinct groups of the highest importance. Those are gliadins, glutenins, albumins, and globulins. Together they create the storage proteins of the wheat and usually take up around 10-14% of the grain weight (Cornell 2012).

Gliadins and glutenins make up gluten, which is the main determinant of dough properties and as such is further described in the following chapter. Though they do not have an impact as significant as gliadins and glutenins, albumins and globulins affect dough too. Without them present, baked products usually have a low volume (Cornell 2012). They make up around 20% of wheat protein (Sluková et al. 2017). Some essential amino acids like lysine, threonine and tryptophan are present in higher amounts in albumins and globulins than in gliadins and glutenins. Moreover, due to the composition of amino acids, albumins and globulins have a high nutritional value (Islam et al. 2012). However, both protein fractions have been found to also have a negative impact on health, relating to wheat allergies, as described in 2.1.7.

2.1.3.1. Gluten

'Vital' wheat gluten is a term for gluten that has been washed out of flour dough, dried and can be later turned back into its original state using water. It is made up of roughly 80% protein, 10% starch, 5% lipids and other minor components (Cornell 2012). Prolamins make up the largest part of the proteins present in gluten (Shewry et al. 2002). Previously prolamins were described according to their solubility in alcohol-water mixtures (Osborne 1924). However, later the definition changed due to a need to include a type of proteins that are not, in their natural state, soluble in alcohol-water mixtures. Since then, prolamins have been categorised into two groups: monomeric gliadins and polymeric glutenins Shewry et al. (1986) which together form gluten.

Gluten can be easily obtained from wheat flour by washing wheat dough in a solution of salt and distilled water. With this easy method gluten proteins in their normal form are achieved. This is conditioned by the properties of the proteins. They are only soluble in alcohol solutions and individual gluten proteins are held together by both covalent and non-covalent forces, which enables the extraction of the gluten proteins as a cohesive mass (Shewry 2009). Gluten is what gives an advantage to wheat flour over flour from a different source that does not contain gluten. Properties such as viscoelasticity and dough strength are gravely influenced by the volume and composition of gluten present in the dough. Most importantly a specific group of glutenins, called the HMW subunits are responsible for dough strength (Shewry et al. 2003). The formation of a cohesive elastic dough is influenced by glutenin's ability to create a three-dimensional network made of molecules that are held together by disulphide and hydrogen bonding as well as hydrophobic interactions (Cornell 2012). The flour must be sufficiently hydrated, mixed, and kneaded to ensure the proper formation of the gluten network. After the mixing, follows the phase of dough development. The dough development is a very important step because it helps to change the dough's physical properties and most importantly improves gas retention, which is necessary, especially during fermentation, when carbon dioxide is released by yeast and the dough must incorporate this gas to achieve the required bread texture and volume (Cauvain 2012).

Although gluten is a very important component in baking, in many individuals its digestion can cause various health problems, which are covered in 2.1.7.

2.1.4. Lipids

The amount of lipids present in wheat is affected by factors like genetic variation and environmental conditions during wheat growth (Chung et al. 2009). Most lipids in wheat are present in the parts that are later removed during milling such as bran and germ. The endosperm, which white flour is made of, contains only around 2% (Morrison 1978). Thanks to lipids' amphipathic characteristics, which enable them to associate with proteins and starch, inclusion complexes are made between proteins and starch notably affecting the quality and texture of wheat products (Cornell 2012). Lipids together with protein affect the formation of gas cells in the dough. Baked products made from flour with low lipid content have finely distributed gas cells of similar size resulting in a fine texture. In terms of loaf volume, it was found that non-polar and polar lipids have an opposite effect, with non-polar lipids decreasing the volume and polar lipids increasing the volume. Flour condition is also affected by the presence of lipids in such a way that the fewer lipids there are the whiter and finer the flour is (MacRitchie 1983).

2.1.5. Enzymes

For wheat, as for any other plant, enzymes are a crucial component. Without them, the plant would not be able to synthesise the resources for living and growth. The enzymes present in wheat, especially amylases, can also be useful in breadmaking as they influence some flour properties (Cornell 2012). Enzymes can be a great replacement for chemical additives, providing the same results, while maintaining a better health profile. The addition of enzymes can, for example, prolong the shelf life of products, increase the volume of bread, make a better crumb structure, and allow for a deeper colour of the crust. Enzymes need a good substrate in order to work and in flour, this substrate is already present which is very beneficial (Kornbrust et al. 2012).

There are two main groups of enzymes: amylases and proteases. Amylases and proteases belong to the category of hydrolases. Amylases act as a catalyst in the hydrolysis of starch polysaccharides. Two main enzymes are found in wheat: α-amylase and β-amylase. The α-amylase is the most important due to its activity in the dough making process as well as the baking process (Cornell 2012). Effects like enhanced dough fermentation, dough stability, crumb structure, crust colour, increased volume and extended shelf life are all conditioned by the α-amylase (Kornbrust et al. 2012). The level of α-amylase activity in flour and wheat can be studied through various methods: falling number, rapid visco analyser and amylograph. To achieve proper dough formation starch must be broken down by α-amylase to ensure a supply of fermentable sugars. Nonetheless, if there is too much of this enzyme, starch is broken down into dextrins and simple sugars, which results in unwanted dough properties (Carson & Edwards 2009). The resulting product has a sticky and gummy crumb texture and is altogether too moist to be considered a high-quality product (Kornbrust et al. 2012). The β-amylase reacts with damaged starch, resulting in the creation of maltose. The amount of α- and β-amylases signifies wheat quality. Wheat of high quality should have only low amounts, otherwise, it would point to a wrong time of harvest, when the wheat is wet from rainfall (Cornell 2012).

In doughs and batters that have been mixed and rested, proteases act as a reducing agent for consistency. In white flour, proteases are not so important because there is low proteolytic activity in the endosperm, with the aleurone layer, the pericarp, and the embryo as the main sources of the proteolytic activity being removed during milling (Cornell 2012). For a different type of flour, such as hard wheat flour, the addition of protease can be very helpful in reducing dough strength and improving dough handling, as well as the texture of the final product. However, it is important to note that protease must be added with much caution to avoid accidental breakdown of the gluten protein structure (Carson & Edwards 2009).

Cytases, which are another type of enzymes, have a crucial role in the malting process, where they enable the hydrolysis of protein and starch by allowing entry of amylases and proteases into the cell walls. Phytase is yet another important enzyme that can lower the amount of phytic acid and therefore enable proper intake of some minerals. Some enzymes from the oxidase group can oxidise specific substrates through the utilisation of molecular oxygen, which has been found to improve the rheological properties of the dough (Cornell 2012). The most important enzyme from this group is glucose oxidase, which can improve dough strength and stability, enhance dough texture by reducing its stickiness, and increase bread volume (Kornbrust et al. 2012).

2.1.6. Minerals

Minerals and trace elements make up an important part of wheat. Because wheat is cultivated all over the world, its contribution to the intake of minerals is highly significant. However, the highest concentration of minerals in wheat is found in the germ and bran, which are almost entirely removed during milling, therefore white flour contains fewer minerals than whole wheat flour (Piironen et al. 2009). In all of the grain there is only around 2.5% of minerals, of which the highest amount is in the aleurone layer, so the difference in mineral content between grain and flour is markable. White flour usually has only around 0.5% of minerals on a dry matter basis (Sluková et al. 2017).

Wheat and some other cereals are important sources of iron and zinc. Both iron and zinc have a widespread nutrient deficiency mostly in countries with low-income economies but also pose as a threat in countries where the economy is good. When it was suggested that older wheat varieties used to contain more minerals than the current modern varieties, many concerns began to rise (Shewry 2009). It was assumed that it might be due to the importance of high agronomic yield in modern wheat breeding instead of focusing on nutritional quality. A study focused on both modern and old wheat varieties confirmed a decrease in the mineral content of iron and zinc in higher yielding varieties (Zhao et al. 2009).

Another important mineral present in wheat is selenium, an essential micronutrient, that must be provided in just the right amount as both its deficiency and toxicity when consumed in excess are a health concern. The concentration of selenium unlike the other mentioned minerals highly depends on its deposit in the soil (Shewry 2009). Moreover, the presence of selenium in the grain depends on the occurrence of sulphur in the soil as sulphur inhibits the intake of selenium into the plant. Therefore, using sulphur in fertilisers in order to increase grain quality can consequently decrease the amount of selenium in grain (Zhao et al. 1997).

2.1.7. Wheat impact on human health

As previously stated, wheat consists of many nutritionally important components, however, its impact on health can also be negative. There are a few known medical conditions connected to wheat and, more specifically, its proteins. A respiratory allergy, commonly called bakers' asthma, has a long history with humanity reaching as far as Roman times. Because it is most impactful in a workplace environment, it is placed on the list of occupational allergies. In many patients, with baker's asthma, a large variety of grain proteins were found to interact with immunoglobulin E, these proteins include glutenins, gliadins and many others (Shewry 2009). However, albumins and globulins are believed to have the biggest influence on baker's asthma (Weiss et al. 1997). Other types of allergies include food allergy, wheat-dependent, exercise-induced anaphylaxis and contact urticaria (Sapone et al. 2012).

Wheat intolerance is more frequent than wheat allergy in the human population. The most known medical condition connected to wheat intolerance is coeliac disease (CD). CD causes physical modifications of the lining of the small intestine which leads to malabsorption of nutrients (Losowsky 2008). CD is a direct result of an autoimmune response that is caused by gluten peptides that bind to T cells of the immune system. Due to the widespread of CD, scientists were trying to find a way to produce wheat that will not contain toxic proteins for many years. Initially, it was believed that eliminating α-gliadins would suffice in the creation of a non-toxic wheat variety, though, after conducting more research it became apparent that most gluten proteins cause toxic reactions in at least some people, which significantly complicated the process. However, the following research discovered different approaches that have the potential to make the production of wheat varieties safe to consume by CD patients possible (Shewry 2009). Another condition with an autoimmune reaction is dermatitis herpetiformis which occurs alongside CD in some patients. It is a disease that affects the skin, causing blistering rashes. The last in this category is gluten ataxia, which causes damage to the nervous system and results in disordered movement coordination (Sapone et al. 2012).

Apart from wheat allergy and coeliac disease, there is also a condition called gluten sensitivity, which is less severe and usually doesn’t cause any changes in the small intestine. For gluten sensitive patients simply following a gluten-free diet might be enough to rid them of uncomfortable symptoms with no residual health problems. However, the diagnosis of gluten sensitivity is a slightly complicated process due to the similarity of symptoms to other gluten-related disorders. Firstly, it is important to run a series of tests to rule out wheat allergy or coeliac disease. If both of these conditions can be excluded, finally, a double-placebo gluten challenge is performed to give certain results about gluten sensitivity (Sapone et al. 2012).

2.1.8. Importance of wheat in tropical regions

As described in 2.1.1, wheat is an important source of energy and nutrients for most of the population. Due to its many versatile uses, the demand for wheat production all over the world grew. Thus, despite the divergent climatic conditions from the temperate region, wheat is also grown in the tropical area. For example, in Africa, most of the wheat is grown in northern or highland areas, where the conditions are a bit better, but the warmer areas are not excluded either (Gooding 2009). Nevertheless, wheat is susceptible to heat stress so there are challenges connected with wheat production in tropical areas mainly during the flowering and grain filling phases of wheat growth. Heat stress in these stages may result in lower grain yield (Wahid et al. 2007). To provide enough wheat supply in these countries, wheat is a largely imported commodity (McDonald et al. 2008).

2.2. Flour

Flour is a product of milling and separating grains until the desired form is achieved (Campbell et al. 2012). It is used for many purposes in the food industry. The condition of wheat grain and the method of milling affects flour quality which then determines the quality of the final product so there are many tests performed on milled flour samples before they can be put on the market (Cornell 2012).

The difference in nutrient composition between wheat grain and flour occurs due to milling during which the bran and germ are removed and only endosperm is left. The germ contains large amounts of proteins (around 25%) and lipids (around 10%) as well as minerals so its removal greatly influences the flour's nutritional value (Cornell 2012). Bran has a rich supply of fibre, so its removal also results in a decreased nutritional value in white flour as mentioned in 2.1.1. However, there is also an anti-nutritional compound largely present in bran and germ fractions called phytic acid, which disrupts the absorption of some minerals mainly iron, calcium, and zinc (Rosell 2012). Despite the loss of nutritional value, the removal of bran and germ is important to achieve flour that is almost entirely digestible and with a long-lasting shelf life (Cornell 2012).

Flour can be divided into categories according to its content of ash. When organic compounds present in the wheat burn at high temperatures, only inorganic residues are left, and they are what we call ash. Most of the ash is concentrated in bran layers, therefore the degree of milling (how much of the bran was removed) influences the ash content of flour (Tilley et al. 2012). Categories are described as a number which gives information about the percentage of ash present in the flour. For example, flour labelled 550 contains around 0.550% of ash (Posner 2009). The effect of ash content on flour properties lies mainly in changes of colour, as ash content increases the colour of flour darkens due to the higher amount of bran present. Another effect of a higher ash content is an observed decrease in dough strength as well as an overall decline in baking performance (Carson & Edwards 2009).

Flours with different compositions have distinct properties that predetermine the best use for the selected flour type. Wheat flour is very commonly used flour in households all around the world and can be further divided into many subcategories like common wheat flour, durum wheat flour, noodle flour, semolina, spelt and others. Common wheat flour can come from two methods of wheat cultivation: conventional and organic. Both of these types are made from the grain's endosperm, which holds the majority of the wheat grain protein and is therefore considered the most important part of the grain (Cornell 2012).

