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DEVELOPMENT OF FRENCH PASTRIES BASED ON HERITAGE CEREALS

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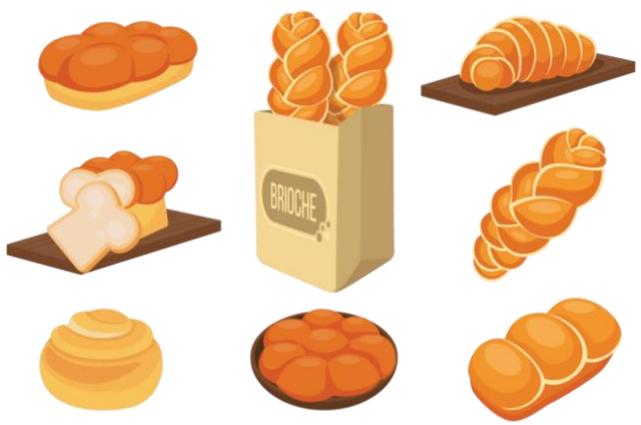

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HC: Heritage cereals

MC: Modern cereals

ATIs: Amylase and Trypsin Inhibitors

FAO: Food and Agriculture Organization of the United Nations.

ANSES : Agence Nationale de Sécurité Sanitaire de l'Alimentation, de l'Environnement et du Travail, France.

CIQUAL : Centre d'Information sur la QUalité des Aliments.

TPA: Texture Profile Analysis.

N: Newton.

AF: Adhesive Force.

Sd: Standard Deviation.

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Finally, I would like to thank all the people who contributed to the success of this internship and who helped me during the writing of this report.

Abstract

Consumer preferences are constantly changing, and trends are moving towards local and sustainable crop production. Heritage grains fit perfectly into this context as they are suitable for organic farming and can also contribute to a healthy and balanced diet. For a more regular consumption of these cereals, it would be interesting to build on the formulation of popular and nutritious food products that have a growing commercial potential.

The main objective of this study is focused on the development of innovative sweet recipes based on ancient cereals. In this approach, it was decided to focus on the formulation of French pastries, namely brioches, that are likely to appeal to consumers with three different cereals (Helkorn, Öland and Källunda Variety Evolutionar). A study on the variation of certain ingredients such as butter and sugar were conducted to determine the potential impacts. According to this model, 4 recipes were selected for each type of cereal, for a total of 12 different brioche samples. Subsequently, the project focused on the characterization of the final products. The objective was to analyze the dough's swelling power, texture, and colour but also, we used both analytical and hedonic sensory analysis to determine the sensory characteristics as well as the consumer preferences. The food matrix is extremely complex and involves a large number of biochemical reactions. As we have seen, the variation of ingredients such as butter and sugar can influence the formulations on various aspects. At the end of these analyses, we have seen that sugar appears to be a major ingredient in the formulation and appreciation of consumers. Indeed, its increase or decrease has an impact on the final products in terms of Texture Profile Analysis results, colour, dough swelling power and general consumer preferences. The type of cereal does not appear to be an influential factor in relation to variations in sugar and fat.

Keywords: Heritage cereals, formulation, brioches, characterization of the final products, consumers.

1. Introduction

Context

Currently a second-year student in the engineering cycle at ESIROI, specializing in Food Processing, I had the opportunity to do an internship in an English-speaking environment. It was a 4-month research internship (from April 26th to August 31st, 2022) which took place at the University of Kristianstad in Sweden. I was supervised by Karin Wendin and Viktoria Olsson in the gastronomy laboratory.

My internship was mainly focused on the formulation of brioches from heritage cereals (HC). Within this framework, I was able to take an interest in different characteristics of the products such as the texture, the colour, but also, in the preference of consumers on the various formulated brioches. My internship was mainly focused on the formulation of brioches from heritage cereals. In this context, I chose to formulate French brioches from these local cereal crops. I was then able to look at different characteristics of these products such as texture, colour, but also, consumer preference. This subject is part of a project to introduce historical HC on a larger scale. A Swedish research team consisting of 6 scientists, 3 contractors and 1 extension agent will have to:

- Evaluate organic production of HC and modern cereals (MC) wheat and rye during three consecutive years at two sites to establish the effect of environment and management on yield, yield components, nutritional and technical quality, as well as consumer preferences regarding the produced bread.
- Identify nutritional and sensory profiles of bread.
- Identify factors that attract consumers to buy bread baked from HC.
- Initiate the development of innovative organic HC products using the knowledge gained.

Background

Cereals are often the main ingredients in food formulations. For thousands of years, they have been associated with important sources of fiber, protein and bioactive compounds with antioxidant and anti-inflammatory effects. Indeed, since prehistoric times, they were used to

make bread or porridge. There is a wide variety of cereals spread all over the world and the main ones are wheat, rye, rice, barley, oats and corn [1].

Current consumer trends are undergoing several changes and are moving towards a healthier, local, and sustainable diet. In this context, HC find their place, especially because of their nutritional values, unique phytochemical profile and sensory characteristics [2], [3]. Despite the large amount of data, there is no real definition of MC and HC. According to *Giambanelli et al.* (2013), HC can be defined as "forms that are represented by populations that have not undergone any modern breeding or selection, sometimes retaining characteristics of wild ancestors, such as individual variability, height, brittle rachis, low harvest index, and, in some taxa, hulled grains" [4].

The development of innovative food products based on these HC could enhance the vast market potential and thus, boost whole grain consumption. The recommendation for whole grains in the Nordic countries is 70 g per day for women and 90 g for men [5] but consumption is too low in many countries [6]. A recent survey in Sweden of adult dietary habits showed that the average whole grain consumption was 39 g for women and 46 g for men [7]. The best-known variety is spelt, which has also been used to introduce other ancient local varieties such as Öland wheat. Increasing the consumption of products made from these grains could also contribute to improving public health as well as the environment and sustainable development. The advantages of whole grains over refined grains are well known [8]. Indeed, these cereals have overall higher levels of fiber, protein, carbohydrates, minerals, and vitamins compared to MC and may also have a positive impact on certain diseases [8].

It is an excellent source of fiber and appears as an interesting ingredient to regulate the transit and promote intestinal well-being but especially in their role of prevention against non-communicable diseases [8]. According to EFSA [9], for adults, the recommended dietary fiber intake varies from 25 to 38 g/day but in many EU countries this intake is below the recommendations in all age categories [10], [11]. In addition, HC would be more suitable for organic farming as they may not require the addition of mineral fertilizers [12], [13]. To this aspect, we can also add a greater resistance to drought and extreme climatic events than MC. The growing concerns about global warming, is

prompting awareness and turning to this type of grain more and more [14], [15]. This ability to adapt to the environment could, according to several authors, be related to their genetic resources [16]. It would even appear that these genetic factors are determinant for cereal protein content [17], [18]. HC are also richer in zinc and iron so combining them with other plant foods would contribute to the recommended daily mineral intake [19], [20], [21].In addition, phenolic compound content may be found to be higher in some ancient wheat species according to a HEALTHGRAIN study than in more modern ones [22], [23].

These cereals may also have a positive impact on certain cardiovascular diseases, type 2 diabetes and cancer. Further research is needed to conclude on the influence of HC. Gluten-related digestive disorders are on the rise [24] and among them we can mention the autoimmune celiac disease which affects the absorption villi in the small intestine. This results in preventing the proper absorption of nutrients and particularly concerns α-gliadin and γ-gliadin from gluten [25], [26]. However, high amounts of amylase and trypsin inhibitors (ATIs) are reported to cause gastrointestinal symptoms by stimulating Toll-like receptors (TLRs) [27]. There is no treatment other than to be careful with one's diet by avoiding gluten. Information is circulating among consumers that HC have less immunogenic properties than conventional ones. Some of them would therefore appear to be less impacting for patients with celiac disease [28]. ATI content was measured in soft wheat, durum wheat, spelt, einkorn, and emmer [29] and the results show that three einkorn cultivars contained lower concentrations of ATI compared to other wheats. In contrast, spelt and emmer contained significantly higher concentrations of AI than soft wheat [29]. Thus, HC could produce toxicity compared to modern varieties.

For several months, the current geopolitical context of war between Ukraine and Russia has been impacting the entire world. According to the FAO (Food and Agriculture Organization of the United Nations), world food prices could increase by 8% to 20% and this conflict would also lead to a sudden drop in wheat exports from Russia and Ukraine. Nearly 20 million tons of wheat in storage have not been able to leave Ukraine due to the war, which has jeopardized the year's sowing and therefore the upcoming harvest. Exports of fertilizers, on which the agriculture of many European and African countries depends, are also prevented. Therefore, using local products would reduce this dependence on imports. Bakers will have local flours at their disposal

in order to continue to formulate products that will meet the demands of consumers. Sweden is already starting to think about the development of its food security by promoting the use of its local resources in a sustainable and ecological way [30]–[32].

Methodological background

The formulation of the recipes is done with the help of the creative design methodology. This technique is based on the generation of prototypes according to the desired attributes - soft, golden brioches like those sold in France in this study - which will be tested by consumers. From an initial selected recipe, a series of prototypes is developed according to the sensory characteristics and usage properties determined. This technique ensures that all creativity, experience, and scientific methodology are used to develop a product that meets expectations [33].

To study our products, several analyses can be performed to characterize them. We could carry out physico-chemical analyses such as the swelling power of the dough, of color or of texture. Even if physico-chemical tests can avoid sensory tests for reasons of convenience and speed, some aspects can only be studied by sensory science. The correspondence of the results of the two techniques is known for color and texture. However, the sensory attribute of odor is not imitable by physicochemical measurements. Considering both sensory and textural aspects is therefore paramount in the creation of new products. A more specific sensory test with a trained panel would allow to obtain the profile of the products which would complete these analyses.

Experimental design:

Recipe development is typically done using creative design methodology. This technique allows to propose several prototypes according to a selection of predefined attributes to be tested by consumers. From an initial recipe, the series of prototypes is developed according to the sensory characteristics and usage properties determined. This technique ensures that all creativity, experience, and scientific methodology are used to develop an effective product that meets expectations.

Three steps were necessary for the development of the products. First, the main ideas were combined with kitchen trials to determine prototypes that met the requirements. These prototypes were created by varying the type of ingredients used and the proportions. Then, physical-physical analyses in the laboratory provided the physical characteristics of the products (color, texture profile analysis). The last step was the realization of consumer tests, whose purpose is to determine which product can be proposed to future consumers or if it is necessary to carry out new experiments. But also, to obtain product profiles from a panel of experts through sensory analytical evaluation.