2.2.1. Conventional flour

The term conventional flour refers to flour made from conventionally grown wheat. It is wheat that is treated with chemicals such as synthetic fertilisers and pesticides. While chemicals and fertilisers can positively affect the quality and yield of the grain, they pose as a threat to the environment (Draghici & Popa 2011). Nonetheless, in Czech supermarkets, conventional flour is still in a much larger supply than organic flour. It is most likely due to a higher demand influenced by a lower price.

2.2.2. Organic flour

Unlike conventional flour, organic flour must be made from strictly organically grown wheat, meaning without any use of artificial fertilisers and synthetic fungicides and herbicides, instead green manure and crop rotation are used to enhance soil fertility (Wrigley 2009). This alone gives organic flour an advantage due to the ecologically friendly and healthy outlook that some consumers prefer. However, it might be possible that the lack of nitrogen fertilisers in organic wheat could result in the production of flour with a lower protein content than desired. In a study comparing conventional and organic wheat, it was found that on average the protein content was 6% higher in the conventional farming system, although it meant that in organic wheat the protein content was still sufficient, most likely due to the use of wheat varieties with adaptability to lower nitrogen supply (Hahn et al. 2007). The absence of fungicidal treatment in organically grown wheat caused concern about potentially higher mycotoxin levels in organic flour, however, in the same study as mentioned above there were no significant differences found between mycotoxin levels in organic and conventional wheat (Hahn et al. 2007).

2.3. Determination of flour properties

Unique properties of flour help decide what is the best use of the flour. Flour characteristics are affected by its moisture content, gluten content, falling number and overall rheological properties. To assess the flour properties, the following analyses are carried out.

2.3.1. Moisture content

Before the grain is milled it goes through a process called tempering. During this process water is added to the wheat grain and the grain is left in the water for some time to increase its moisture content. This helps with separating the endosperm from the bran as well as reducing mechanical starch damage (Campbell et al. 2012). The standard moisture content for white flour is around 13.5-14.5%. However, according to the law, the highest acceptable value is 15% (Sluková et al. 2017). Moisture content in flour mainly influences the storage conditions as moisture over 15% would worsen the flour consistency. If the values are standard the dough properties are rather expressed by the water absorption capacity (Sluková et al. 2017). The relationship between moisture content and water absorption capacity is that with lower moisture content occurs higher water absorption capacity and vice versa (Cauvain & Young 2012).

2.3.2. Gluten content

The determination of gluten content is a very important step in the research of flour properties. Some important dough characteristics such as dough elasticity and extensibility are predominantly determined by the amount and quality of vital wheat gluten (Chen et al. 2010). The dough's end use quality is directly affected by the balance between these two properties. The dough intended for breadmaking should be highly elastic, while the dough for baking cakes should be more extensible (Shewry et al. 2002). Gluten itself is highly influenced by wheat flour composition. Namely the content of protein, starch, pentosans and other added ingredients like fat or salt, as well as processing aids such as enzymes. Finally, it is also affected by process parameters like mixing time, temperature, and mixing water (Wang et al. 2003). Altogether, the final structure and properties of gluten are based on the overall amount and type of specific proteins present in the flour and can significantly change gluten's quality or functionality due to a shift in protein composition (Bietz & Lookhart 1996).

Gluten content is often described as gluten index (GI) and wet gluten content which provides a determination of gluten quantity and quality. Gluten index method is a rapid and fully automatic method of acquiring information about gluten strength as well as wet gluten quantity in the flour. These characteristics are expressed as the GI, which directly relates to the remaining fraction of gluten present on the sieve after centrifugation (Curic et al. 2001). Wet gluten content in white flour should be between 28-33% (Sluková et al. 2017). Gluten quality can be categorised into three groups based on strength according to the GI. Weak (GI < 30%), normal (GI = 30-80%) and strong gluten (GI > 80%) (Oikonomou et al. 2015).

2.3.3. Falling number

The falling number (FN) method is often used as a flour quality indicator. It is an indirect measurement of α-amylase activity, based on the viscosity of the sample. If the FN is too low, it means that there is starch damage caused by excessive enzymatic activity, the starch properties are poor and so is the flour, therefore it is not suitable for bread baking. At a first glance, this could indicate that low FN means high enzymatic activity, however, this is not the case for waxy wheat starches. This means that the FN method would present inaccurate results of α-amylase activity for waxy wheat varieties and as such cannot be used in these cases (Eliasson 2012).

The FN can be influenced by many factors. One of the factors that affect the FN is the storage time and the storage temperature of the flour. Amylolytic activity lowers and FN value rises after an extended period of flour storage. This is dependent on storage temperature. Significant changes showed at 30°C and the biggest changes were observed at the storage temperature of around 38°C (Brandolini et al. 2010). Other factors include altitude, nitrogen fertilisation, fungicide treatment, wheat cultivar, climatic conditions of wheat growing, method of harvest and treatment after harvest (Hrušková et al. 2004; Wang et al. 2008).

For white flour, the values of FN should be somewhere between 250-350s. Values lower than 160s signify a very high α-amylase activity, meaning the starch is broken down too much. Starch binds water in the dough, so if there is not enough starch, the products will come out moist and sticky, with poor quality. However, if the values are higher than 350s it means that α-amylase activity is too low and that is also not a good sign for the product's quality. The dough made from such flour will be dry and crumbly. Nonetheless, if the α-amylase activity is too low it can be relatively easily regulated by adding malt flour or enzymes (Sluková et al. 2017).

2.3.4. Rheological properties

The testing of rheological properties can be done using various laboratory equipment such as Mixolab, Alveograph, Extensograph, Mixograph and Farinograph. The acquired data help with the determination of the suitable composition of the final flour blend according to the preferred characteristics (Carson & Edwards 2009). Important rheological characteristics include elasticity, viscosity, and extensibility. Farinograph and Mixograph serve to study the kneading properties of the dough. Force and deformation of the dough are studied using Extensograph and Alveograph, which provide information about the stretching properties of the dough (Banu et al. 2011). An overview of rheological properties observed using different laboratory equipment is expressed in Table 1.

Table 1 - The overview of the technology determining rheological properties

	Alveograph	Extensograph	Farinograph	Mixograph	Mixolab
Water absorption			•		•
Kneading properties			•	•	•
Elasticity, extensibility	•	•			
Starch gelatinisation					•
Amylolytic activity					•

Source: (Carson & Edwards 2009; Codină et al. 2010; Banu et al. 2011)

Mixolab

Mixolab is a piece of unique equipment because it combines analysis of mechanical changes during mixing and heating as well as thermal changes during baking. Thanks to this the user conveniently acquires information about many different properties in just one test (Rosell et al. 2007; Codină et al. 2010). The typical Mixolab curve that shows the results of the analysis has five different stages with their respective peaks. During the first stage the dough develops, and the temperature is constant at 30°C, the results correspond to the farinograph curve and give information about the development time, stability, and water absorption of the flour. In the second stage thermal protein weakening is analysed. It is the first stage of dough warming. During this time the dough consistency decreases and based on the extent of this effect the protein quality and strength are measured. Stage three signals the beginning of starch gelatinisation and it corresponds to the second stage of dough warming when the temperature rises above 50°C. In this stage viscosity increases due to the starch granules absorbing water and swelling and amylose molecules seeping out of the starch. With the start of the fourth stage, the α-amylase activity increases at a constant heating rate which prompts a decrease in dough consistency. In the final fifth stage, as the dough cools, starch gelatinisation is complete and its retrogradation is triggered, which ultimately increases the dough's consistency (Kahraman et al. 2008; Codină et al. 2010; Dubat 2010; Banu et al. 2011; Rachoń et al. 2016).

3. Aims of the Thesis

This thesis aimed to compare several characteristics important in the baking industry of two types of wheat flour (organic and conventional) and to monitor their trends throughout one year period.

4. Methods

New organic and conventional wheat flour was bought each month from a supermarket in Prague and analysed in the laboratory. Monthly analyses occurred over the course of one year. Table 2 shows the brands of analysed flours and their basic description. The flour was randomly picked from the store shelf so there was a chance of analysing the same batch in more than one monthly analysis. The specific lot numbers are shown in Table 3.

Table 2 - Flour overview

	Nature's Promise Bio	**Ramill**
Flour origin	organic	conventional
Flour type	plain	plain
Producer	PRO-BIO s.r.o.	Goodmills Česko s.r.o.
Nutritional value	1460 kJ per 100 g	1461 kJ per 100 g

Table 3 - Flour lot number

	Nature's Promise Bio	**Ramill**
Date	Lot number	
February 2022	15.08.2022	08.12.2022
March 2022	30.09.2022	10.02.2023
April 2022	06.12.2022	14.04.2023
May 2022	25.12.2022	21.04.2023
June 2022	18.01.2023	13.06.2023
July 2022	08.02.2023	21.06.2023
August 2022	28.02.2023	01.08.2023
September 2022	17.04.2023	03.08.2023
October 2022	13.06.2023	21.06.2023
November 2022	26.06.2023	21.10.2023
December 2022	10.07.2023	26.09.2023
January 2023	06.08.2023	02.12.2023

All the research was done in the Laboratory of Food Processing Technologies at the Faculty of Tropical AgriSciences. Every piece of equipment and material (except for the flour) was provided by the university. Chosen quality parameters of the flour to be measured were moisture content, gluten index, falling number and complex rheological properties.

Each analysis was performed in duplicate.

4.1. Moisture content

The Moisture Analyzer MAC 110 (Radwag, Poland) was used for this analysis. Upon starting the process, a small circular aluminium tray was placed inside the device and after weighing the tray, the tare button was pressed. Then approximately 10 grams of flour were transferred onto the tray and afterwards the lid of the device was closed so the measuring could begin. The result was presented on the screen, after approximately 15 minutes, in a percentage of moisture content.

4.2. Gluten index

The Glutomatic 2200 (PerkinElmer, Massachusetts) was used to measure the gluten index. The first step was to prepare a salt solution to mix and later wash the flour with. Using the Precision Balance PS 600.R2 (Radwag, Poland) 20 g/l of NaCl was measured and put in a graduated cylinder of the desired volume (depending on the estimated volume of solution needed for the analysis) and filled up with distilled water. The solution was mixed with a glass stirring rod and poured into the water tank. Next 10.0 g ± 0.01 g of flour was weighed and put into each of the two wash chambers. After that, 4.8 ml of salt solution was added to the flour in the wash chambers and spread over the whole surface with circular movement. Wash chambers were then placed in the device and the analysis was started. After about 6 minutes the washing was completed. The washing chambers were removed, and the two gluten pieces left were transferred to the sieve cassettes, placed in the Centrifuge 2015 (PerkinElmer, Massachusetts), and centrifuged for one minute at 6000 ± 5 rpm. Then the fraction passed through the sieves was scraped off with a spatula and weighed. Later the rest of the gluten was added to the small fraction and weighed. The results were then used to calculate the Gluten index and wet gluten content.

For the calculation of GI and wet gluten content, the following formulas are needed:

Equation 1 - Gluten index

$$Gluten\ index = \frac{wet\ gluten\ on\ sieve\ (g) \times 100}{total\ wet\ gluten\ (g)}$$

Equation 2 - Wet gluten content

$$Wet\ gluten\ content = total\ wet\ gluten\ (g) \times 10$$

4.3. Falling number

To perform the falling number test, the Falling Number 1000 (PerkinElmer, Massachusetts) was utilised. Using a correction table, the correct measurement of the flour sample was determined according to moisture content. The flour sample was weighed and moved into viscometer tubes. For each test tube with the sample, 25 ml ± 0.2 ml of distilled water was measured into beakers. After the device stabilised the temperature of the water bath, the analysis was started. The distilled water was poured into two viscometer tubes with samples and the tubes were plugged with a rubber cork. After grabbing one viscometer tube in each hand and pressing thumbs over the cork, the tubes were shaken in an upward and downward motion approximately 40 times ± 10 times. If there was still a residue of the dry sample a few more shakes were performed until a homogenous mixture was formed. Next, the corks were removed, and the excess mixture was wiped on the rim of the viscometer tubes. Viscometer-stirrer was then used to scrape off the residue on the walls of the tubes and left inside the tubes. Tubes with stirrers were placed inside a cassette which was inserted into the device with a boiling water bath. Immediately after, the plastic cover was lowered, so that the test could start. The suspense was stirred inside the device for 60 seconds. The time it takes for the stirrers to drop was counted and at the end, the results presented in seconds were shown on the screen.

4.4. Rheological properties

To identify the rheological properties of the flour, the dough was analysed using Mixolab 2 (CHOPIN Technologies, France). The Chopin + test was conducted to get a complete set of results. To do so an estimated value of water absorption and the actual value of moisture content was filled out in the protocol and the software calculated the exact measure of the flour to be weighed. After weighing the flour and preparing the device, as well as turning on the cooling system, the test was started. After being prompted to do so, the flour was added to the mixing bowl. At around 30 second mark the nozzle was placed on the device and the specific amount of distilled water was automatically added. If the required value of torque for C1 was not reached, the estimation of water absorption was re-evaluated, and a new test was started. This procedure was repeated until the optimal torque value was reached. After the test ended at 45 minutes, the software presented the results as a Mixolab curve and a Profiler index.

4.5. Data analysis

Data were analysed using the Microsoft Excel platform. The results were presented as an arithmetic average of duplicate analysis performed. The minimum and maximum values were also expressed, as well as an average value and standard deviation (SD).

5. Results

5.1. Moisture content

Table 4 - Moisture content value of analysed flour samples

	Organic	**Conventional**
Date	Moisture content (%)	
February 2022	12.8	13.6
March 2022	12.5	14.7
April 2022	13.9	13.2
May 2022	13.4	13.7
June 2022	12.7	14.7
July 2022	12.7	13.8
August 2022	13.8	14.1
September 2022	13.4	13.3
October 2022	13.8	13.7
November 2022	13.3	13.9
December 2022	13.2	14.9
January 2023	13.4	14.4
Descriptive statistics		
Min.	12.5	13.2
Max.	13.9	14.9
Average	13.2	14.0
SD	0.46	0.53

The standard values required for white flour were, as previously mentioned in 2.3.1, between 13.5-15%. As shown in Table 4, in the moisture analysis it was found that for both flours the minimum value observed did not reach the standard moisture content while the maximum value was in the range of the standard. For organic flour, the minimum value was lower than the standard by 1% and for conventional flour, it was only by 0.3%. As shown in Figure 2, the conventional flour performed better and reached the required value in almost all of the analyses except for April 2022 and September 2022. In comparison, organic flour only fell into the standard category in three cases, with the average value lower than the standard by 0.3%. Since the standard deviation was of a relatively low value in organic and conventional flour samples, the data were clustered around the average and could therefore be considered reliable.

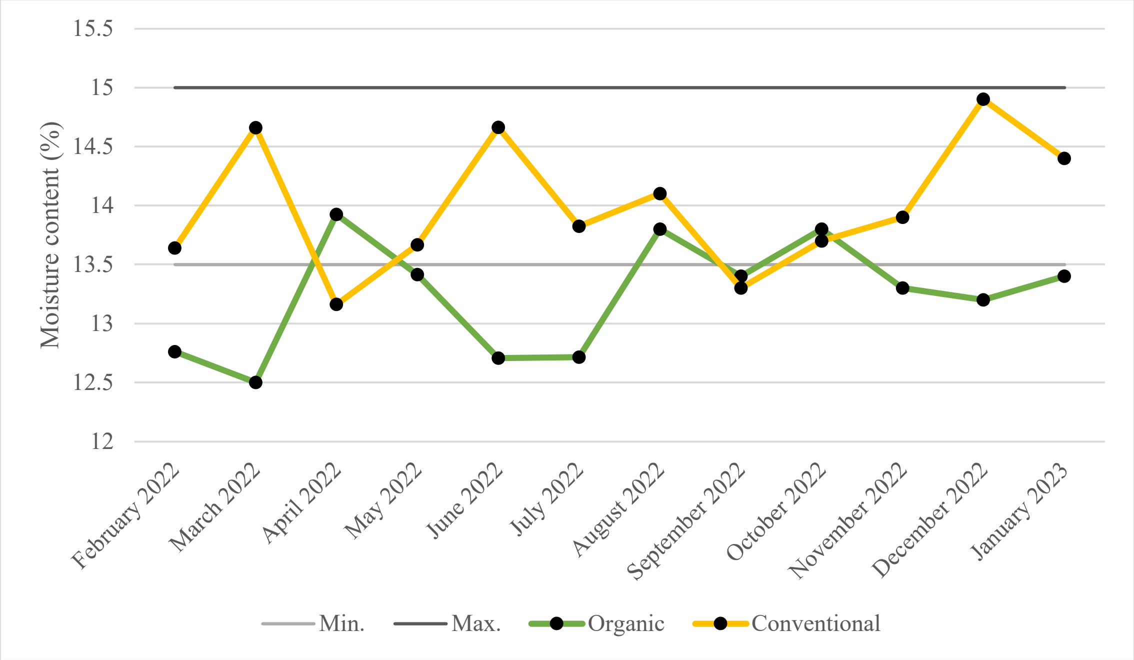

Figure 2 - Moisture content changes in flour samples throughout the year

5.2. Gluten content

Table 5 - Gluten index values of analysed flour samples

	Organic	Conventional
Date	Gluten index (%)	
February 2022	94	98
March 2022	97	95
April 2022	97	93
May 2022	98	95
June 2022	97	91
July 2022	95	88
August 2022	98	94
September 2022	98	97
October 2022	96	96
November 2022	100	96
December 2022	99	98
January 2023	98	96

Continued Table 5 - Gluten index values of analysed flour samples

Descriptive statistics		
Min.	94	88
Max.	100	98
Average	97	95
SD	1.57	2.73

The standard values of GI in white flour were mentioned in 2.3.2 and described as three gluten categories: weak (GI > 30%), normal (GI 30-80%) and strong (GI > 80%). Results of the analysis described in Table 5 showed that the minimum for both flours was in the strong category, although for conventional flour it was only 8% away from the normal category which was relatively close. The maximum was very high in both cases and therefore belonged in the strong section. Even the average values of the analyses were in the strong category. As shown in Figure 3 a similarity between both trends was seen starting with a raise of GI in May 2022, continuing with a drop peaking in July 2022 and then another raise until September 2022 where the values dropped once again. Standard deviation was relatively low in both organic and conventional flour, meaning the results were close to the average and could be considered as reliable.

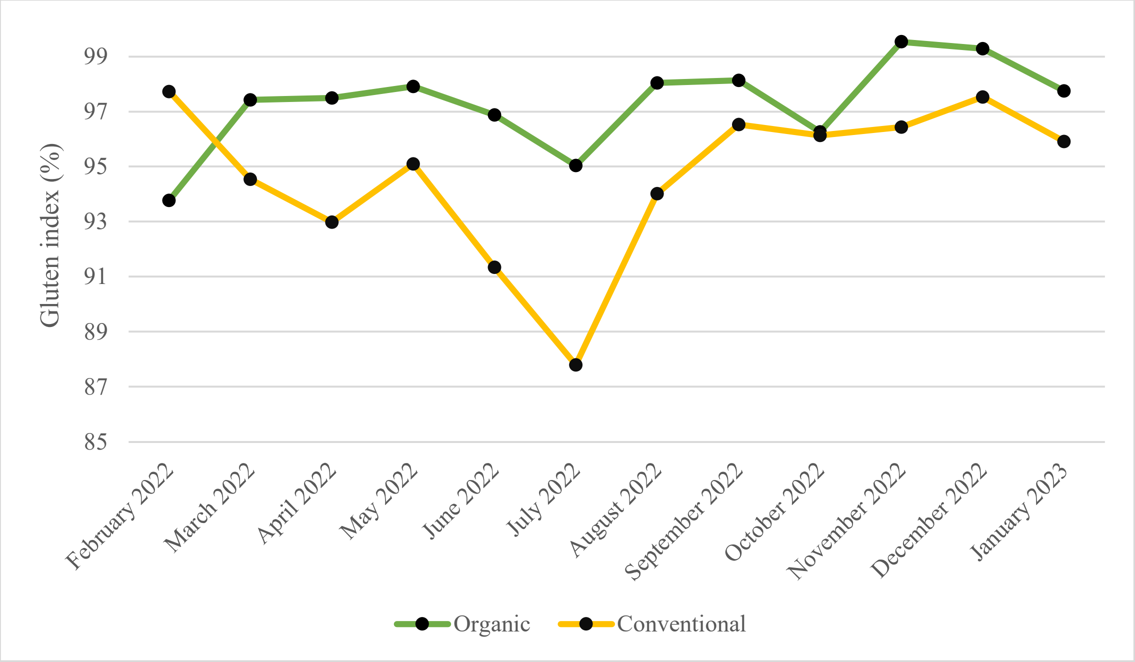

Figure 3 - Gluten index changes in flour samples throughout the year

Table 6 - Wet gluten content values of analysed flour samples

	Organic	**Conventional**
Date	Wet gluten content (%)	
February 2022	30.5	31.9
March 2022	25.9	36.2
April 2022	27.3	32.6
May 2022	28.0	31.9
June 2022	32.1	34.0
July 2022	32.5	37.2
August 2022	28.9	33.4
September 2022	23.8	27.2
October 2022	24.1	31.3
November 2022	23.9	30.4
December 2022	24.7	29.4
January 2023	25.8	32.5
Descriptive statistics		
Min.	23.8	27.2
Max.	32.5	37.2
Average	27.3	32.3
SD	3.00	2.63

The results of wet gluten content stated in Table 6 showed that the observed minimum values of both flours were below the standard value which was, as stated in 2.3.2, between 28-33%, although in conventional flour only by ~ 1%. The maximum of organic flour was in the range while for the conventional flour, it was ~ 4% above the spectrum. However, the average value showed that organic flour was ~ 1% lower than wanted and conventional flour stayed in the standard scale. Contrary to gluten index analysis, for wet gluten content the conventional flour provided a more reliable set of results with a lower standard deviation than that of organic flour. With the standard deviation directly related to the average, it was found that only the conventional flour was in the desired range. This was also well-demonstrated in Figure 4, where seven measurements of the conventional flour were in between the minimum and maximum required values while only five measurements of the organic flour fell into that same category.

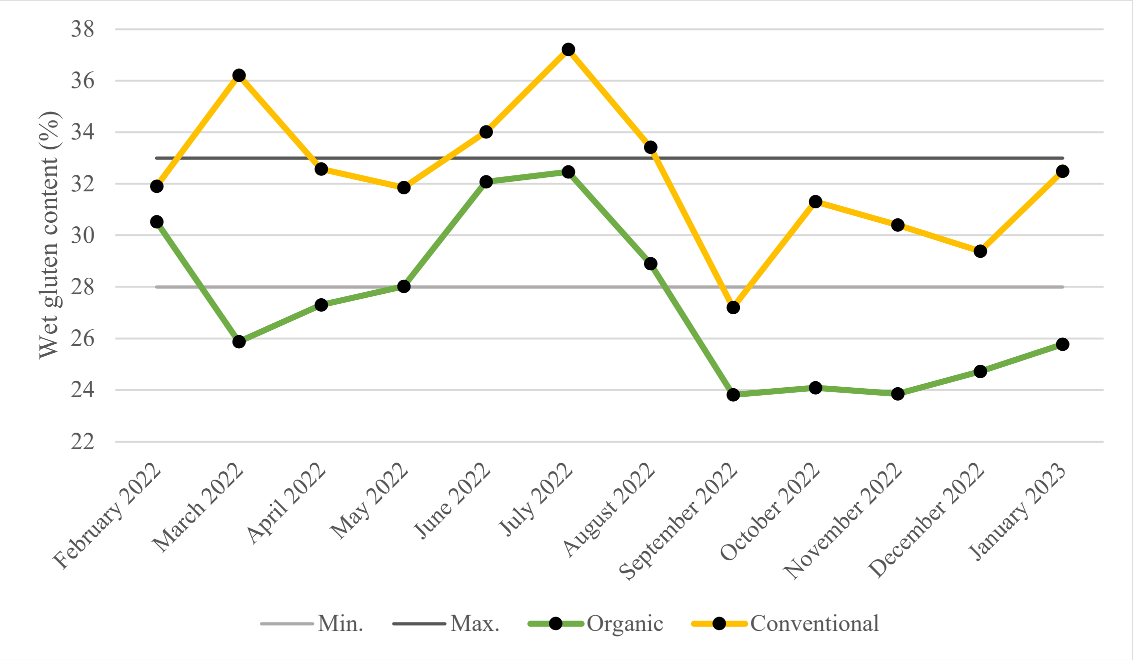

Figure 4 - Wet gluten content changes in flour samples throughout the year

5.3. Falling number

Table 7 - Falling number values of analysed flour samples

	Organic	**Conventional**
Date	Falling number (s)	
February 2022	258	368
March 2022	410	454
April 2022	406	313
May 2022	408	342
June 2022	427	385
July 2022	436	417
August 2022	445	424
September 2022	447	422
October 2022	374	446
November 2022	333	463
December 2022	339	423
January 2023	324	427

Continued **Table 7 - Falling number values of analysed flour samples**

Descriptive statistics		
Min.	258	313
Max.	447	463
Average	384	407
SD	56.34	43.92

The standard values for white flour were, as earlier mentioned in 2.3.3, between 250-350s. In the results of the falling number analysis, as shown in Table 7, it was found that both minimum values were in the standard spectrum while neither of the maximum values were. The maximum values were much higher than the acceptable value, by ± 100s. The average values were also higher than the standard spectrum, although, for organic flour, the average value could be considered normal, if a human error during analysis is allowed for. With this in consideration, as shown in Figure 5, the maximum acceptable value was raised to 400s. This meant that for organic flour, it was observed that five of the analyses reached the requirements and for conventional flour, it was only four. The standard deviation value suggested that the results were more reliable in the statistical sense in the case of conventional flour, however, the results of organic flour were found to be in better compliance with the wanted results.