Estimation of the volume of swelling of the dough:

The making of this kind of products involves a fermentation step because in the recipe, there is an addition of fresh yeast. This is an alcoholic fermentation that takes place in an anaerobic environment. Indeed, the yeasts degrade the simple sugars contained in the dough into carbon dioxide, ethyl alcohol and other important compounds for the taste of the bread and this will modify the physical properties of the dough. For example, ethanol but also acetic and lactic acids, propionic, pyruvic, etc., and flavoring aldehydes and ketones. There will be a first fermentation which lasts between one and two hours then a second fermentation, the fermentation of "push" lasts between one to three hours, but it is necessary to take care not to spread out too much in time because the balls of dough would be likely to fall back during the cooking [34]–[36]. I was interested in measuring the volume of swelling of the dough during the first fermentation to compare the different flours and quantities of ingredients. For this, we followed the protocol below which can be seen in *Figure 1*:

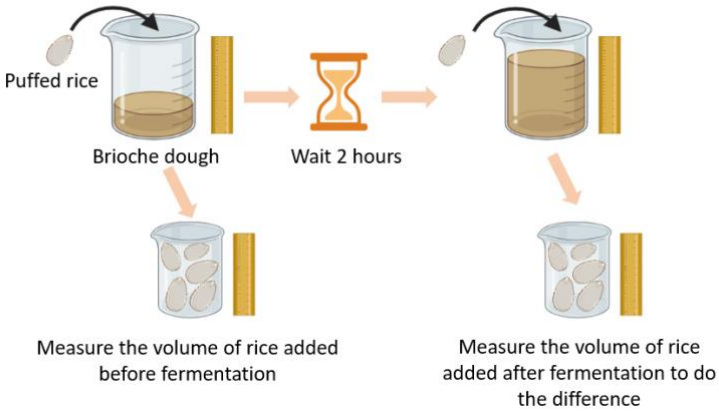


Figure 1: Simplified diagram of the dough swelling measurement method.

Texture:

The analysis of the texture of a food product is commonly measured using a texturometer. The analyses were carried out by a CTX texture analyzer (Ametex Brookfield, Middelboro, MA, USA). To characterize my product, I performed a texture profile analysis (TPA). This is a double compression test that determines the textural properties of foods. Therefore, the samples are compressed twice with a cylinder (reference AACC36) to give an overview of their behavior when chewed. The main advantage of TPA as an analytical method is that it can quantify several texture parameters in a single experiment. TPA tests must be performed with correct and specific test parameters, otherwise the results will not be calculated correctly. For that, bibliographical studies were carried out followed by tests and adaptations according to the samples [37]–[40].

The instrument starts recording data when the automatic trigger has reached the force specified in the test parameters. Then the probe compresses the sample at the test speed and travels the target strain distance. Once the target distance is reached, the probe climbs to the original trigger position at the test speed. The instrument waits for some time before the second compression occurs at the test speed. At the end the probe moves back up to the starting position at the post-test speed.

Colour:

The colour of the brioches was measured using the Konica Minolta CM-700d colorimeter (Konica Minolta Co Ltd., Tokyo, Japan). The colour characterization is carried out using the CIE 1976 L*a*b* colour space where L* is lightness from black (0) to white (100), a* is green (-) to red (+) and b* is blue (-) to yellow (+). More simply, these are the lightness L* which indicates the luminance of the surface and the a* and b* which indicate the deviation of the colour from that of a gray surface of the same lightness [41].

By abuse of language, it is often said that this type of device can quantify what the human eye sees. It gives results very quickly, but it is much less accurate than a spectrophotometer which perfectly controls the conditions of measurement. Indeed, a measurement taken with the portable colorimeter can vary in relation to the external environment: the brightness of the room, the time of day when the measurement is made, possible movements in the vicinity.

Analytical sensory evaluation:

The idea here is to rely on a selected and trained analytical sensory panel, specialized in the characterization of "texture", "appearance", "taste" and “flavour”, able to characterize, describe and deduce the sensory profile of products from an appropriate and diversified vocabulary [42], [43].

The first part was a training part and consisted in initial analyzing the samples coded as "extreme" (high fat/sugar and low fat/sugar) as well as the intermediates, then positioning them on a rating scale according to the attributes studied. This positioning considers the opinion of the entire panel and will be used for the next step. Thus, this first positioning will serve as a training session for the panel so that they are able to correctly evaluate the product attributes. For the second part which is the analyze-part, we had to do the same thing but this time with all the samples to be tested by the panel.

Each product profile was obtained using a consensus method described above. A consensus was established on the definition of each attribute determined during the training session. Then, each excerpt was examined one by one by rating each attribute on an intensity scale of 0 to 100, where 0 = no intensity and 100 = the highest possible intensity.

Then, after discussion, a consensus had to be reached to determine a single intensity value for each attribute.

Hedonic test:

The acceptability of products can be measured with naïve assessors such as consumers during hedonic tests. The principle of sensory analysis is that it is based on the use of the five human senses: sight, hearing, smell, taste, touch. Consumers, will be able to answer several questions on the visual aspect, the aroma, the taste, the texture or the general opinion of the products according to their preferences [42], [44], [45].

Statistical analysis:

Generally, the data collected are analyzed as mean ± standard deviation of means (SD). Regarding the data on physical characteristics the use of the Student's Ttest can be used to deduce the importance of the ingredients in the discrimination of the products. The type and quantity of ingredients can be treated as fixed factors. Student's t-test is a statistical test for comparing the means of two groups of samples. The question is whether the means of the two groups are statistically significantly different. To do this, the value of $p < 0.05$ is often used to show whether or not there is a significant difference between them.

To see if there is a correlation between the different results, the Pearson correlation is recommended. It was decided that a value greater than 0.7 or less than -0.7 in the Pearson test would indicate a correlation.

Aim

Initially, the objective was to develop innovative food products from HC. Thus, we turned to the formulation of French pastries, namely brioches, likely to appeal to consumers. To do so, we varied certain quantities of ingredients such as butter and sugar to determine their potential impact.

Afterwards, the project focused on the characterization of the final products. The objective was to analyze the texture and the colour and to determine the sensory characteristics and the preferences of the consumers through sensory analyses.

2. MATERIALS AND METHODS

2.1 Recipes formulation

2.1.1 Presentation of the three cereals used

Öland wheat is a very old and particularly hardy variety of wheat, originating from the Swedish island of Öland, located in southeast Sweden. It is quite similar to wheat and specially to spelt, of which it has all the qualities. Rich in proteins and gluten, it gives bread a marked and very aromatic flavour, an elastic consistency, and a darker crumb if we use the whole grain that retains moisture well and makes it keep particularly well. In addition, it is a so-called cultural variety, which means that it is not as transformed as other modern wheat varieties. The flour we use contains all the hull parts - both coarse and fine - as well as the seed white and germ. This led to a high fiber content and a lot of flavours from the grain. The nutritional data used are those from the Ciqual table of ANSES (agence nationale de sécurité sanitaire de l'alimentation, de l'environnement et du travail, France). We took the averages of the data entered for "whole spelt, raw". *Helkorn* wheat: Whole meal flour is a whole grain product that retains all the ingredients of the grain [46], [47]. It is rich in magnesium, iron and has a high content of dietary fiber. This cereal is an ancient variety with attributes close to rye as currently used. The data also comes from CIQUAL as above. I took the averages of the data entered for "whole rye, raw". The nutritional values are as follows in *Table 1*: for **100 g**:

Table 1: Nutritional values according to CIQUAL.

Name	Average Content for spelt	Average Content for rye	Average Content for soft wheat
Calories	344 kcal	334 kcal	356 kcal
Protein	15,6 g	10 g	9,94 g
Carbohydrates	59,5 g	61 g	75,9 g
Fats	2,43 g	1,97 g	0,82 g

Sugars	6,68 g	0,98 g	0,41 g
Saturated fatty acids	0,41 g	0,25 g	0,13 g
Sodium chloride salt	0,02 g	0,0073 g	0,0098 g

Källunda Variety Evolutionar. Concerning this variety, there is little or no precise information available because it is cultivated by a single farmer on his farm. Moreover, it is an "evolutionary" variety which means that each year, the crops evolve and thus adapt to the surrounding environment.

2.1.2 Pre-trials

From the start, I was given a free hand in choosing the final product, but it still had to be sweet in nature. So naturally I went for the pastry of my childhood, the French brioche. Moreover, most of the Swedish people didn't seem to know or at least had never tasted them [45].

We started by looking for a recipe corresponding to the characteristics of a French brioche. A soft, sweet, and golden brioche with a honeycombed structure, an airy, stringy but melting texture in the mouth. After several trials of recipes found in the literature, we finally retained my family recipe which was unanimously approved by the laboratory team [48]. The basic recipe that has been selected is as follows in *Table 2* below:

Table 2: Selected recipe for the reference brioches.

Ingredients list	Amounts	References
Flour	430 g	Fullkorns - Vete mjöl
Warm milk	80 g	Mjölk - Fetthalt 1,5%.
Butter	125 g	Svenskt smör. Smör normalsaltat 82%.

Sugar	70 g	Svenskt - Strösocker. Sockerbeta (*Beta Vulgaris*).
Salt	Half a teaspoon	Falksalt. Salt finkornigt.
Crumbled fresh yeast	12 g	Kron Jäst.
Egg	5 units (One for gilding)	Kronägg. Ägg från Skåne.

Concerning the material, we used kitchen utensils specific to the realization of pastry, we find in particular: the mixer, the scale, the oven for the biggest equipment. Then, bowls, knives, spatulas, circular molds and consumables such as baking paper or transparent food film.

2.1.3 Experimental design

It was decided to create designs for French pastries, the brioches. Then, in order to study the impact of some ingredients (here, sugar and fat) "high" and "low" levels were defined in the pre-tests. The aim is to "stretch" this design to obtain new products but not necessarily a good brioche. To be considered, these levels must be imperatively symmetrical to the normal value of the recipe. The different steps are represented in the form of a food manufacturing diagram in the following *Figure 2* [35], [36].