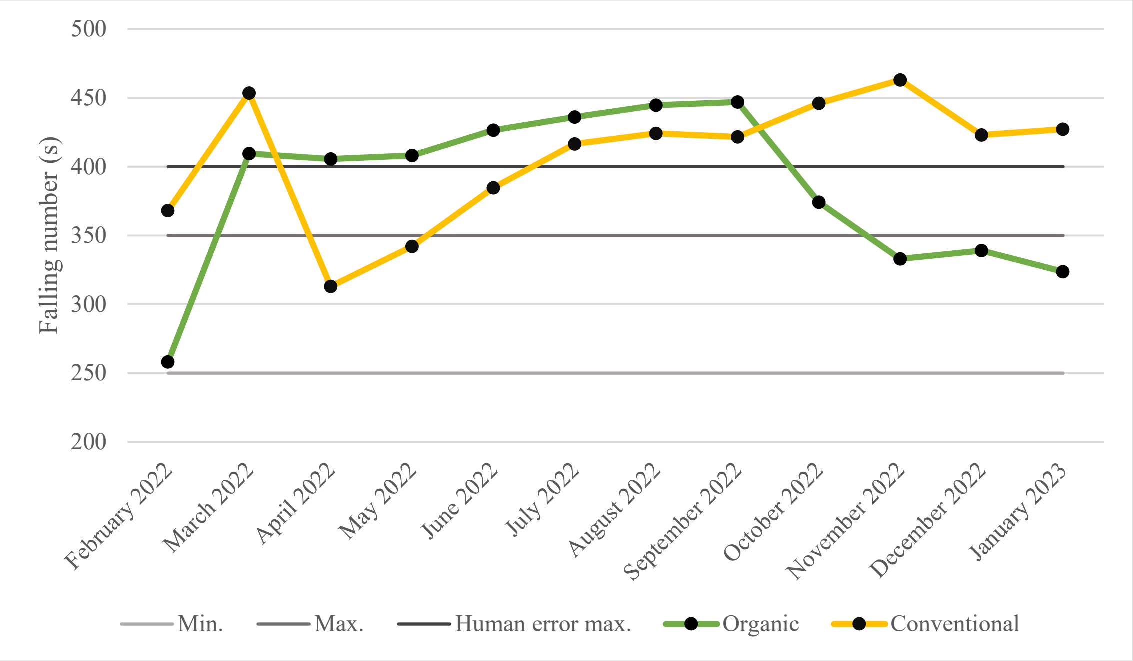

Figure 5 - Falling number changes in flour samples throughout the year

5.4. Rheological properties

Table 8 - Water absorption values of analysed flour samples

	Organic	**Conventional**
Date	Water absorption (%)	
February 2022	59.3	58.2
March 2022	57.0	60.7
April 2022	59.8	57.5
May 2022	59.2	57.0
June 2022	59.3	57.7
July 2022	58.6	57.6
August 2022	59.1	57.6
September 2022	59.9	59.3
October 2022	58.6	57.6
November 2022	58.3	57.0
December 2022	58.7	59.5
January 2023	59.0	58.2
Descriptive statistics		
Min.	57.0	57.0
Max.	59.9	60.7
Average	58.9	58.2
SD	0.73	1.08

In the analysis conducted using Mixolab, it was found that the average water absorption was 58.9% for organic flour and 58.2% for conventional flour as shown in Table 8. According to the value of standard deviation the data were clustered around the average for both flour types.

Mixolab curve

Three example Mixolab curves were chosen to demonstrate the different results obtained during the analysis. The first one, as shown in Figure 6, was the most unique result and it was the only one of this kind. Vertical lines were added to differentiate the five stages of the analysis. In the first stage, the maximum torque was 1.113 Nm and water absorption was 59.3%. In the second stage, the torque reached its minimum at

0.339 Nm. In the third stage, the torque raised again peaking at 1.489 Nm. In the fourth stage, the torque dropped to 0.781 Nm. In the final fifth stage, the torque raised for the last time reaching 1.239 Nm.

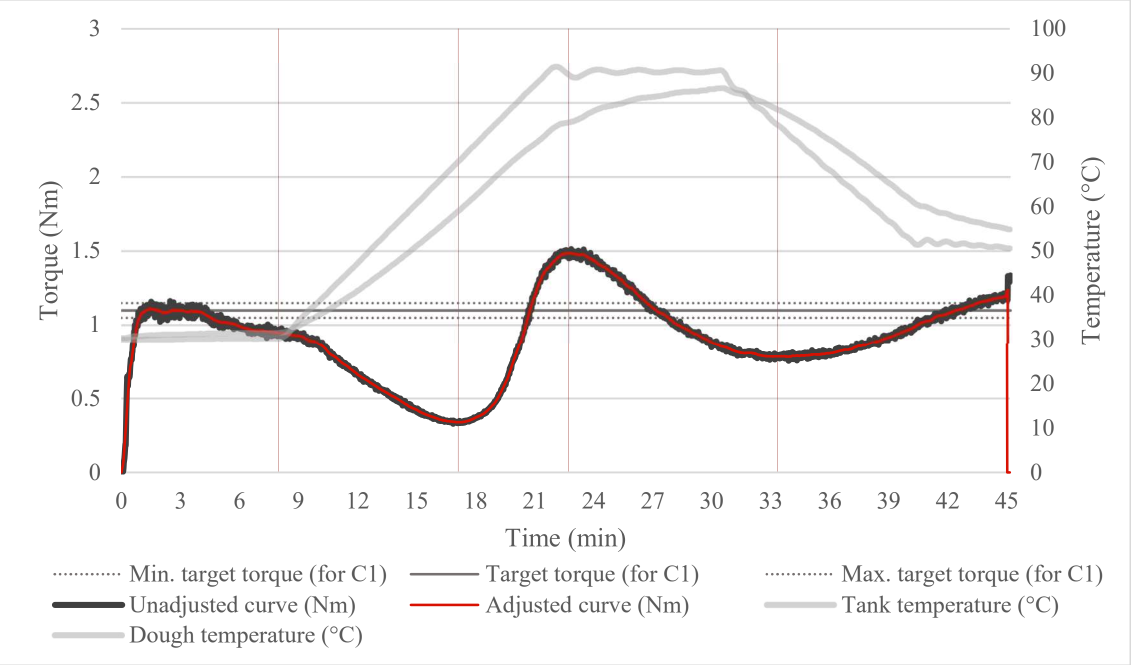

Figure 6 - Mixolab curve (organic flour - February 2022)

The second Mixolab curve, as shown in Figure 7, was a common result of the analysis.

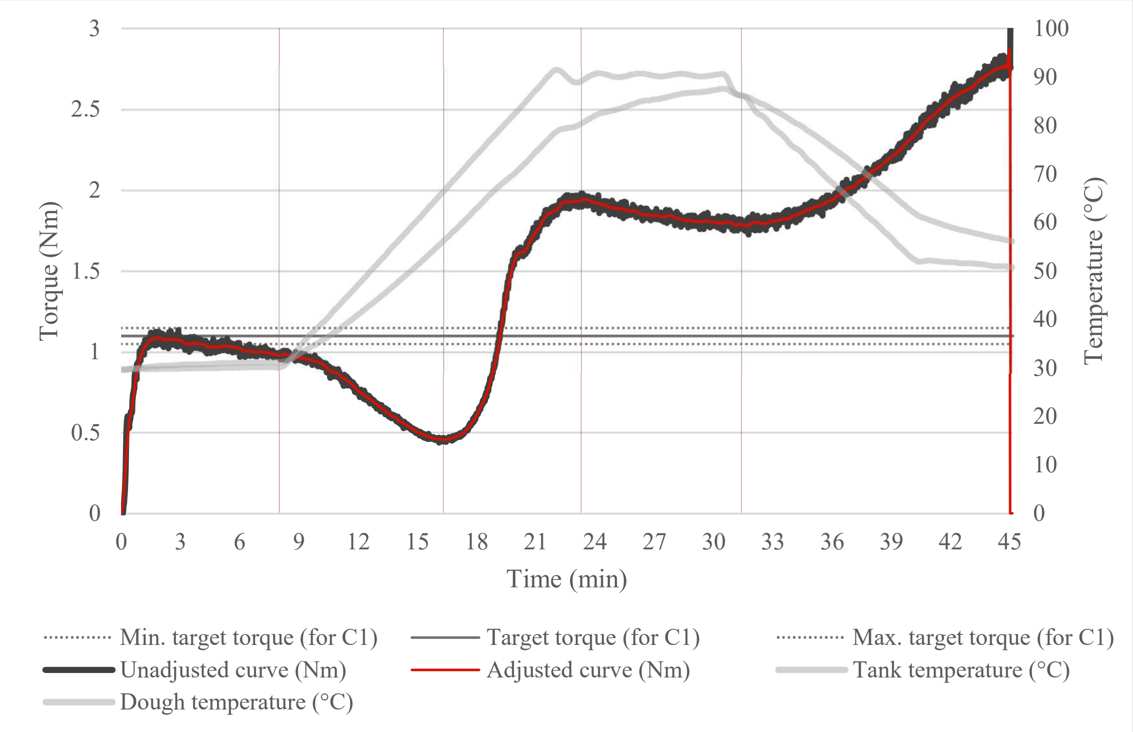

Figure 7 - Mixolab curve (conventional flour - October 2022)

At a first glance, the obvious changes between the first and the second Mixolab curve begin in the third stage, where torque peaked at 1.948 Nm, making it almost 0.5 Nm higher than in the first Mixolab curve. In the fourth stage, the difference continued to grow as maximum torque reached 1.778 Nm, meaning it was 1 Nm higher. And in the final fifth stage, the torque raised to 2.880 Nm, which signified the largest variation between these two analyses, where the torque was around 1.6 Nm higher.

The third Mixolab curve, as shown in Figure 8, described the other common result of the analysis. It can be seen as a middle result between the first and the second Mixolab curve.

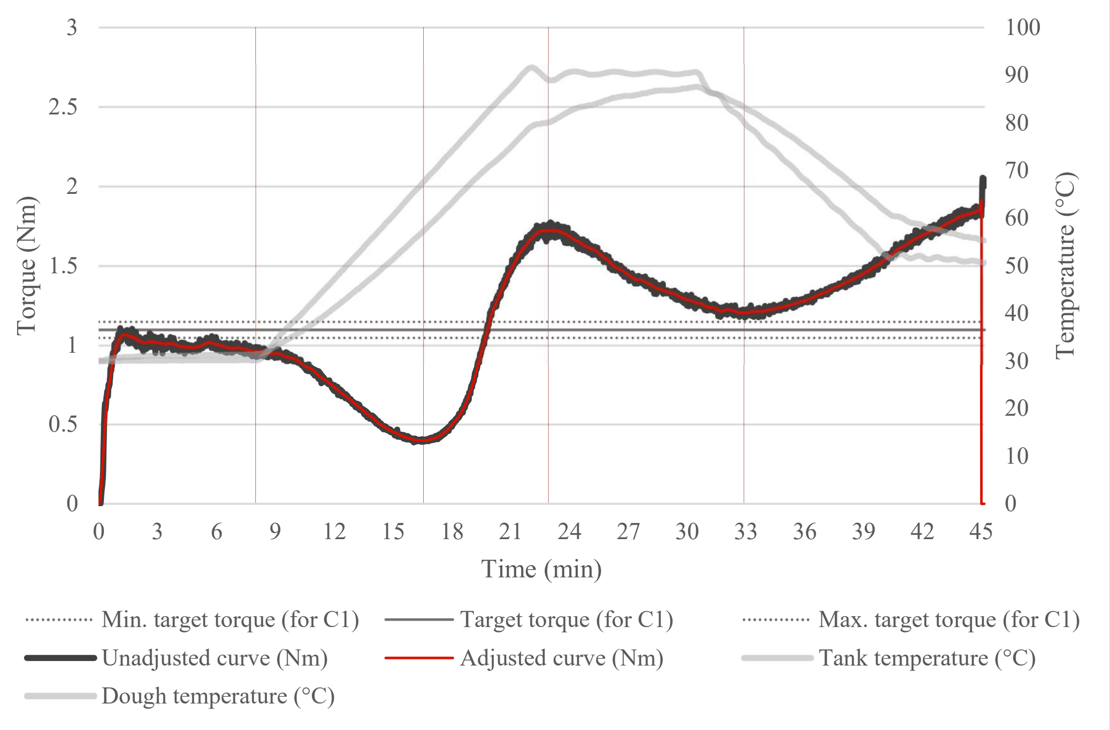

Figure 8 - Mixolab curve (organic flour - December 2022)

The first and the second stage were not much different among the three Mixolab curves. In the third stage, the torque peaked at 1.729 Nm, which was situated in the middle of the two other findings. In the fourth stage, the peak value of torque was again in the middle, at 1.201 Nm. In the fifth stage, the torque reached 1.914 Nm, which was a bit closer to the first Mixolab curve, with a difference of approximately 0.7 Nm.

All the remaining individual results were presented in the Appendix.

Profiler Index

To simplify the results obtained in the Mixolab curve, the Profiler index was used. It described the five stages of the analysis as six indexes, corresponding to the main rheological properties observed during the five individual stages.

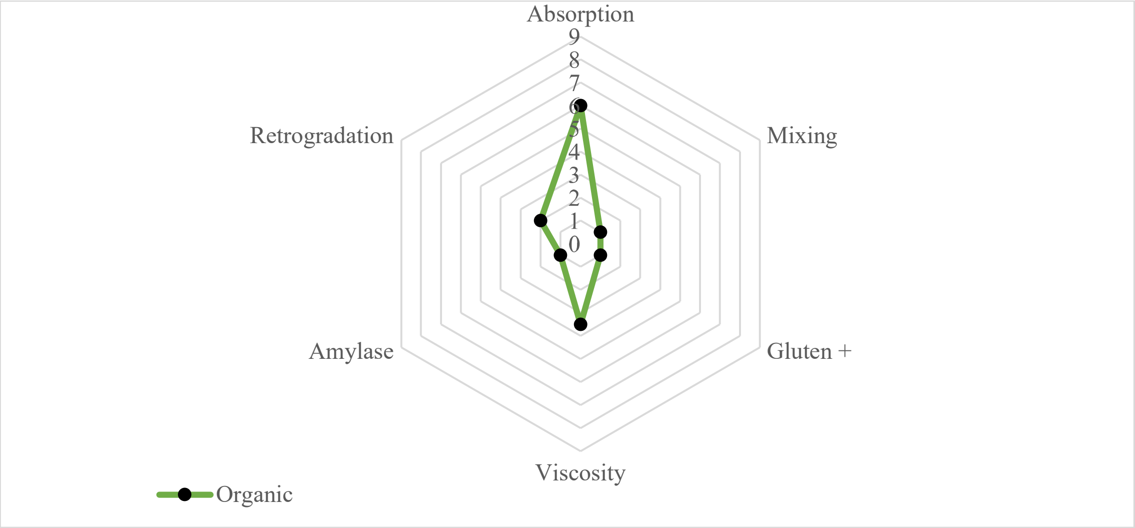

Figure 9 - Profiler index (organic flour - February 2022)

The Profiler index in Figure 9, had a high value of absorption index, as confirmed by the actual value stated in Table 8. The mixing, gluten + and amylase indexes were very low. The low amylase index corresponded to the FN value in Table 7, where it was the lowest in February 2022. The viscosity index was in the middle. And the retrogradation index was very low, as was apparent in Figure 6.