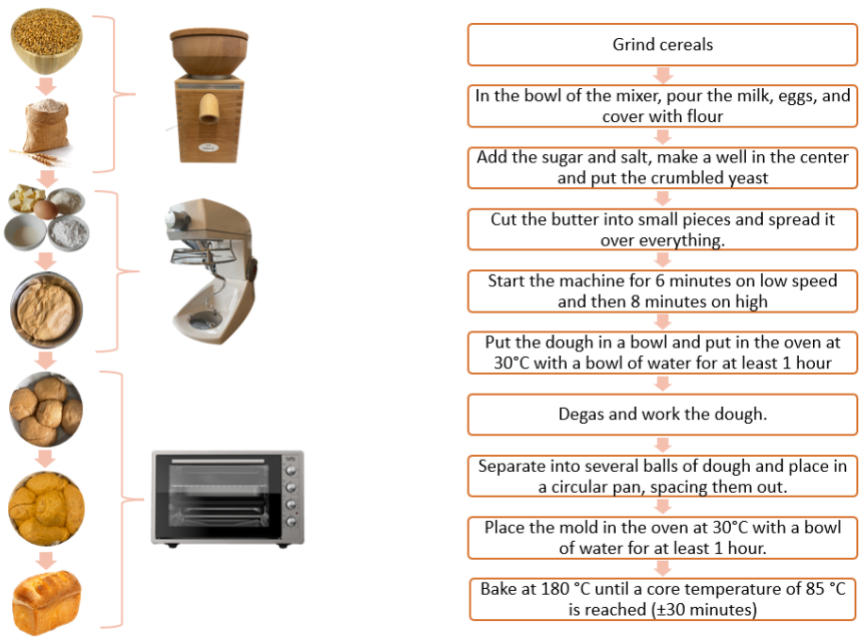


Figure 2: Diagram of how to make a brioches with heritage cereals.

Now that the basic brioche recipe has been selected, the next step is to apply it with HC. The first step to take before embarking on the butter and sugar variations is to make the brioches with the three types of cereals following the "normal" recipe. To limit the number of samples, we chose to grind the flours only finely and not to vary the particle size. It is likely that the change in particle size has an impact on the products, but it will not be considered in this study.

We will proceed to create the design by varying some parameters of the recipes. In our case, it will be a question of playing with the percentage of fat and sugar. A design can be defined as a set of variations within a given recipe to analyze the influence of ingredients on the product. From an initial recipe, a series of prototypes is developed according to the sensory characteristics and usage properties determined. This technique ensures that all the creativity, experience and scientific methodology are exploited to develop efficient products.

Thus, we focused on "high" and "low" levels for the ingredients selected in the pre-tests. The aim was to extend the design so that it would always be like the reference, but not necessarily identical.

Furthermore, these "high" and "low" levels should be symmetrical to the normal value of the recipe. Finally, we will have for each flour:

- A brioche with a low level of butter and sugar (-B-S);
- A brioche with a high level of butter and sugar (+B+S);
- A brioche with a low level of butter and a high level of sugar (-B+S)
- A brioche with a high level of butter and low sugar (+B-S).

I made several brioche tests trying to determine the maximum and minimum amounts of butter and sugar individually to observe the real effects of these ingredients. After these different tests, I was able to determine the maximum and minimum values that I was going to use for the following experiments. In the *Table 3* below, we find the reference recipe as well as the low and high levels of the ingredients of interest.

Table 3: Summary of the different quantities of the ingredients.

	Ingredients				
Recipe	**Normal**	**+B+S**	**-B-S**	**+B-S**	**-B+S**
Flour	430 g	430 g	430 g	430 g	430 g
Warm milk	80 g	80 g	80 g	80 g	80 g
Butter	126 g	**212** g	**40** g	**212** g	**40** g
Sugar	70 g	**130** g	**10** g	**10** g	**130** g
Salt	5 g	5 g	5 g	5 g	5 g
Crumbled fresh yeast	12 g	12 g	12 g	12 g	12 g
Eggs	4 units	4 units	4 units	4 units	4 units

Then, physical analyses in the laboratory provided the physical characteristics of the products and allowed the selection of the products to be tested by the consumers. There were 4 variations of recipes and 3

types of cereals, making a total of 12 different brioches to make. To facilitate the reading and compression of the 12 different brioches with the variations of butter/sugar/cereals, sample codes have been established and can be seen in *Table 4.*

Table 4: Full names of samples and associated codes used in the report.

O+B+S	Öland with a high level of butter and sugar	**O-B-S**	Öland with a low level of butter and sugar
K+B+S	Källunda with a high level of butter and sugar	**K-B-S**	Källunda with a low level of butter and sugar
H+B+S	Helkorn with a high level of butter and sugar	**H-B-S**	Helkorn with a low level of butter and sugar
O+B-S	Öland with a high level of butter and low sugar.	**O-B+S**	Öland with a low level of butter and a high level of sugar
K+B-S	Källunda with a high level of butter and low sugar.	**K-B+S**	Källunda with a low level of butter and a high level of sugar
H+B-S	Helkorn with a high level of butter and low sugar.	**H-B+S**	Helkorn with a low level of butter and a high level of sugar

2.2. Products characterization

2.2.1 Estimation of the volume of swelling of the dough

The volume results are approximations indicating an order of magnitude of the swelling power of the different brioches recipes. However, in order to obtain representative results, it will be necessary to take care to respect a fixed and precise volume for the filling of the puffed rice at each measurement.

2.2.2 Texture and colour analysis

Texture:

Each sample was tested three times and the analyses were carried out on the crust and on the crumb to have a precise analysis of the texture of the products [37]–[40]. Below, the list of parameters defined for the following analyses in *Table 5*:

Table 5: The parameters used for the TPA measurements of crusts and crumbles.

Parameters			
Software	Texture Pro 1.0.15	*The number of Cycles:*	2
Length	50 mm	*Test Standard:*	TPA - compression
Depth	30 mm	*Probe:*	TA-AACC36
Trigger Load	0,3 N	*Target Type:*	Distance
Distance for the Crust	15 mm	*Distance for the Crumb*	5 mm

Colour :

We cut slices of brioche 2 cm thick, and the calibrated device is positioned above. This measurement will be made on the crust and on the crumb of the brioche. Each result should be done in triplicates to have statistically reliable results [41].

2.2.3 Sensory evaluation panel

However, this type of sensory panel implies a certain cost and is generally not available during the period of realization of this test because it is the summer vacations. For these reasons, we formed and trained ourselves a panel for this test during my project. This panel is made up of the laboratory technician, two teachers from the food science department, my internship tutor and finally, another internship student.

This test took place over a whole day in the gastronomy laboratory and was divided into two parts.

The 12 brioches were coded with three-digit codes beforehand and they were served in a randomized order so as not to influence or distort the results. The 12 photographs of the final formulations can be seen in Appendix 4.

2.2.4 Hedonic test

Firstly, care should be taken to anonymize the samples to have a blind presentation. The sample should be representative of the product. The samples should be presented in neutral containers with minimal product information. Samples were labeled with three-digit codes and presented in random order in a Latin square design [49].

Secondly, the presentation of the products should be homogeneous (room temperature and identical weight for each product per person). The order in which the samples are presented will also be determined by random selection so as not to distort the results between the different consumers [49].

Lastly, we will have to consider sensory fatigue and therefore control the duration of the session. As this is a hedonic test, it will be shorter overall than a descriptive or discriminative sensory evaluation. Each session should last about 20 minutes [49].

Participants. The hedonic tests of the twelve recipes were conducted in four different sessions over a whole week. The participants were teachers and students from Kristianstad University (Sweden) and their relatives. They were informed about the event by email, through the university's social networks or via flyers posted in the university (see Appendix 1). To receive as many consumers as possible (about 100 people were expected), the tests did not take place in a conventional sensory evaluation room. Instead, participants came directly to the laboratory to collect a bag containing the samples and to perform the tests at home using a QR code (Refer to Appendix 2). Thanks to the online sensory software EyeQuestion (version 3.9.7, Logic 8, Elst, The Netherlands), the participants were able to give their opinions on the samples. I wrote the questionnaire in English, and it is broken down into five questions covering:

- Appearance,
- Smell,

- Taste,
- Texture,
- and finally, overall product appreciation.

The entire template for this questionnaire can be found in Appendix 3. By proceeding with a home test, we are aware that all the conditions stated for a hedonic test could not be respected. However, in terms of the number of people expected and the current health context, it seemed much too complex to accommodate them in the sensory analysis room. For this reason, it was decided to be lenient on the rigor of these rules and to have the consumers participate at home.

Products. The different brioches were kept in the freezer at -20°C before being offered to the consumers so that they were all in the same conditions. The products in this session are 6 Brioche samples. The products contain cereals with gluten, eggs, milk, and milk-based products. The data provided is anonymous, and the data collected will be processed anonymously. Once analyzed, the results will be presented in a student report. The distribution and coding of the samples is summarized in *Table 6*.

Table 6: Coding of the brioches samples for the consumer test.

TEST 1		TEST 2	
O+B+S	Öland with a high level of butter and sugar	**O-B-S**	Öland with a low level of butter and sugar
K+B+S	Källunda with a high level of butter and sugar	**K-B-S**	Källunda with a low level of butter and sugar
H+B+S	Helkorn with a high level of butter and sugar	**H-B-S**	Helkorn with a low level of butter and sugar
O+B-S	Öland with a high level of butter and low sugar.	**O-B+S**	Öland with a low level of butter and a high level of sugar
K+B-S	Källunda with a high level of butter and low sugar.	**K-B+S**	Källunda with a low level of butter and a high level of sugar

H+B-S	Helkorn with a high level of butter and low sugar.	**H-B+S**	Helkorn with a low level of butter and a high level of sugar

Instructions. The procedure for evaluating the products was indicated in the online questionnaire before the questionnaire began. Participants were instructed to rinse their mouths with water before testing each sample and to carefully follow the order of tasting indicated. Each sample was tested and then evaluated in sensory terms - appearance, smell, taste, texture - followed by general appreciation. The 9-point hedonic scale was used to measure the different ratings (from 1 = dislike extremely to 9 = like extremely).

At the end of the test, there was also a comment line for suggestions for improvement. These tests met the requirements found in the General Data Protection Regulation. Demographic data were collected, including gender and age. All participants consented to participate in this preference study.

2.2.5 Statistics analysis

Data were expressed as mean ± standard error of means (SD). Data for physical characteristics-texture and colorimetry-were analyzed by a Student Ttest. A significant difference is observed for a p-value < 0.05.

For the study of correlations between the different results, the Pearson test was used. A value greater than 0.7 or less than -0.7 would indicate a correlation.

3. RESULTS AND DISCUSSION

3.1 Estimation of the volume of swelling of the dough

As we have explained in the previous section dedicated to the description of this method, these are approximate results which are represented in *Table 7*. Thus, it will be the difference between the volume of puffed rice added initially and that added after the two-hour fermentation of the dough.

Table 7: Results of dough swelling volume estimates.

The brioches	Initial rice volume (L)	Final rice volume after fermentation (L)	Difference between initial and final volume (L)
O+B+S	1,2	0,7	0,5
H+B+S	1,3	0,8	0,4
K+B+S	1,2	0,9	0,3
O-B-S	1,3	1,1	0,2
H-B-S	1,3	1,2	0,1
K-B-S	1,4	1,3	0,1
O+B-S	1,2	1	0,2
H+B-S	1,3	1,1	0,2
K+B-S	1,3	1,1	0,2
O-B+S	1,3	1	0,2
H-B+S	1,3	1,1	0,2
K-B+S	1,3	1,1	0,2

The estimation of the swelling power was obtained by a difference between an initial and a final volume of the dough. As mentioned in the method section, making brioche involves a yeast fermentation step. The yeast produces carbon dioxide in the dough during a fermentation process. This gas accumulates in the cells that develop in the crumb during baking. In addition to these main compounds, ethanol and carbon dioxide, higher alcohols, aldehydes, esters, acids are formed in smaller quantities and are formed in smaller quantities and participate qualitatively in an important and complex way to the formation of the flavours and the flavour [36]. In the table above, we can see the results obtained after two hours of rest. First, we can compare the brioches in terms of “sugar and fat composition”. The brioches with the highest results are those with higher amounts of sugar and butter. Indeed, sugar is one of the essential elements for alcoholic fermentation by yeast. Then, we notice that the results are relatively close for the other samples, around 0.2 L. The addition of more sugar alone does not seem to affect the swelling power and the same is true for fat alone. Thus, it would seem that the combination of increasing these two ingredients allows for a better swelling of the dough. Secondly, brioches can be compared according to the type of grain used.

As a reminder, the Öland variety is like our current wheat varieties in its composition and its ability to bake. Helkorn is a spelt-like flour with a high content of nutrients, complete proteins, and B vitamins. From a nutritional point of view, it is therefore much more interesting than soft wheat flour, which it can completely replace. And finally, we don't have much more information about Källunda flour. When we compare the volumes of the different cereals, they are very close and even similar in some cases. This seems to imply that the factor "type of flour" does not have as much impact as the factor "proportion of fat and sugar" in the formulation of brioches.

It would be interesting to compare these data with traditional soft wheat flour used in pastry making (*Table 1*) [50], [51]. We notice that the main difference is found in the carbohydrates which are in less important quantity in the soft wheat. Spelt and wheat contain quite similar protein levels. If we look at the starch composition, soft wheat is in first position (69.3%) followed by spelt (62.2%) and just behind rye (62%) [46], [51], [52]. It will therefore be difficult to relate the amount of starch to the differences that could be observed in the formulation from rye/spelt because the % are very close. Starch is classified as a carbohydrate and contains amylose and amylopectin. It is important for the colour, the flavour (Maillard reaction), the smell and especially for the fermentation by the yeasts (multiplication and growth). Starch is insoluble in water and is capable of absorbing 1/3 of its weight, which allows it to become a viscous/gelatinous starch when heated. This sugar will be able to form non-covalent bonds (H) with proteins which will contribute to the structuring of our dough.

Another interesting point of comparison for these three cereals, could be the quantity of insoluble proteins, namely gluten. It will influence the "plastic" property of the dough because in contact with water, it will become soft and elastic due to its capacity to absorb 3 times its weight in water. It will also give "strength" to the dough by forming a flexible and elastic network. Moreover, it allows to retain the carbonic gas which is formed during the fermentation which will give to the bread its lightness (gas retention). Finally, it is under the action of water, that these insoluble proteins, will be brought to agglutinate and form very extensible protein fibrils also called, the glutinous network. Cereals with a high gluten content are spelt (10 to 12 g/100 g of type 630 flour), soft wheat (8 to 14 g/100 g of type 405 flour) and rye (3.2 g/100 g of

type 815 flour) [33], [53]–[55]. Gluten could therefore be one of the parameters influencing the final product.

According to a study by Frakolaki et al (2018) [56], bread made with spelt had reduced volume, lower specific volume, crumb and crust Spelt contains higher protein content and different protein fractions compared to white wheat flour, which may explain some of the differences in spelt-based bread compared to white wheat [56]. These results are consistent with those we have observed for swelling power from ancient cereals close to current spelt.

3.2 Texture analysis results

The TPA test that I applied to my different brioche samples allows to obtain many information such as: spring index, chew index, adhesive strength, or hardness. However, in the context of my project, I will only focus on the adhesive strength, hardness, cohesiveness, and resilience. These four parameters are very important and interesting to study when comparing brioches with the factors of amount of sugar, fat, and type of cereal.

Several studies have suggested that older wheat varieties have poorer rheological and technological properties than modern varieties [29], [57], which we will investigate here.

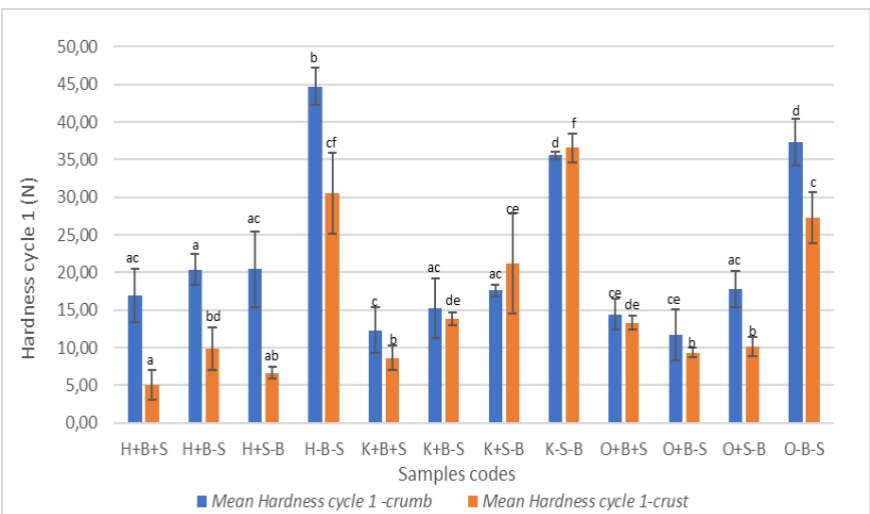


Figure 3: Graphic of average values of the hardness of brioches (N). The bars show the average and standard deviation (SD). The letter(s) above each bar indicates the degree of statistical significance between bars. Thus, if two bars have different letters, , this indicates that there is a significant difference between them ($p < 0.05$). The calculations of the significant differences were carried out on the crusts between them and then on the crumb between them in an independent way.

To define it sensorially, it is the force needed to compress a food between the molars. And instrumentally, as the peak force of the first compression cycle. These results are shown as a histogram in *Figure 3*. Firstly, it can be seen that the crumb and crust results are different in terms of the compression force required but they seem to follow the same pattern. It is important to note that in general, the crumb samples would have higher hardness values than the crusts. This observation goes against what logic would lead us to think about the crumb's brittleness in comparison to the softer and more melting crumb.

Secondly, when we focus on the type of cereal, we notice that it is not so much the change of cereal that impacts the results but rather the formulation. However, we can see that the Helkorn variety has the highest values in each of the recipes. Indeed, the levels of butter (+B/-B) and sugar (+S/-S) would influence the texture and these modifications can be observed in this bar graph. By combining the decrease of these two ingredients, the hardness data are higher. This is probably since butter and sugar are involved in obtaining a brioche-like texture (soft, melting, airy). So, by decreasing the quantity, the products should be more compact and crumblier. When we look independently at butter and sugar, it appears that butter is the ingredient that works the most in favour of a lower compression force required.

Finally, the recipes containing the highest levels of the ingredient are those that do not require as much compression force as the others. Thus, we can be led to believe that these are the two most important ingredients in determining the final texture of the product, based on these data.

Previous studies have shown that the reduction of ingredients (sugar and fat) has important structural and textural consequences on cookies. Drewnowski et al (1998) [58] found that there was not necessarily an apparent line between fat reduction and texture-related attributes; rather, it depended on the type of cookie. A study on the formulation of

spelt bread showed an increase in the hardness of the crust and crumb. Spelt is a variety of cereal that has the particularity of containing a higher protein content and different protein fractions compared to white wheat flour, which may explain some of the differences in spelt-based bread compared to white wheat [56].

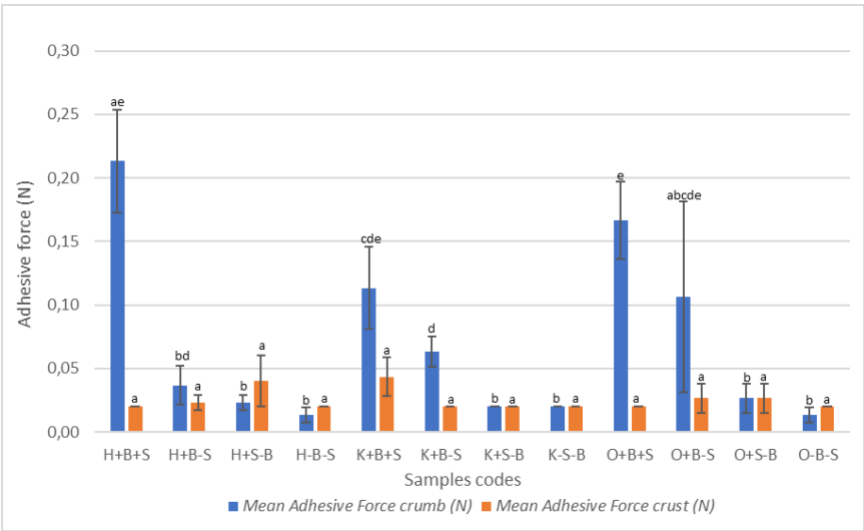


Figure 4: Graphic of average values of the adhesive forces of brioches (N). The bars show the average and standard deviation (SD). The letter(s) above each bar indicates the degree of statistical significance between bars. Thus, if two bars have different letters, this indicates that there is a significant difference between them ($p < 0.05$). The calculations of the significant differences were carried out on the crusts between them and then on the crumb between them in an independent way.

Adhesive force (AF), or Adhesion, is a measure of resistance to probe withdrawal from the sample on the first compression. The values measured as the energy and force required to separate a probe from the sample on the return stroke. Here, it appears that the overall adhesive strengths of the crust samples are close or even similar for the most part. There is also no apparent significant difference between them whatever the level of butter, sugar or the variety of cereal used. These data are presented in *Figure 4*.

When we now focus on the results from the crumb, the conclusions are not the same. Indeed, a greater majority of samples obtained AF values

lower than 0.05 N, namely 7 out of 12. Concerning the others, the H+B+S and the O+B+S have respectively AF values of 0.21 and 0.16 N. Furthermore, there is no significant difference between these two as they have a letter in common above their bars. It could be suggested that it was the butter and sugar levels that drove this increase and when looking at the K+B+S, it is only 0.1 N but still in the group of higher AF than the overall average. These results will be correlated with the rest of the data to determine whether or not these observations are related to the characterization of the individual brioches.