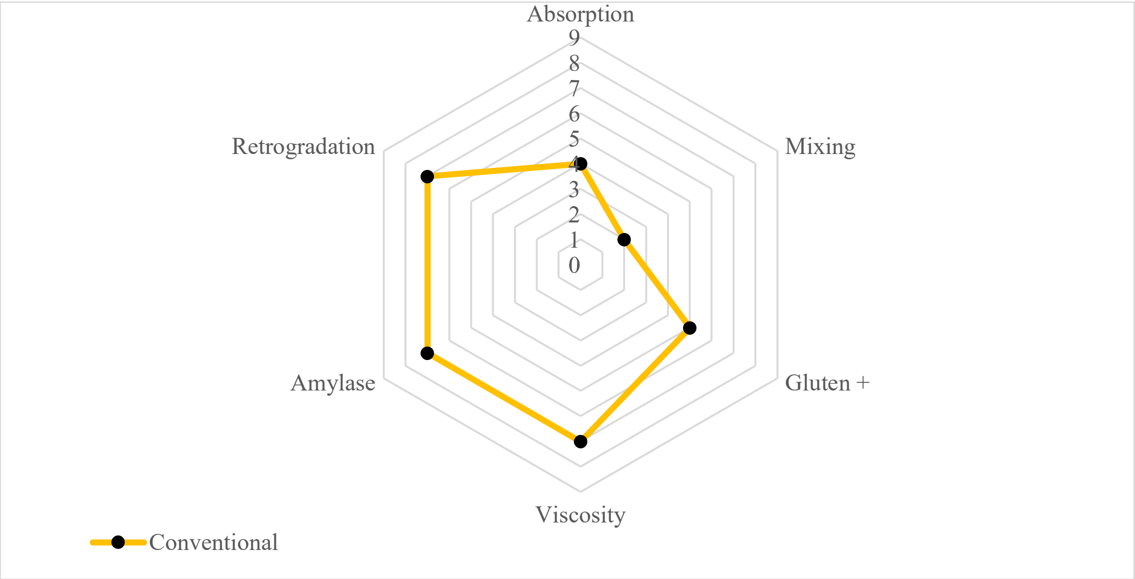

Figure 10 - Profiler index (conventional flour - October 2022)

The Profiler index in Figure 10, had a medium absorption index. The mixing index was low, similar to the first Profiler index. The gluten + index was a lot higher as were the rest of the indexes, which belonged in the top half of the scale. The amylase index in this analysis also corresponded to the FN value in Table 7, where the FN was the third highest. Even the high retrogradation index is well-demonstrated in Figure 10.

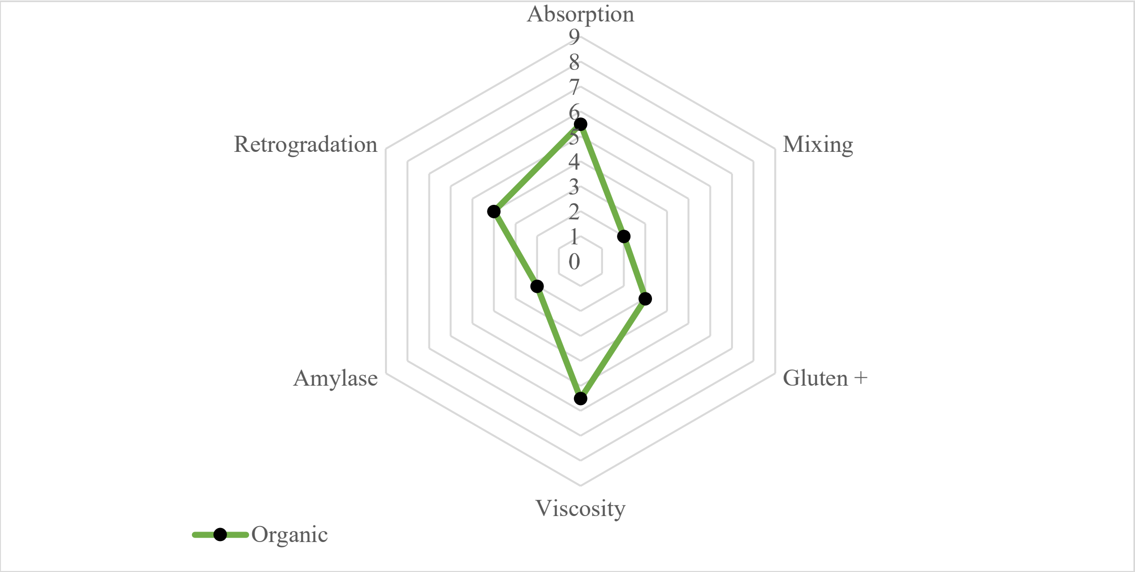

Figure 11 - Profiler index (organic flour - December 2022)

In the Profiler index in Figure 11, the absorption index was the same as in the first analysis, while the other indexes were higher. The mixing index was the same in the third and the second analysis. The gluten + index was a bit lower. The viscosity was relatively high, almost as in the second analysis. The amylase index was low, this time not corresponding to the FN value in Table 7 as well as it did in the previous two analyses. The retrogradation index was of medium value as evident in Figure 11.

A comparison of the three analyses was made and presented in Figure 12. It showed that organic flour maintained a similar shape, even with some different values. Meanwhile, conventional flour differed from organic flour significantly in the gluten +, viscosity, amylase and retrogradation indexes.

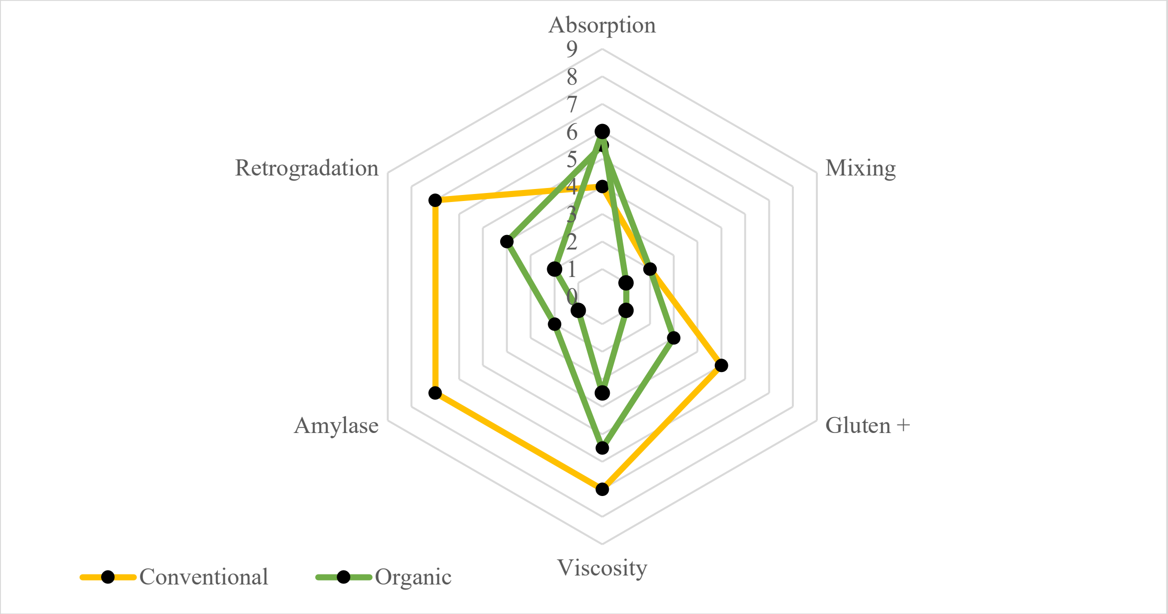

Figure 12 - Profiler index comparison

6. Discussion

For moisture content analysis, as shown in Figure 2, the conventional flour performed according to the standard requirements, which meant that the processing of this flour was done sufficiently. The organic flour was in most cases below the standard, meaning it was of lower moisture content than desired, which was probably due to insufficient tempering of the grains. This generally points to a lower flour quality (Sluková et al. 2017). It is probable that to achieve a finished product of good quality, more water must be added, to make up for the lower moisture content in flour. Therefore, conventional flour was considered better suited for baking in terms of moisture content.

All observed values of the gluten index showed that these particular flour samples belonged in the strong gluten category. This meant that only a very small part of gluten went through the sieve, presumably because of its high elasticity. These findings were in accordance with a previous study comparing the GI value of organic and conventional flour, where the average GI for organic flour was 100% and for conventional 98% (Draghici & Popa 2011). The similar trend in increasing and decreasing values of GI, shown in Figure 3, suggested there was a possible influence of environment, harvesting process or also grain storage throughout the year on both flour samples. However, this was refuted in a study where there was no significant influence found connected to the environment. Instead, an influence of genotype was observed (Sekularac et al. 2018). When using GI to predict the volume of the finished product, it was found that using this method only presented inconclusive results and it was suggested to also use wet gluten remaining on the sieve after centrifugation as a parameter of quality, which showed a better correlation with the results of different methods of analysis (Popa et al. 2014). On the contrary to these findings, it was reported that in samples with very high GI (>95%), there was a significant decrease in loaf volume (Curic et al. 2001). Nonetheless, there was no significant difference found between organic and conventional flour in the present GI analysis, thus it could not be concluded, which would be better suited for baking.

In wet gluten content analysis, it was found that conventional and organic flour had a similar number of measurements that belonged in the standard category. However, when looking at the measurements outside of this category, for conventional flour the values were mostly found above the maximum, meanwhile, for organic flour, they were below the minimum. It was safe to assume that the presence of more wet gluten content was a better result than less since gluten has such an important role in baking. Therefore, in wet gluten content analysis, conventional flour was found to have better results than organic flour. This was confirmed in another study, where conventional flour also had a higher gluten content than organic flour, however, it was proved to not have a significant effect on the quality of the finished product (Hahn et al. 2007). Contradicting results were also found, where organic flour had a much lower wet gluten content than conventional flour, respectively 14.7% and 26.8%. This was probably due to a very low protein content found in both flours, which was even lower for organic flour than conventional flour (Draghici & Popa 2011). Low protein content was presumably caused by insufficient nitrogen intake during wheat growth, which would naturally be lower in organic wheat as it cannot be added in the form of artificial fertilisers. Unfortunately, in the present study, the influence of protein content could not be confirmed as it was not analysed.

As for the results of the falling number analysis, most of the observed measurements were very high, above the standard maximum value for both flours. This pointed to low α-amylase activity. These findings were very different from a previous study comparing organic and conventional flour, where conventional flour was barely in the standard range and organic flour was much lower than required, pointing to a strong α-amylase activity (Draghici & Popa 2011). However, a similarity between these results was also noticed. In both studies, organic flour showed lower FN values than conventional flour. In a study where higher FN values were found in certain wheat cultivars, it was believed to be influenced by low starch damage and high protein content (Every et al. 2002). Since these factors could not be observed in the present study, other possible types of influence were contemplated. When looking at Figure 5 there was a noticeable change in the FN values throughout the year. This suggested a different type of influence on the two flour types. Organic flour was most likely newly produced and sold right after harvest, so there was no influence of long storage time, which would have potentially increased the falling number value. Meanwhile, conventional flour might have been sold a long time after production or it could have been produced from a mixture of new grains as well as old ones. Another cause for such high results that had to be considered was the influence of the human factor while performing the analysis. As one crucial part of the analysis, the shaking of the sample to homogenise the substance, relied solely on the person doing it, it was assumed that the procedure was not done uniformly throughout the year and might have altered the results, possibly increasing the FN value. While also considering the average values, it was established that organic flour was closer to the requirement concerning the falling number analysis. Therefore, it was assumed that organic flour would have better results in the quality of baked products than conventional flour, although both would still produce drier finished products than desired.