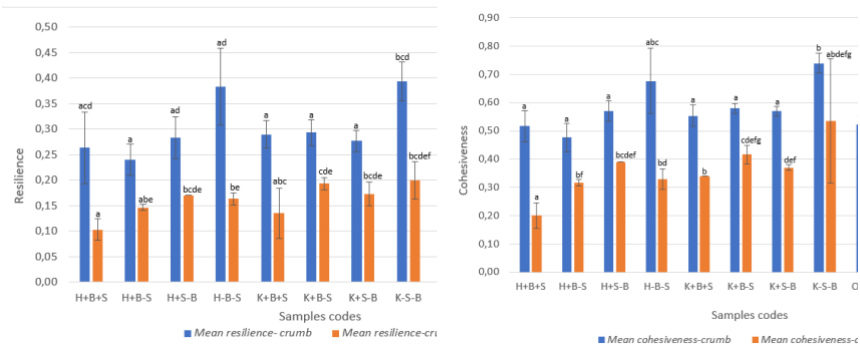


Figure 5: Graphic of average values of the resilience and cohesiveness of brioches. The bars show the average and standard deviation (SD). The letter(s) above each bar indicates the degree of statistical significance between bars. Thus, if two bars have different letters, this indicates that there is a significant difference between them ($p < 0.05$). The calculations of the significant differences were carried out on the crusts between them and then on the crumb between them in an independent way.

Figure 5 above groups the resilience and cohesiveness results. Resilience is an indicator of how a sample recovers from deformation, including both speed and strength. Defined as the ratio of the area before the deformation target to the area after the deformation target when the first depression is applied. We will be able to analyze resilience from *Figure 5*, which combines the crust and crumb data. The 12 results of the resiliencies of crusts are lower than those of crumbs. This conclusion was expected because the texture of the crust is much more crumbly, sandy, and fragile than the crumb which is soft and melting. These differences may justify the fact that the crumb will be easier to compress without being destroyed and regaining its initial shape. As for the crust, because of its texture, it can be brittle and more

or less resistant to compression. Now, if we look at the comparison of the crumb results between them, we can notice that the three samples containing little butter/sugar have higher values and they have common letters above the bars. This may lead us to believe that the reduction of these two ingredients would favor the elasticity of the brioche and thus its capacity to return to its original shape. We notice that a large number of samples share a common letter, i.e., there is no significant difference between them according to the student-test (except for K-B-S and O-B-S). However, both samples have the same letter "d", so it is conceivable that the decrease in butter/sugar impacted resilience but not the type of cereals. Let's move on to the analysis of the crusts. It would seem that the formulations based on the Öland variety are those that have a greater capacity to resist deformation. However, there are not necessarily significant differences between these samples and the others (from other cereals). If we compare to the global average of the samples, we can conclude that all the brioches are close in terms of crust resilience.

Cohesiveness is defined as the ratio A2/A1 with A2 -the area under the impact of the second compression- and A1 -for the first cycle-. If the structure of the sample is destroyed in the first compression, this ratio is zero. If the sample is perfectly elastic and is not damaged at all by the first compression, this ratio is 1. Most food products are between 0 and 1.

First of all, we can notice that none of the results are zero and therefore there was no destruction. On the other hand, there are also no samples above 0.75 for either the crust or the crumb. Second, the same observation can be made as for resilience, all crumb results have higher values of cohesiveness. Indeed, this is in adequacy with our expectations because the crumb is clearly more elastic than the crust due to its texture and its internal location. The H-B-S/K-B-S/O-B-S samples have the highest values and are the same three formulations with less butter and sugar. This modification would lead to textural modifications of the products by making them more elastic. In addition, we can notify that they have significant differences between H-B-S and O-B-S as well as K-B-S and O-B-S. So, the type of cereals would also play on the parameter of cohesiveness. If we focus on the crusts and compare against the average value, they are all quite close. There are still significant differences between several brioches, but no one group, or sample stands out. Therefore, it is difficult to deduce any influence of butter, sugar, and cereal type on the cohesiveness of the crusts.

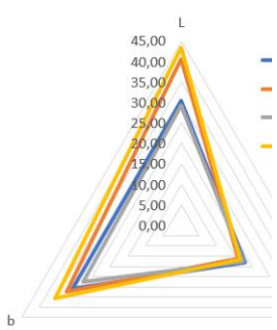
However, when comparing bread formulated with spelt to that formulated with soft wheat, it appeared that spelt gave the bread a greater elasticity of the crumb, but a low homogeneity of the crumb cells. These results may be explained by particular rheological attributes of spelt dough [59].

The study by Amorin et all (2021) [60], involved rice muffin formulations containing 100% of the amount of sugar present in the original recipe (100S), 75% sugar + 0.8% Galacto-OligoSaccharides (75GOS). These can be compared to a commercial muffin. The reduction of the sugar content has modified the characteristics of the air bubbles (size and population with a greater number of tunnels) but also, we notice an increase in the hardness and the chewability. Nevertheless, very relevant textural parameters were still obtained for 75GOS muffins, such as elasticity and resilience, and these were considered acceptable and comparable to those reported in the literature for commercial muffins, anticipating a good acceptance by consumers [60]. This is very interesting since tests on brioches containing standard amounts of butter and sugar have not been performed.

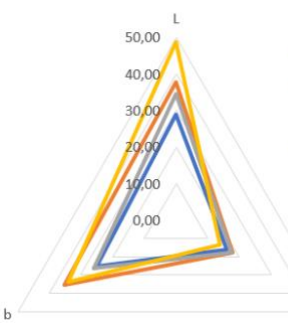
3.3 Colour analysis results

The change in colour between preparations with different HC and as a function of sugar and fat content was studied.

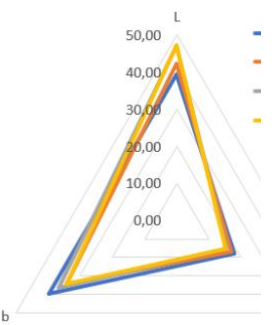
A- Crust



Källunda cereal variety.

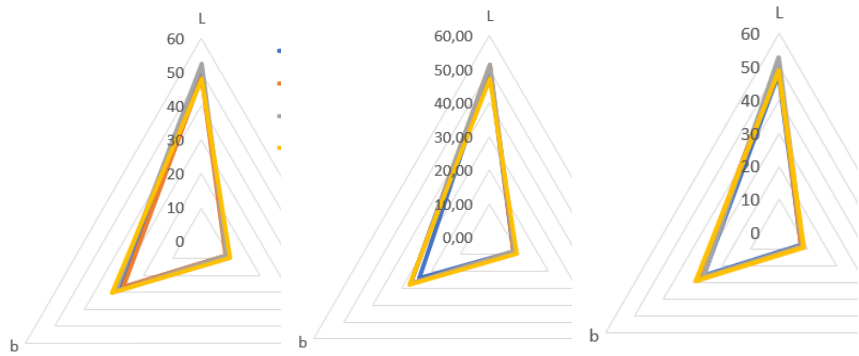


Öland cereal variety.



Helkorn cereal variety.

B- Crumb



Källunda cereal variety. *Öland cereal variety.* *Helkorn cereal variety.*

Figure 6: Characterization of the colour of the crumb and the crust of the brioches according to the L, a, b system.

For the presentation of colour data (according to the L, a, and b system), crusts and crumbs were separated but also by the type of cereals and its visible in *Figure 6*. The sample codes contain an additional first letter, namely, E for Exterior (crust) and I for Interior (crumb). Focusing first on the crusts, it appears that *-B-S* brioches of the three cereals have higher L-values and therefore tend to be lighter in colour. We also have the brioches with *+B-S* which pull towards the L in a more important way than the brioches: *+B+S* and *-B+S* whatever the cereal used. For the parameter b from blue to yellow, the Källunda and Öland brioches *-B-S* and *+B-S* have higher values than the others. And for the Helkorn variety, it is the *+B+S* and *-B+S* brioches. Concerning the a, all the values are relatively close when we compare the recipes between them by type of cereal. One could therefore conclude that the brioches less rich in sugar, whether it is one variety or another, have overall lighter colours than the others.

A comparative colour study was performed on breads baked according to the optimized dough method (reference AACC 10-10 B) with small spelt, durum wheat and bread wheat. The results showed that small spelt gave a lighter crust color than bread wheat and durum wheat. It has been suggested that small spelt suffers less thermal damage than modern wheat during baking, as the low levels of α- and β-amylases would participate in limiting starch degradation [61]. As a result, the reduced generation of reducing sugars in the dough will act to limit Maillard reactions during food processing. The degradation of carotenoids could be limited by the low lipoxygenase activities present in the dough containing small spelt [61].

Now, we are interested in the colours of the crumb, and we can easily notice that the four formulations of each type of cereal are very close because the lines overlap. Thus, it would seem complex to differentiate them even according to the cereal used because the profiles are almost identical. Indeed, the parameters L, a, and b of the crumb of these 12 brioches are of the same order of magnitude. The crumb being located inside the product, it will not be in direct contact with the heat source (the oven) as the crust can be. This one will necessarily undergo more physico-chemical changes because its exposure is more important. We could mention in particular the Maillard reaction which is partly responsible for the browning and the deployment of the flavours. In addition, several external factors can impact the colour of the crust such as the positioning of the brioches in the oven, too wet atmosphere, malfunction of the material, poor distribution of heat, etc. It is true that the crumb from its internal location is less subject to these factors and undergoes fewer biochemical changes. All the data obtained during the project, from the consumer test to the colour and texture analyses, are available in Appendix 6 with the means and Sd.

Another study was conducted on the same three types of cereals but on crunchy cookies. It appears that the type of cereal used has an impact on the color. Their sample containing "butter + flour +" has a much more yellow color with the cereal *Öland Vete* than with the two other cereals used (Källunda and Helkorn). On the contrary, the "butter +" sample has a less yellow color with this cereal. In comparison with our study, we do not obtain the same results with soft pastries (brioche). Indeed, our color profiles at the level of the crumb were very close and thus did not indicate any impact in relation to the type of cereal or even the increase of butter [62].

3.4 Sensory evaluation panel

Below in *Table 8*, the set of selected attributes and the associated definitions for the positioning.

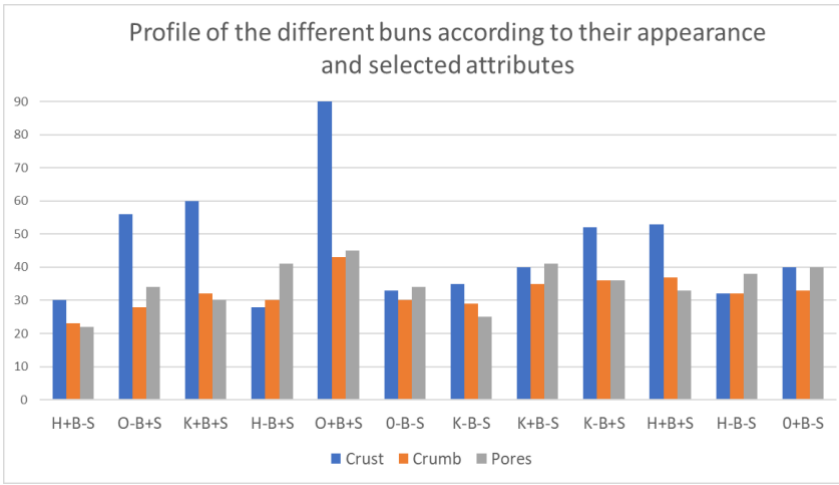
Table 8: Attribute definitions for evaluating brioches.

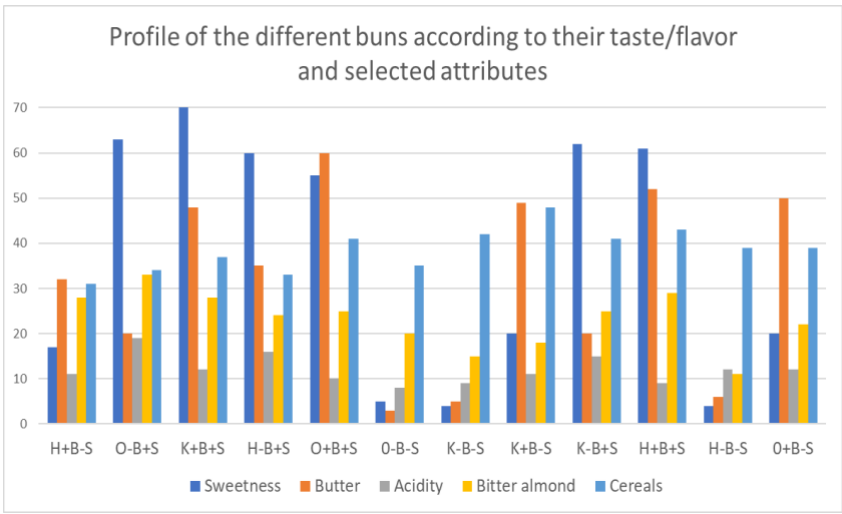
Selected attributes			
APPEARANCE	**AROMA**	**TASTE/FLAVOUR**	**TEXTURE**
Colour of the crust: Shades of brown (little-much)	Cereals (little-much)	Sweetness (little-much)	Dry: opposite to moist

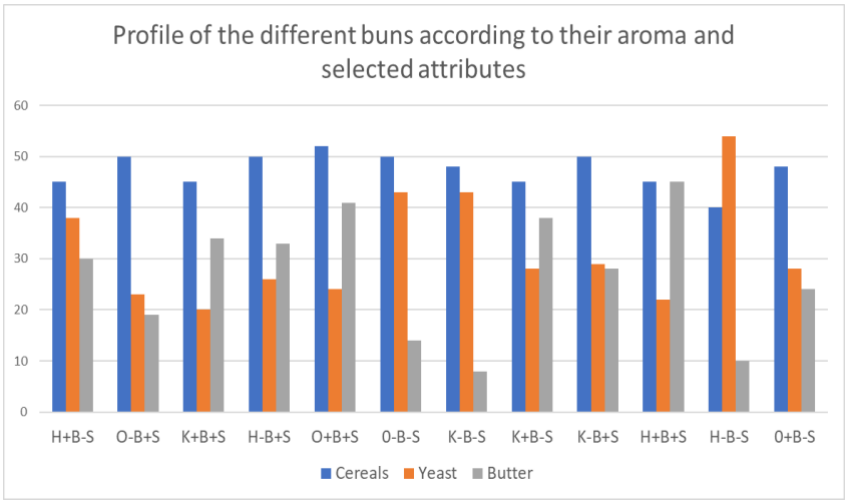
			(little-much)
Colour of the crumb: Shades of brown (little-much)	Yeast(little-much)	Butter (little-much)	Fatty: grasy, oily, mouthfeel (little-much)
Pores/Holes/Bubbles (little-much)	Butter (little-much)	Acidity (little-much)	Crumbly (little-much)
		Bitter almond (little-much)	
		Cereals (little-much)	

The attributes we selected in this project can be compared with those of other studies also involving ancient grains. A qualified analytical sensory panel and gas chromatography were selected to analyze odour and flavour differences of cooked grains, flours, boilable and bread wheat from ancient and modern species [63], [64]. A list of odour descriptors could be selected from these sensory analyses. These were cocoa, oatmeal porridge, and øllebrød (a traditional Danish dish, a porridge made from leftover bread) which were common to all wheat products. However, the intensity of sensory attributes varied between varieties as older species, e.g. spelt, were sensorially characterized as having a light oatmeal aroma, odour and flavour. While some of the more modern wheats had an øllebrød, wild rice, cocoa, vanilla, and sugar [63].

We have a total of 4 histograms representing: the appearance, the flavour, the aroma, or the texture of the different samples. We can notice that the profiles are quite varied and that the brioches are perceived differently by the panel. This can be explained by the use of three different types of flour but also by the variation of fat and sugar in the recipes.


Profile of the different buns according to their appearance and selected attributes
90
80
70
60
50
40
30
20
10
0
H+B-S
O-B+S
K+B+S
H-B+S
O+B+S
0-B-S
K-B-S
K+B-S
K-B+S
H+B+S
H-B-S
0+B-S
Crust
Crumb
Pores


Profile of the different buns according to their taste/flavor and selected attributes
70
60
50
40
30
20
10
0
H+B-S
O-B+S
K+B+S
H-B+S
O+B+S
0-B-S
K-B-S
K+B-S
K-B+S
H+B+S
H-B-S
0+B-S
Sweetness
Butter
Acidity
Bitter almond
Cereals



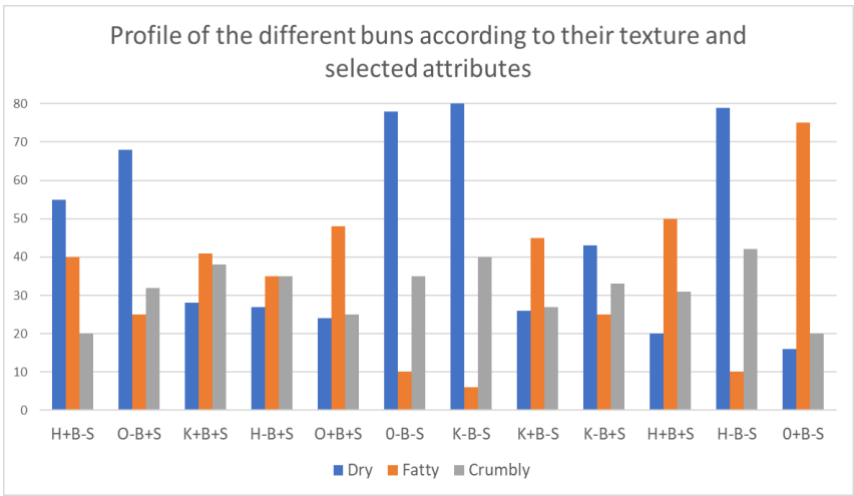


Figure 7: Profiles of the brioches according to the rating of the specific panel.

If we focus on the appearance (*Figure 7*), we can notice that only five brioches (*O-B+S/K+B+S/O+B+S/K-B+S/H+B+S*) have results that stand out by the colour of the crust. In each of these formulations, we have a large amount of added sugar which could play in favour of this more important perception of the colour in particular by the Maillard reaction. The other products do not show such significant variations and are around 30. As for the crumb and the size of the cells, the results are more homogeneous and there does not seem to be any factor affecting these parameters.

In terms of flavour, we observe quite marked variations between products, which would imply that the change of cereals and butter/sugar would modify this parameter. The samples containing low quantities of butter/sugar, regardless of the type of cereal, have very low scores compared to the average for: sweetness, butter, acidity, and bitter almond. Thus, one could think that these ingredients play a major role on the flavours because their simultaneous decrease seems to cause impacts. One point to note is that the perception of cereal flavour is quite important in all the samples, but this does not necessarily allow us to differentiate three types of cereals. Moreover, the acid and bitter almond flavours are not necessarily desired when talking about brioche and these values remain relatively low especially for the acidity. Indeed, the acidity would be a sign of a bad fermentation by the yeasts and thus of a product not gathering the characteristics of the traditional brioche.

Aroma is defined as a pleasant odour that emanates from certain substances. In the case of the brioches, the selected aromas were yeast, cereal, and butter. The results are high for cereals, so the factors butter/sugar/cereal type do not seem to be influential. Then yeast generally comes back high but is not unanimous. The richest brioches would give off less of this sensation than the others. The butter notes are closer in proportion to the quantity contained in the recipes.

Finally, the texture profiles illustrate the role and importance of ingredients such as butter, which is used to provide softness, fondant, and lightness. We notice that the increase of butter seems to be linked to the "fatty" texture felt and on the contrary its decrease with the "dryness" of the product. The sugar would also act on the greasy sensation and dryness whether it is in large or small quantity. The rating on the crumbliness is stable and shows little variation, so we could think that this parameter is not impacted by the changes of recipe.

Comparing our data to that of a cookie formulation project using the same heritage cereals, it appears that the type of cereal has an impact on the aroma of the cookies. Indeed, the "caramel" aroma is slightly less intense with the *Kallunda Varvete Evolutionar* cereal than with the other two cereals. Otherwise, no impact of the type of cereal on the other sensory and textural aspects can be observed [62].

The perception of fats would be through a retro nasal olfactory input in the form of fat-soluble molecules (aroma) that enhance the intensity of the flavour, which is very closely related to pleasure notes according to Abdallah et al. (1998) [65]. In addition, it would participate in increasing the amount of saliva and solubility of sugar compounds in the mouth and thus lead to a more intense sweet perception. There is also a synergy between sugar and fat, as is the case in dairy products with the improvement of the perceived sweetness thanks to fat [66], [67]. Finally, their results suggest that from a sensory perspective, it is easier to reduce fat content than sugar content, at least when products are not perceived as less sweet [66].