In the analysis of rheological properties carried out using Mixolab, three distinct types of Mixolab curves were observed. The first type as shown in Figure 6 was unique and only occurred once in the analysis. The curve showed signs of extensive gluten weakening. This would presumably result in low loaf volume since there would not be a strong gluten network that would be able to hold gas bubbles. Starch gelatinisation was relatively low as demonstrated by a low raise in dough viscosity in the third stage. Amylase activity was strong in this sample, which was also confirmed in the falling number analysis. This meant that the gelatinised starch was broken down by amylase rather significantly. In the final stage, the raise in the dough viscosity was very small, which would potentially result in a product with a long shelf-life. The second and the third type as shown in Figure 7 and Figure 8 were similar in the second stage, where the peak value was higher than in the first type, probably resulting in a normal loaf volume. In the third stage, the increase in dough viscosity was large in both types, meaning there was extensive starch gelatinisation during this phase. The fourth stage was where the differences began. The second type showed low amylase activity, which according to the falling number analysis was one of the lowest for conventional flour in October 2022. What was interesting was the pronounced raise in dough viscosity in the final stage, pointing to a strong starch retrogradation, which would probably result in a product with a very short shelf-life. The third type had dough viscosity in the middle of the two previous types again nicely explained by the falling number analysis, where the value for organic flour was in the standard range in December 2022. In the final stage occurred an increase in dough viscosity that matched the previous decrease. Starch retrogradation was also in the middle of the two other types, resulting in a relatively normal shelf-life. It is obvious that there were some differences among the three types, however, when looking at the individual figures for each month the differences between organic and conventional flour were only minor if any during most of the year. Starting in October 2022 noticeable differences occurred between organic and conventional flour particularly from the second stage onward, which was most likely caused by the changes in wet gluten content and the falling number, which became particularly notable at this time of the year. Nonetheless, these parameters were believed to be influenced rather by the method of harvest and storage time. This could mean that the found differences in rheological properties might not be related to the method of wheat cultivation.

In a study comparing sensory profiles of 60% whole wheat bread made from organic and conventional flour, it was found that the difference only occurred in density and surface texture. The organic bread was found to be significantly denser, which was explained by the loaf volume that was smaller in organic bread. This also reflected the difference in surface texture, which was observed to be firmer than in conventional bread (Annett et al. 2007). When examining the sensory qualities of bread made from white flour acquired from wheat cultivated by organic and conventional method similar results were found with loaf volume. However, these differences were found to be related rather to the year of harvest than the method of cultivation (Kihlberg et al. 2006). This study therefore supported the assumption that differences in rheological properties between organic and conventional wheat flour were conditioned rather by the environment during wheat growth than the diverse methods of cultivation. Thus, it was not possible to determine, which flour was better.

7. Conclusions

Significant differences between organic and conventional wheat flour throughout the year were found in the moisture content and wet gluten content. The moisture content, which was generally lower in organic flour would cause unnecessary processing problems. This could be easily avoided by using conventional flour instead, therefore it was decided that conventional flour was more suitable regarding its moisture content. Wet gluten content also showed differences, where in organic flour the gluten content was mostly insufficient, probably leading to a decreased quality of the finished product. In this study, both of these analyses thus suggested that organic flour had a lower quality than conventional flour.

However, when testing the rheological properties, no major differences were found between organic and conventional flour throughout most of the year. The changes that were recorded throughout the year corresponded to other analyses. Nonetheless, these changes were believed to not be influenced by the wheat cultivation, so this factor was ruled out. It was rather suggested to be influenced by the environment during wheat growth and post-harvest manipulation as the differences began in the months following the wheat harvest.

Due to these reasons, it was not established if organic or conventional flour was better suited for baking. Further research may be recommended, though it is possible that differences in quality are not based on the method of wheat cultivation.

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Appendices

List of the Appendices:

Appendix 1: Mixolab curve results

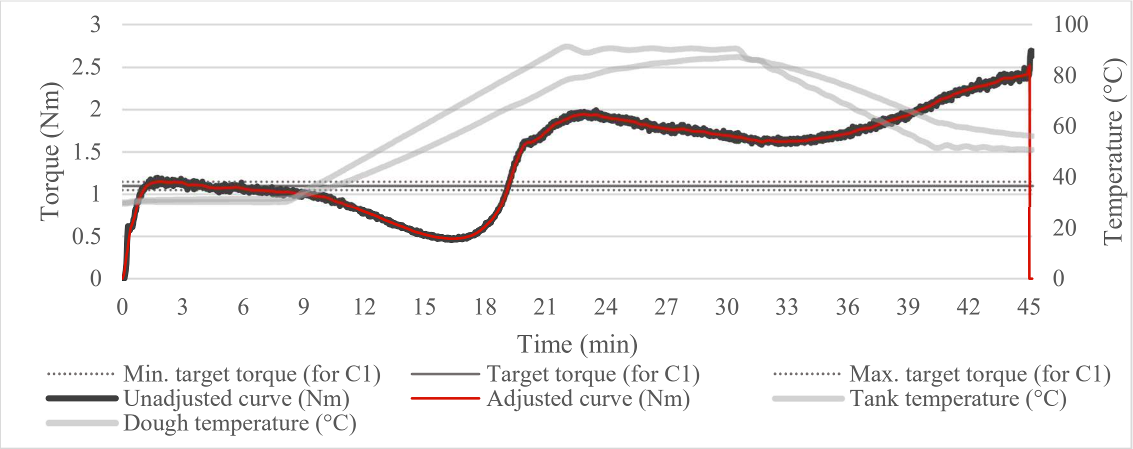

Figure 13 - Mixolab curve (conventional flour - February 2022)

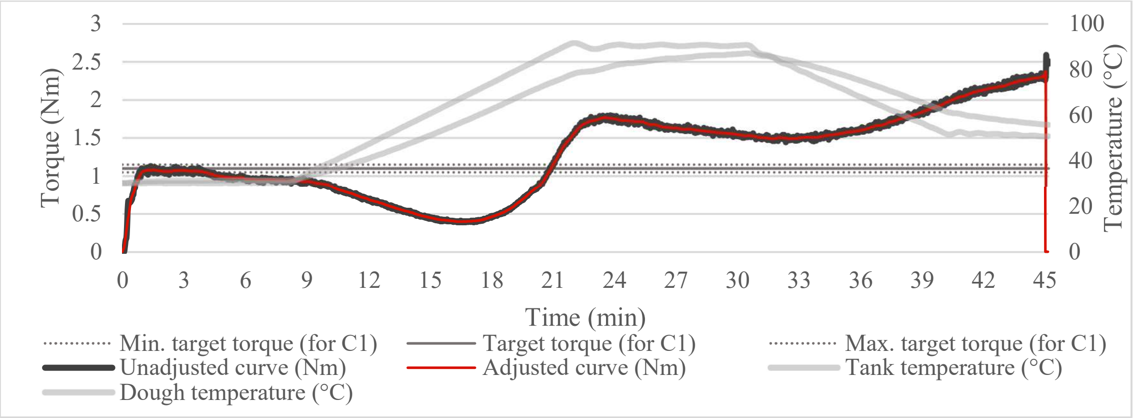

Figure 14 - Mixolab curve (organic flour - March 2022)

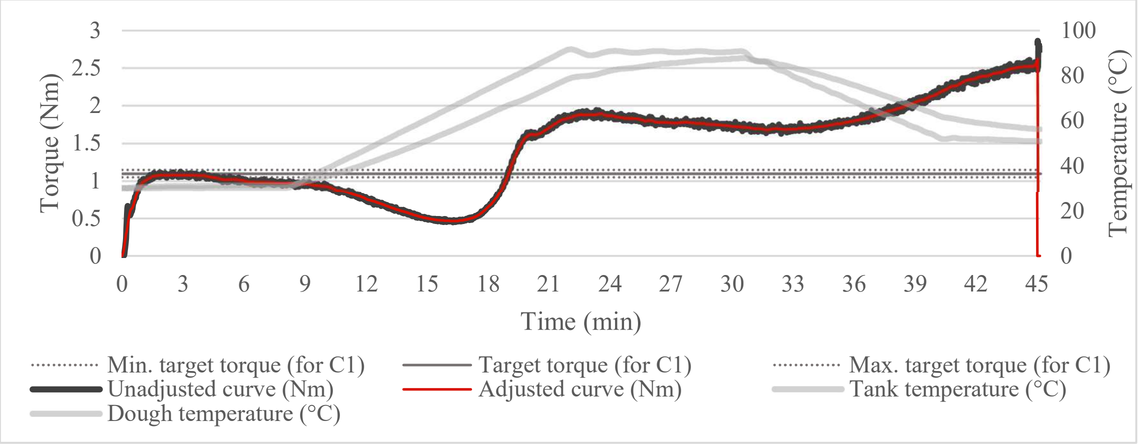

Figure 15 – Mixolab curve (conventional flour - March 2022)

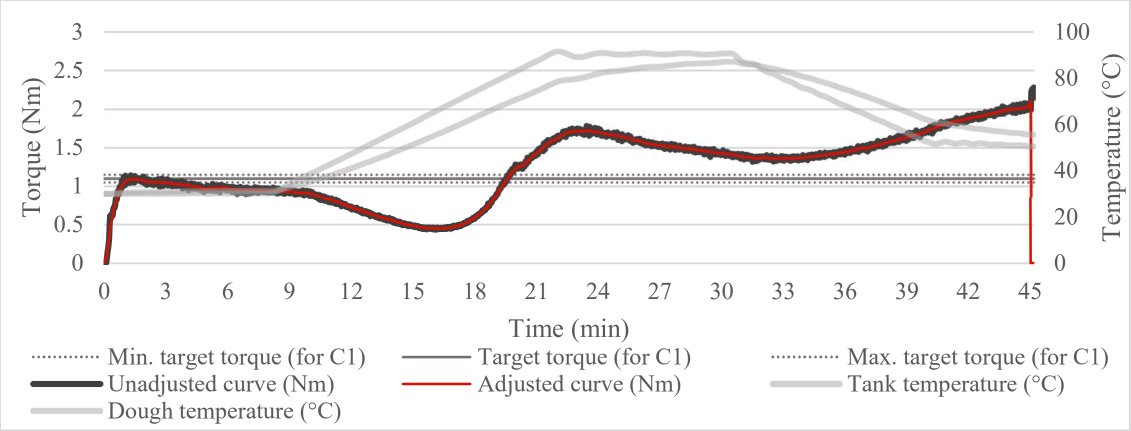

Figure 16 - Mixolab curve (organic flour - April 2022)

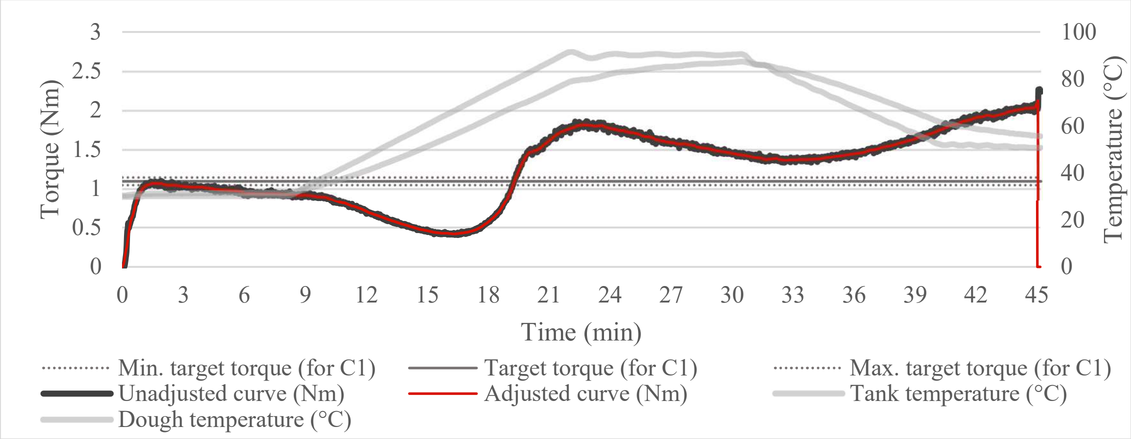

Figure 17 - Mixolab curve (conventional flour - April 2022)

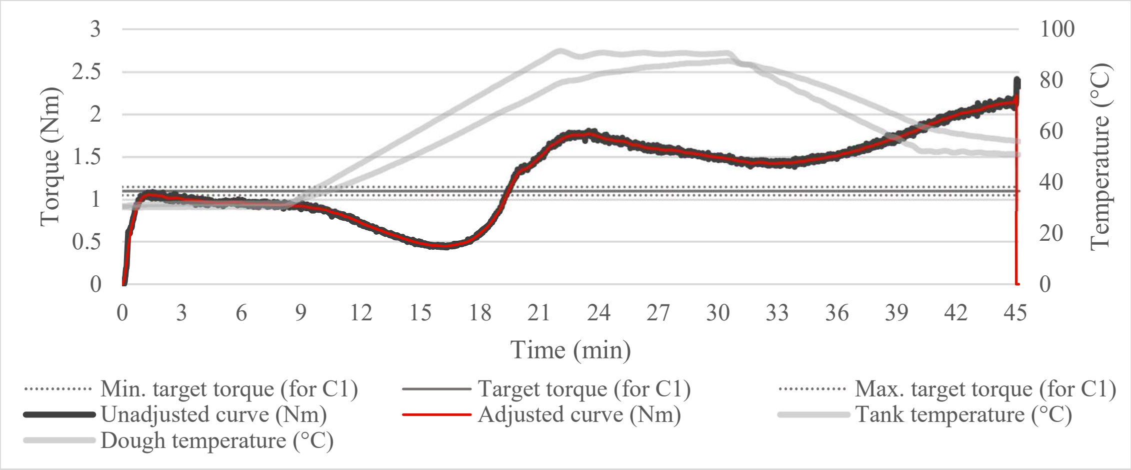

Figure 18 - Mixolab curve (organic flour - May 2022)