3.5 Hedonic test

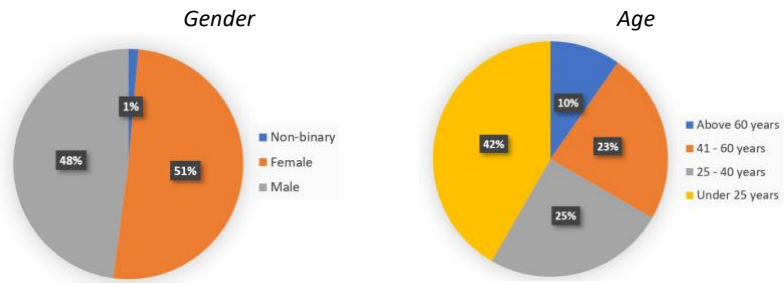


Figure 8: Demographic data of participants in the consumer test.

The hedonic testing sessions took place over four days in the same week. A total of 70 people participated in the sensory evaluation. Regarding the gender of the participants, a balance between men and women was respected. Regarding the age of the participants, a relatively young population was in the majority. The demographics for each session are presented in *Figure 8*. For an acceptability test conducted during the product development process, several participants between 50 and 100 is satisfactory. The number of participants recruited for these sessions was therefore satisfactory in relation to the recommendations in the field.

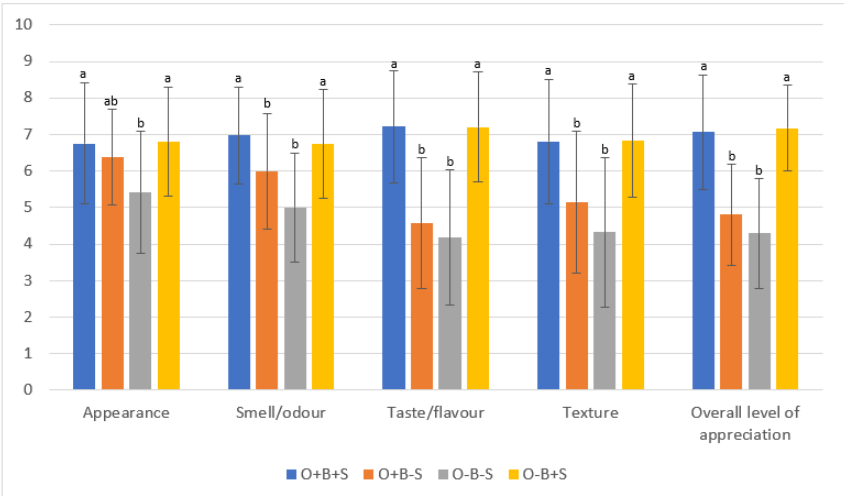


Figure 9: Degree of liking in a consumer test, for the brioches formulations with the Öland variety. The bars show the average and standard deviation (SD) for each property and product composition, according to consumer evaluations. The letter(s) above each bar indicates the degree of statistical significance between bars. Thus, if two bars have different letters, this indicates that there is a significant difference between them ($p < 0.05$).

From this *Figure 9*, we can see that according to the criteria of appearance, smell, taste, or texture, we have two sample groups that stand out. Indeed, the two recipes based on Öland cereal with higher sugar content had a better global appreciation among consumers. Moreover, we can notice that there is no significant difference between these two samples (*O+B+S* and *O-B+S*). The two other samples on the margin (*O+B-S* and *O-B-S*), on the other hand, are less appreciated on all the evaluation criteria and do not have any significant differences either. Finally, it could be concluded that the increase in the sugar content of the brioche recipe is a parameter that favorably influences the overall opinion of consumers. Indeed, only one sample out of two obtained higher scores and this, when associated with an addition of sugar.

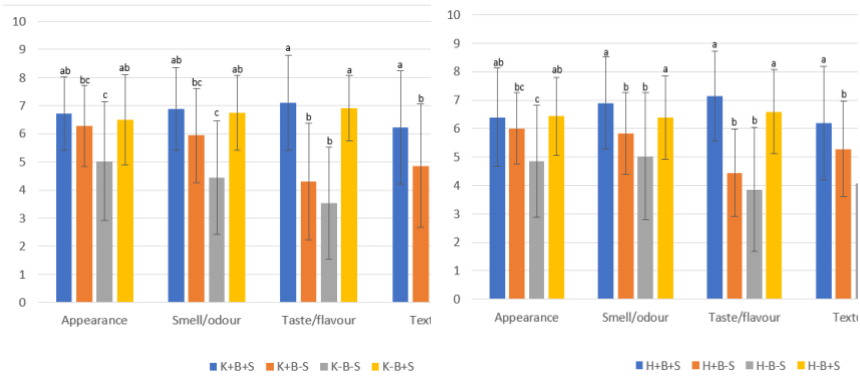


Figure 10: Degree of liking in a consumer test, for the brioches formulations with the Källunda and Helkorn variety. The bars show the average and standard deviation (SD) for each property and product composition, according to consumer evaluations. The letter(s) above each bar indicates the degree of statistical significance between bars. Thus, if two bars have different letters, this indicates that there is a significant difference between them ($p < 0.05$).

In the same way as the previous graph, we will look at the results of the consumer test of the four different brioche recipes in *Figure 10*. The difference here is that these are other cereal varieties, namely Källunda and Helkorn respectively. The four formulations are divided equally into two groups of samples: the sweeter and the less sweet. This observation is further verified by the indication of a non-significant difference between these two groups of recipes (K+B+S/K-B+S and K-B-S/K+B-S). However, if we focus in more detail on the appearance and smell with Källunda, we also have a non-significant difference between K+B-S and the two sweet recipes (K+B+S and K-B+S). We can be led to believe that the type of cereal is not a decisive parameter in the choices of the consumers. Rather, it is the variation in the quantity of certain ingredients (sugar and butter). Sugar is mainly known as a taste enhancer, but it also allows: to act on the coloring during cooking with the Maillard reaction, to participate in the fermentation process by the yeasts or to improve the tenacity and the plasticity of the product. As for butter, it can slow down the fermentation process, make the crumb softer, the crust crumblier and improve the taste, etc.

Finally, after taking all these data into account, it seems that sugar is an influential factor in the appreciation of the brioche. The latter is generally perceived by consumers as a gourmet pastry with its characteristic melting and soft texture but also its fine crumb and sunny

colour. With these expectations in mind, it is easy to understand that the perception of sugar is almost indispensable when tasting a brioche. These remarks are in line with the data because the two recipes containing the most sugar were the ones that aroused the most interest on all the evaluation criteria.

In the free comments section, we were able to differentiate different categories. We find, for example, comments focused on the formulation of the brioches with suggestions for improvement or simply personal opinions. Many times, it comes out that some brioches (the -B) were particularly dry, reliable, and looked more like bread than real brioches. On the other hand, the +B brioches seemed too fatty when tasted and touched. About sugar, this ingredient seems to play a major role in their appreciation of the brioches because there are many references to sugar. We find in particular "*I prefer the sweet bread*", "*Need more sugar*", "*The ones that I preferred had higher sweetness than the other*" but also "*Too sweet sometimes*". It is therefore important to measure the amount of sugar in the products and particularly in the brioche. Salt, like sugar, is a powerful flavor enhancer. Consumers are fond of strong taste when tasting brioche because the suggestion to add more salt is regularly made. We also have ecological awareness about the use of plastic bags for packaging or encouragement. The complete list of these comments is available in Appendix 5.

Acceptable sensory results were obtained in a comparative study with five different spelt varieties in bread form. However, there were significant differences between the five varieties. This study also showed significant differences between the different harvest years, and that weather conditions had a significant impact on flour and bread quality, but also on texture appreciation [68]. This shows that consumers perceived the differences between the types of cereals, which does not seem to have been the case here.

Researchers were interested in the impact of sugar and fat reduction on the perception and appreciation of cookies. For this purpose, different low-fat cookies were made in order to analyze them sensorially. For most of the cookies studied, the least preferred variants were those perceived as (1) less sweet, (2) less sweet and less fatty, or (3) less sweet. The results suggest that a reduction in sugar content has no effect on the perception of fat, whereas a reduction in fat content sometimes induces a reduction in the perception of sweetness. From a sensory

perspective, it is more acceptable to reduce fat content than sugar content in cookies, at least when the products are not perceived as less sweet [69]. We observed a similar phenomenon with our consumers when analyzing the 12 brioches. According to other researchers [58], [65] taste also seems to be more related to sweetness than to fat perception. It appears that preferences for high-fat stimuli have been observed even though they do not include conscious perception of fat content. This observation would be related to the more complex perception and characterization of fat than sweet [70]–[72].

3.6 Correlations between data

Correlations were made using the Pearson test. The Pearson coefficient is an index reflecting a linear relationship between two continuous variables. Moreover, considering that we had decided that a value greater than 0.7 or less than -0.7 in the Pearson test, this would indicate a correlation. Complete Tables of all Pearson coefficients are available in Appendix 7 (for Crumbs) and 8 (for Crusts). In addition, a colour code has been established to facilitate reading. Pink corresponds to values higher than 0.7 and yellow those lower than -0.7. All factors considered in this report were considered. We find high and low amounts of fat, sugar in combination or independently as well as the type of cereals used.

In a first part, we will focus on the correlations of the brioche crumb. We notice that there are a number of correlations between the visual, smell, taste, and texture criteria. Moreover, the quantity of sugar seems to be correlated to these same criteria. These observations are in adequacy with the conclusions which could be established previously at the time of the graphic study and significant differences. Indeed, this only supports the fact that sugar and its quantity are influential factors in the formulation of brioche, its appearance, and its appreciation by consumers. The type of cereal does not appear to have an impact on the results for all the parameters studied for the crumb. As for butter, it is positively correlated with AF and negatively with cohesiveness. However, when we look at the combination of sugar and butter, the correlations are immediately more numerous. We have already seen similar findings in previous sections. Only the L*, b*, taste and overall appreciation do not seem to be concerned. We observe an almost identical phenomenon by adding the type of cereal except that the global appreciation is correlated this time. One could thus conclude that

sugar and butter are two major ingredients in the brioche. Therefore, the variation of their quantity and their simultaneous addition will impact the final product.

In a second part, we will see the correlations of the crusts. As for the crumb, the visual criteria, odors, taste, texture, or general appreciation are all correlated. Sugar also appears to be a major influencing factor because it alone links several outcomes. We can notice that it acts on the L* and the a* which confirms our previous conclusion concerning the colour of the product. The type of cereal is this time correlated with the resilience of the brioche. As a reminder, this is an indicator of how a sample recovers from deformation, including both speed and strength. Butter as a factor alone is less impactful than sugar but their combination is interesting. In terms of hardness, appearance, smell, and texture. These same conclusions are obtained by adding the type of cereal which does not seem to modify the parameters of the brioche. Finally, the fact of making correlations between all the data collected is a very interesting point. This allows on the one hand to bring out new conclusions and on the other hand to support/confirm previous ones during the individual graphical analyses.