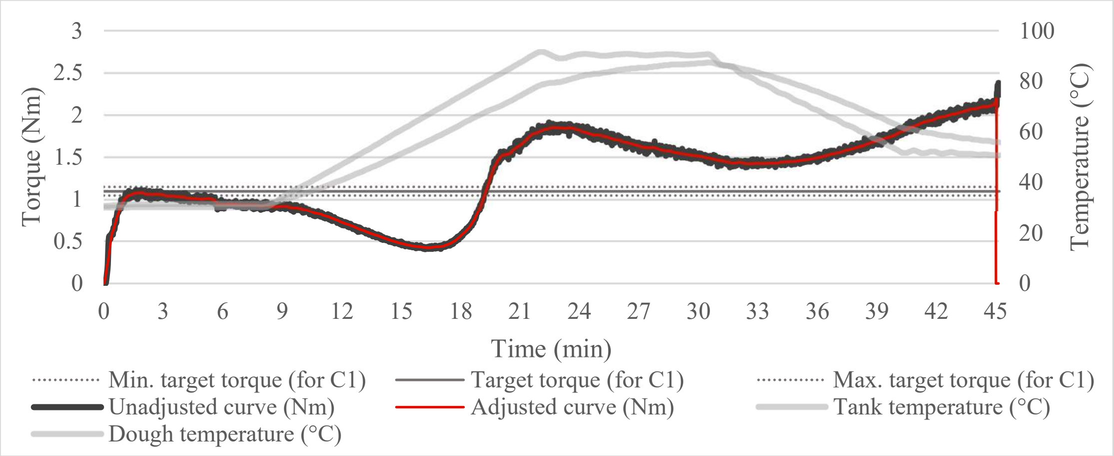

Figure 19 - Mixolab curve (conventional flour - May 2022)

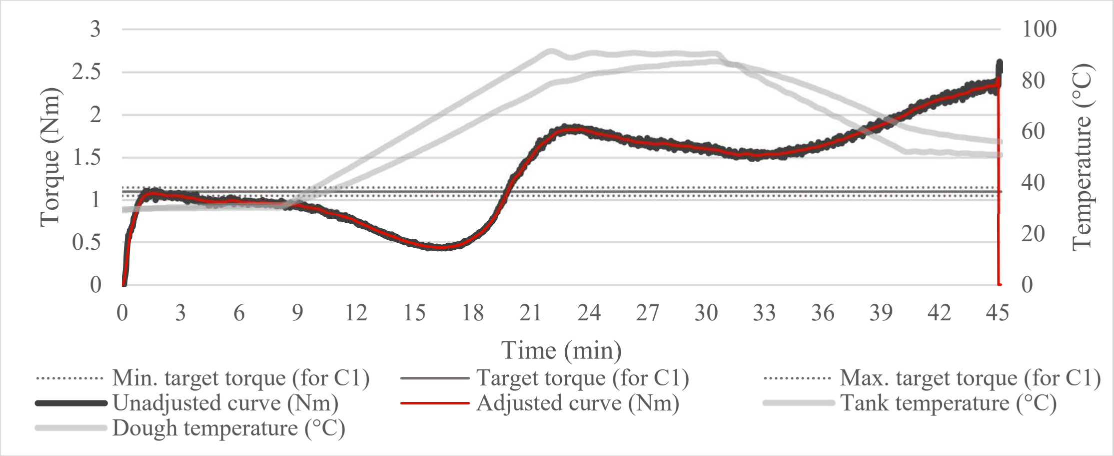

Figure 20 - Mixolab curve (organic flour - June 2022)

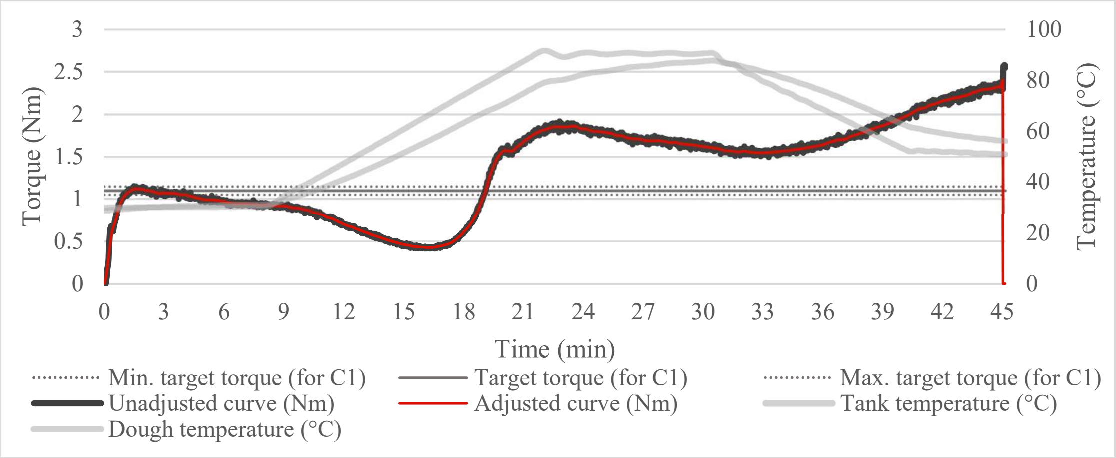

Figure 21 - Mixolab curve (conventional flour - June 2022)

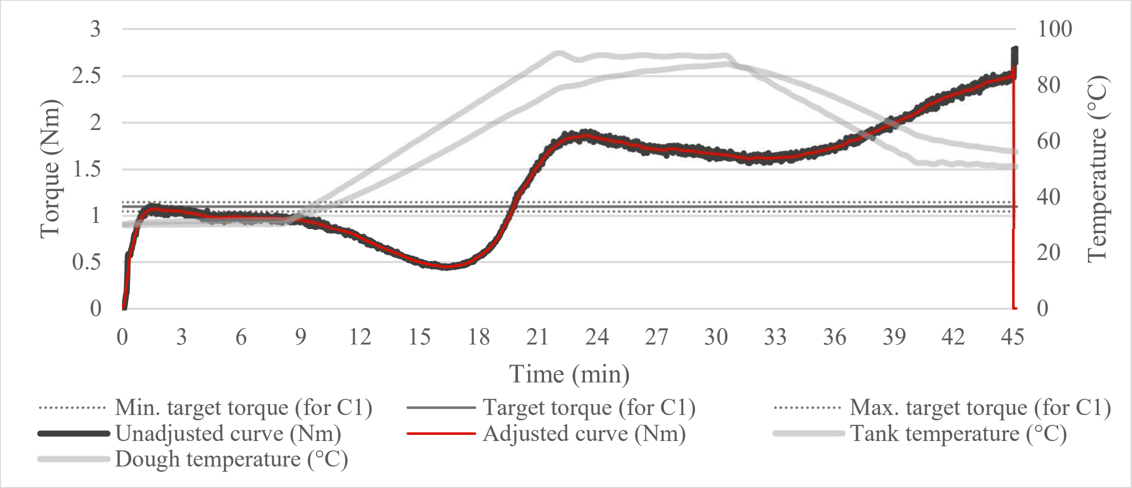

Figure 22 - Mixolab curve (organic flour - July 2022)

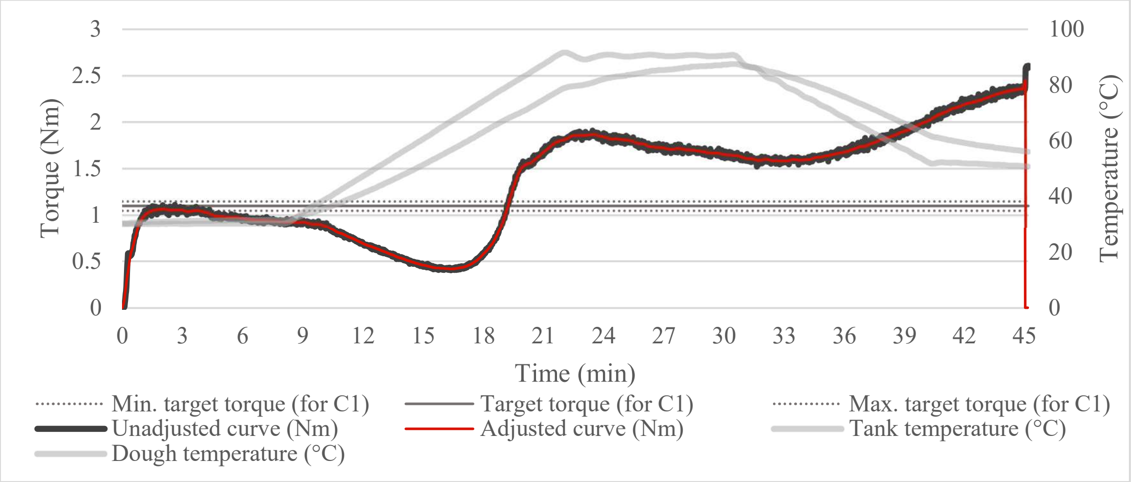

Figure 23 - Mixolab curve (conventional flour - July 2022)

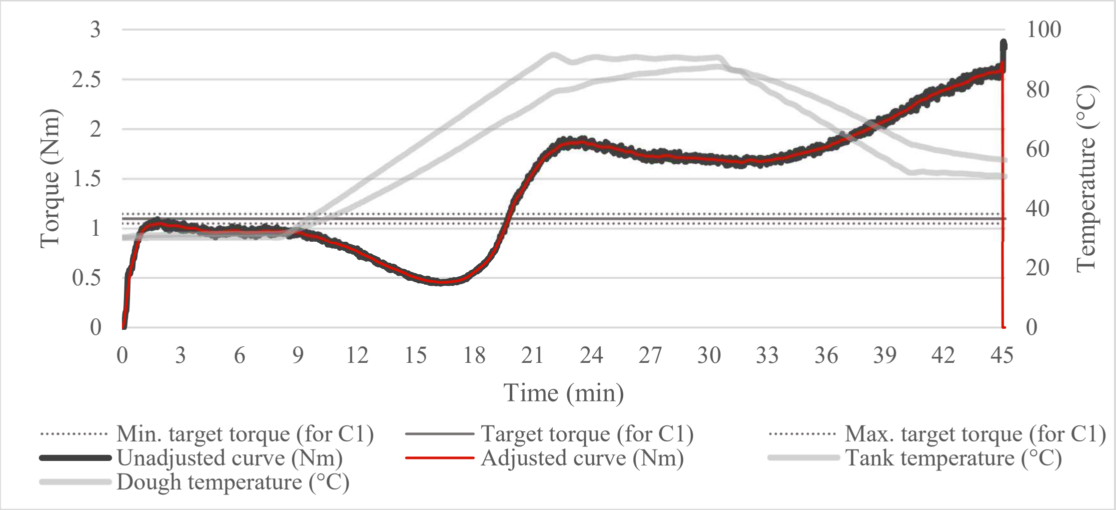

Figure 24 - Mixolab curve (organic flour - August 2022)

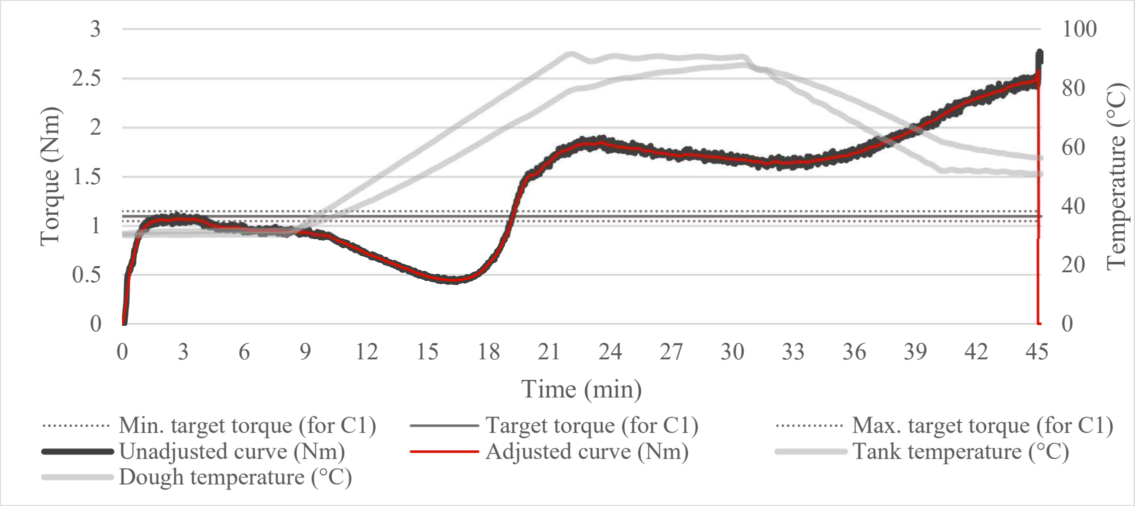

Figure 25 - Mixolab curve (conventional flour - August 2022)

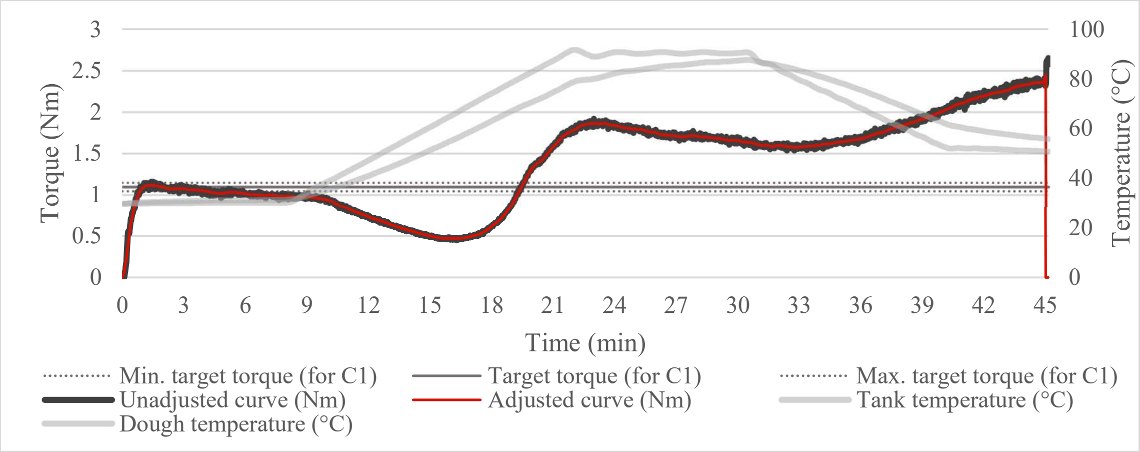

Figure 26 - Mixolab curve (organic flour - September 2022)

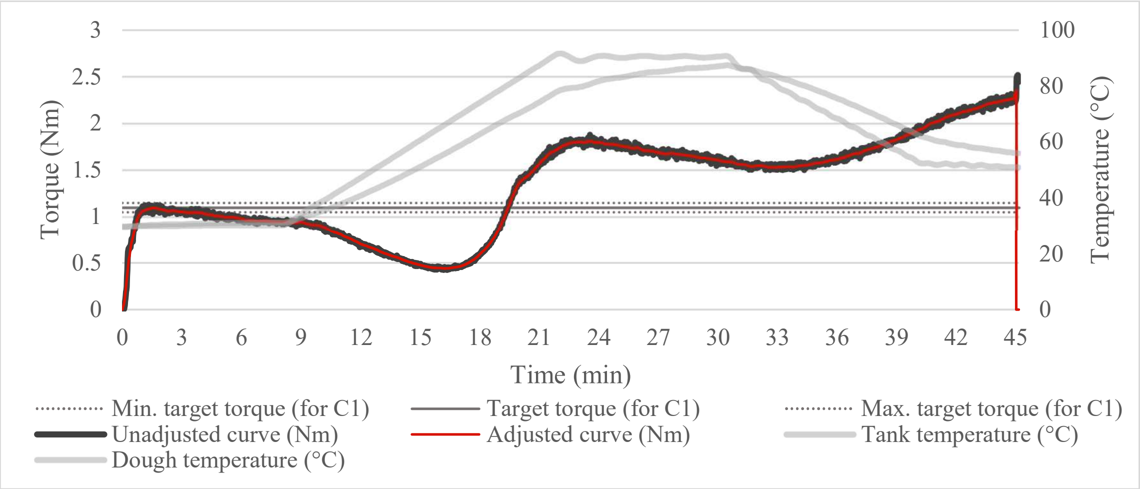

Figure 27 - Mixolab curve (conventional flour - September 2022)

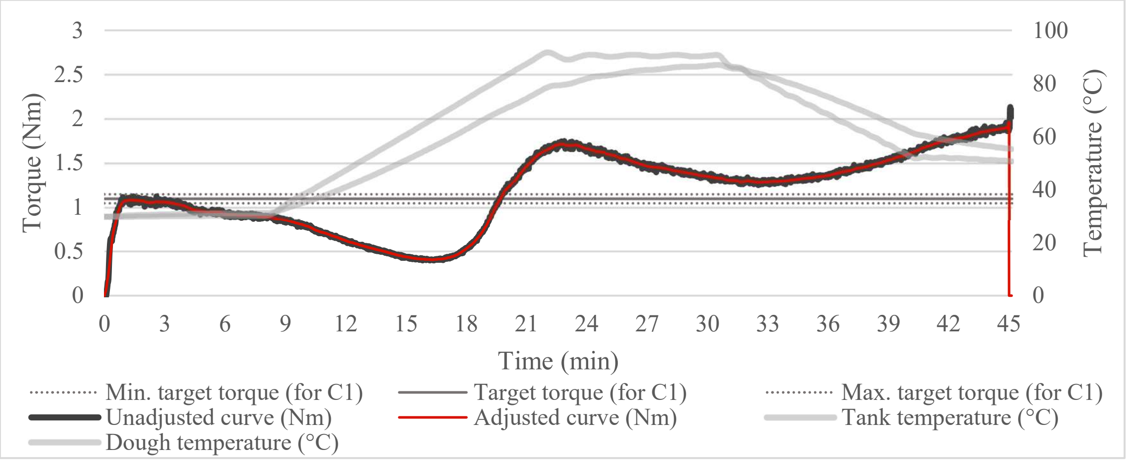

Figure 28 - Mixolab curve (organic flour - October 2022)

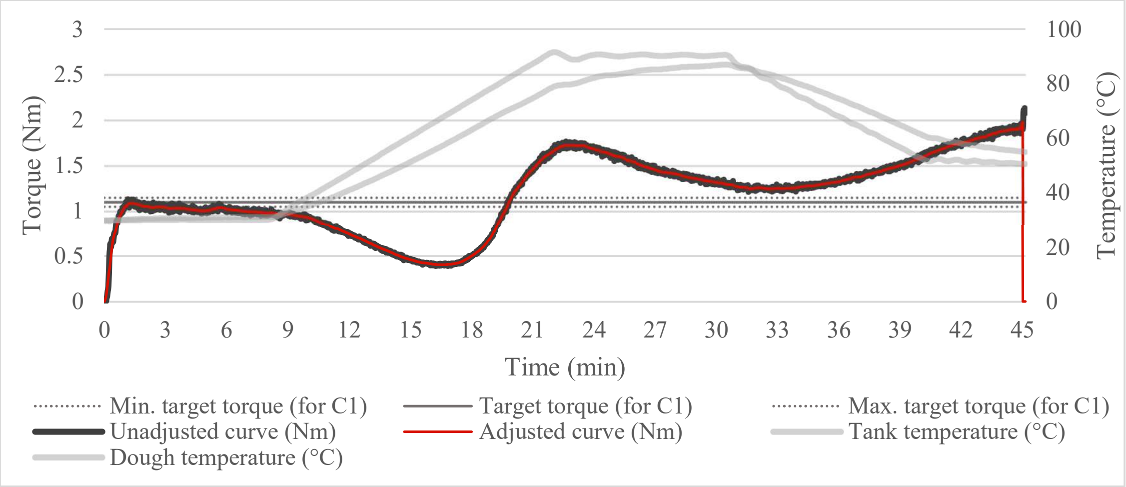

Figure 29 - Mixolab curve (organic flour - November 2022)

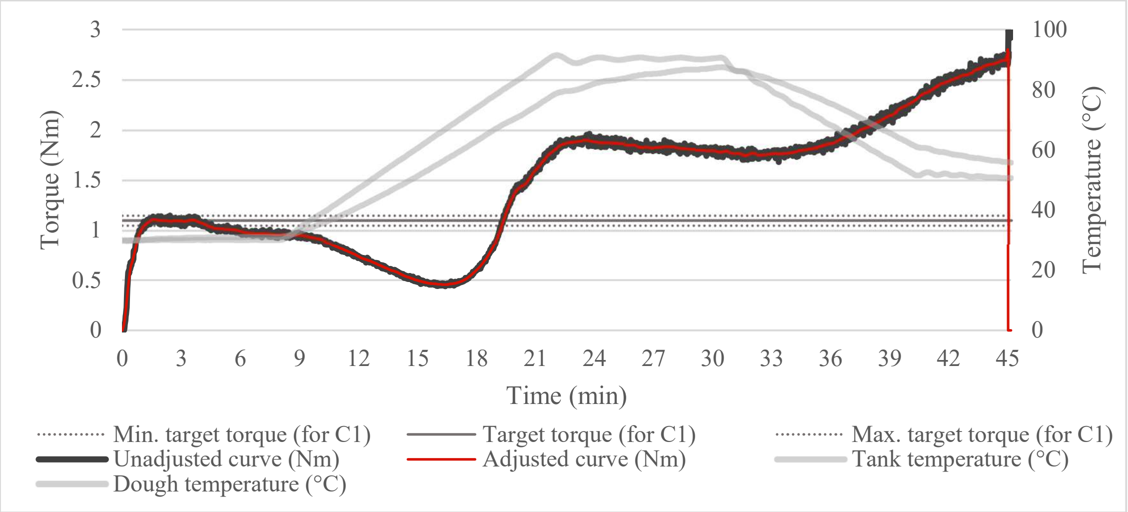

Figure 30 - Mixolab curve (conventional flour - November 2022)

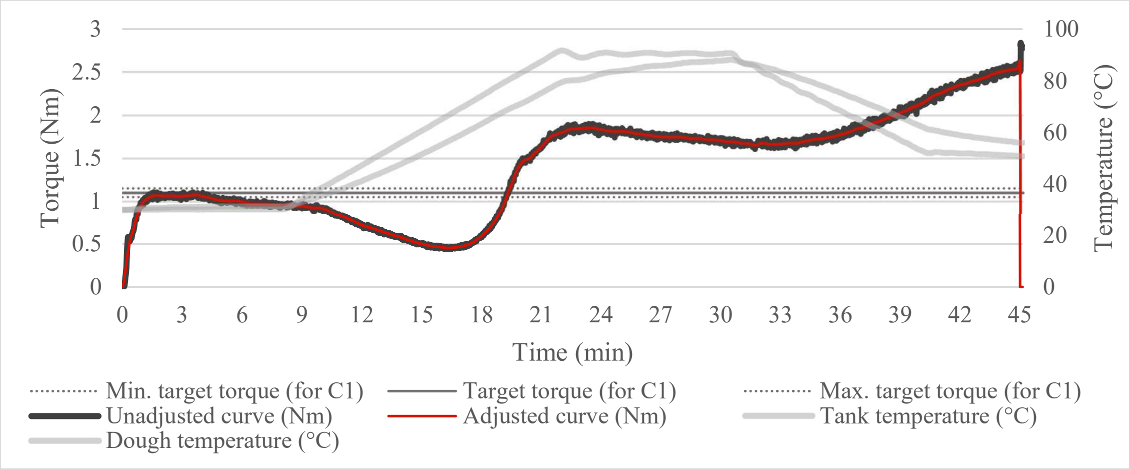

Figure 31 - Mixolab curve (conventional flour - December 2022)

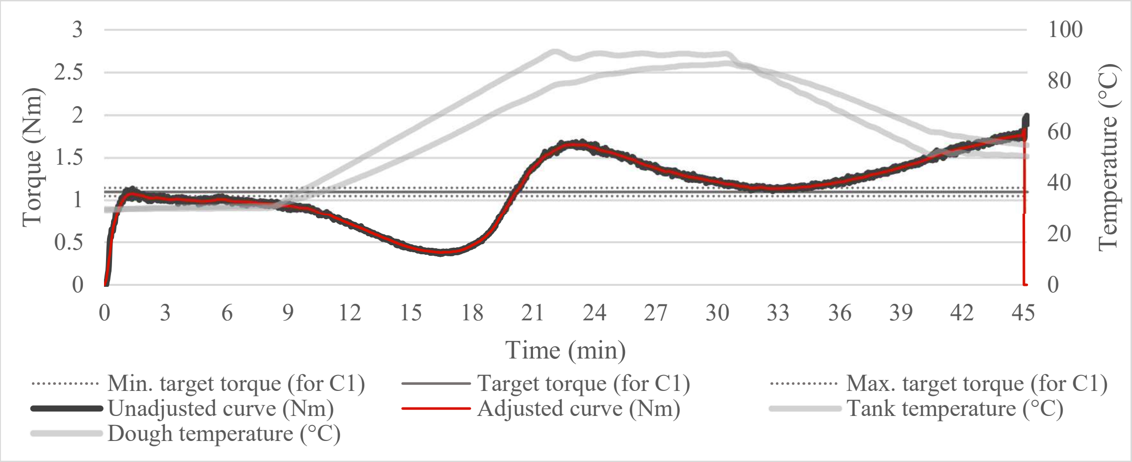

Figure 32 - Mixolab curve (organic flour - January 2023)

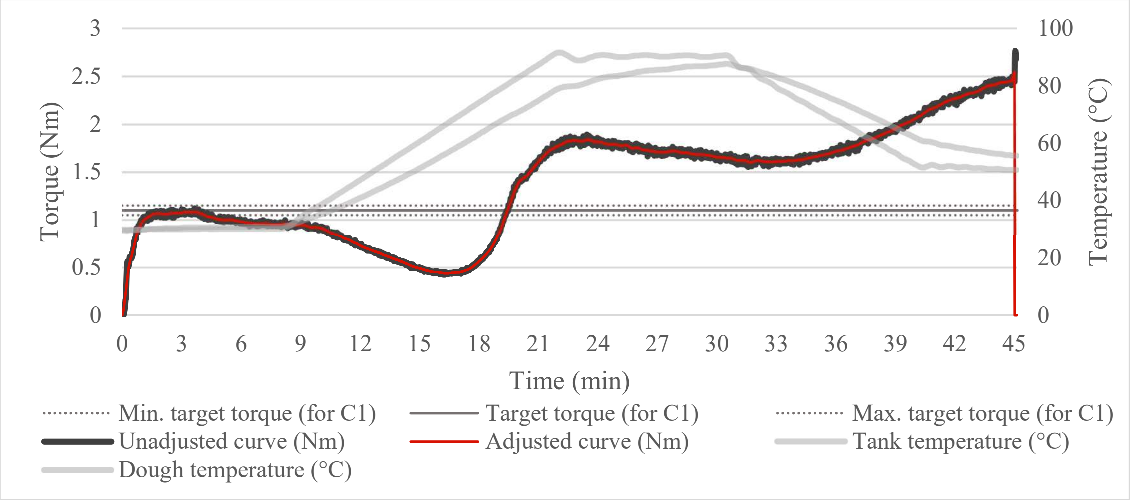

Figure 33 - Mixolab curve (conventional flour - January 2023)