Thus, it appears that sugar is an ingredient with a main role in the formulation of brioche and pastry in general. Sugar and fat are two major ingredients of cookies. They have important structural and textural properties during the formulation (preparation and baking) of the cookie dough, providing the expected shape and texture of the final product [73]–[75]. They also play important sensory functions. Sugar is responsible for sweetness, while fats contribute to the texture, mouthfeel, flavor, and aroma of foods [71], [76], [77].

3.7 General discussion

After several bibliographic research and my knowledge, I tried to establish explanations between my results and the biochemical processes within the food. Considering the variation of the quantities of sugar and butter in the formulation of the buns, it appears essential to be interested in the reactions involving the carbohydrates and lipids.

Carbohydrates are omnipresent in the various formulations of the food industry (products and beverages). This situation, which often makes them unavoidable, is due to the fact that they fulfill many roles in food

processing, both at the sensory and technological levels. But to be taken into consideration, sugar is also a powerful sensory mask, which can make the perception of other associated flavours difficult or even impossible. The making of the brioche includes bread-making steps and involves biochemical processes from carbohydrates in particular. For example, the amylases present in the flour will produce the glucose necessary for the fermentation and the Maillard reaction during baking. These enzymes can only act by penetrating the molecules, hence the importance of a prior destruction of the grain (milling). The glucose thus released will be able to ferment with a release of carbon dioxide, while the dextrins produced will have for role, the retention of water of the pasta. As a reminder, the Maillard reaction comes from a combination between a reducing sugar (free carbonyl function) and a protein, a peptide, or an amino acid (free amine function) [78], [79].

Sucrose is not a reducing sugar, but it is fermentable. Therefore, some microorganisms, like yeast, degrade it into ethanol and other organic molecules. It is sensitive to certain parameters such as temperature. Rapid heating of sucrose crystals, above 140°C, will cause changes in structure and colour. Between 160 and 190 °C, the crystals will melt to give a brown-yellow colour. It is the glycosidic bond breaking that will produce a D-glucose residue, after 15 min at 130 °C. And, from 160 °C, a condensation reaction will produce D-fructose [78]–[80].

When sucrose is added to cereal-based formulations, it increases the extensibility of the dough and its stickiness. The increased sugar content reduces the amount of water used for pouring and the increased extensibility reduces the porosity of the dough and therefore increases the amount of carbon dioxide retained in the viscoelastic network. The presence of fermentable sugar together with yeasts and their enzymes, causes a rapid and often complete hydrolysis of sucrose into glucose and fructose. During cooking, if all the sugars have not been transformed by alcoholic fermentation into ethanol and carbon dioxide, the residual sugars will participate in the non-enzymatic browning reaction. This chemical reaction results in a darkening of the colour of the product, associated with the appearance of new molecules that give it a taste that goes from caramel to burned through that of cooked. In addition, this reaction will cause a decrease in the nutritional value of the foodstuff, as some essential amino acids, such as lysine or tryptophan, see their availability reduced when combined with reducing sugars [78]–[81].

Now we will make the link with the second ingredient that has been modified, namely butter. In products rich in fat, the antioxidant properties of sugar are sought to avoid the oxidation of unsaturated lipids, present in significant quantities in certain vegetable oils. The increase of the sugar content in pastry formulations, by significantly modifying the consistency of the dough, as well as the gelation temperatures of the proteins and gelatinization of the starch, leads to a variation in the development and the internal texture of the products [78]–[81]. In addition, we had also discussed earlier in this report the amounts of gluten and starch in these grains and their role. These two constituents are good indications for the quality of cereals in bread-making and brioche formulation (refer to section *2.1.1 The three types of heritage cereals*) [33], [53]–[55].

Finally, it is therefore some of these reactions that can explain the results that we have previously observed. However, we cannot say which ones they are precisely because they have not been studied or measured (individually or not) in this report. We can only assume that they could be these because our research focused on the influence of the amount of sugar and fat in the bun formulation.

I think that it would have been interesting to perform more analyses of the flours [39], [82], [83]. Here are some ideas for improvement:

- Use of a Chopin alveograph - to measure the strength and extensibility of a dough formed with flour and salt water (25 g/l). The result is called the baking strength noted by the W. Use of the standard *NF EN ISO 27971, July 2008* [39], [82], [83].
- Water content - Weighed after drying at 130 °C for 1h45. Standard method: *AFNOR NF V03-707* [39], [82], [83].
- Measurement of damaged starch content (using iodine absorption kinetics, the proportion of starch granules that are damaged during this process - in % of starch on dry matter). Méthode ampérométrique mesurant l'absorption d'iode par une solution d'amidon. Use of the standard *NF V03-731* [39], [82], [83].
- CO2 production and dough swelling capacity - with a rheofermentometer and according to Standard *AACC 89-01* [39], [82], [83].

- Zeleny Index - A measure of the volume of a deposit from a dilute flour/acetic acid mixture. The volume depends on the capacity of the gluten to absorb water and on its swelling. Standard *NF EN ISO 5529* [39], [82], [83].
- …

When formulating a product, many analytical methods can be considered. In this study on the variation of the fat and sugar content as well as the use of three types of cereals, it would have been interesting to perform other complementary analyses. We can find among these methods the ones mentioned above. Indeed, characterizing the strength and extensibility of the dough represents a very interesting point of comparison, but also the quantity of water, the production of CO2. Thus, we will be able to understand more easily the impacts of the three parameters of the study and to draw more reliable conclusions.

4. CONCLUSION

In conclusion, the consumer test showed the major influence of sugar on all the criteria. According to the specific panel, sugar is an ingredient in favor of a more important perception of the brown color and the perception of the taste of the cereal is felt in an important way but without being different according to the type of seeds. The sugar/butter ratio and the type of cereal influence the flavors. Increased fat is related to "fatty texture" and decreased to "dryness". Changing butter, sugar, and cereal type did not affect flavor. Estimation of dough volume showed better results with brioche richer in butter/sugar and with no change in "flour type". TPA showed that hardness with higher levels of ingredients would result in lower compressive strength. Bond strength was greater for the crumb than for the crust (all very close and without significant differences). As with resilience, the texture of the crust showed lower values and the decrease in butter/sugar seemed to increase elasticity. For cohesiveness, the type of cereal has an influence only at the crumb level. The color analysis showed that the a* values are very close. The change of ingredients or cereals would not have an impact on this parameter. Brioches with less sugar, regardless of cereal type, have a lighter color. Sugar is therefore an influential factor on color perception. For the crumb, the 4 formulations have very similar Lab representations, so the sugar, butter and cereal content have no impact on the color of the crumb. The association of sugar and butter increases the number of correlations, which confirms several hypotheses previously put forward in the report. Finally, sugar and its quantity make it a major ingredient in the formulation of brioche from heritage cereals.

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APPENDICES

Appendix 1: Post to inform consumers of my product testing.

Appendix 2: Document provided with the samples to take with you to do the test and fill out the questionnaire.

Appendix 3: Model questionnaire presented for the hedonic test at home.

Welcome to this session!
Please read this homepage carefully and take note of the information it contains. It aims to inform you about **the objectives of the study** and **how it will be conducted**.

I am a French student in an engineering school specializing in food processing and currently doing an internship in Högskolan Kristianstad. The project I am working on is to formulate brioches from three types of heritage cereals. Consumers are increasingly concerned about their diet and attach importance to the quality and origin of products. Heritage cereals have nutritional and sensory properties that are of interest for the environment and human health. For each recipe, you will taste several different samples of the same type of product.
With your input, my goal is to determine which sample would be most appreciated by these future consumers. In addition, by giving your opinion and feedback, it will allow us to improve the formulation of the preferred sample to meet the requirements.

I thank you very much for your participation which will be very valuable for the continuation of this project.

Do not forget to press "submit" at the end of the test so that your answers are recorded. You are now ready to start the test. Good luck!

Consent

The products in this session are 6 Brioche samples. The products contain cereals with gluten, eggs, milk, and milk-based products. The data provided is anonymous, and the data collected will be processed anonymously. Once analyzed, the results will be presented in a student report.

The questionnaire will take about 20 minutes to complete. You have to answer all the questions, but you have the possibility to leave the survey whenever you want.

By clicking on the button below, you approve your participation in this survey.

Demographic questions

Please indicate your gender: male, female, non-binary

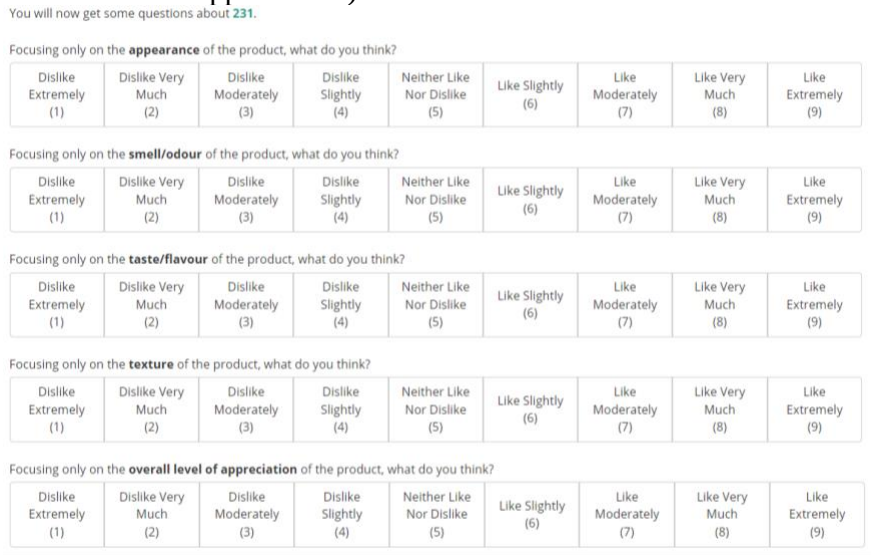
Which of the following age groups do you fall into? [Under 25], [25-40], [41-60], [Above 60] years.

Instructions

Please follow the instructions below:

- Rinse your mouth with water before eating the first sample.
- Taste the products in the order in which they are given in the questionnaire, taking care to rinse your mouth between each sample. You cannot go back after tasting a sample.

Design questions (appearance, odor, taste, texture, overall level of appreciation)


You will now get some questions about **231**.

Focusing only on the **appearance** of the product, what do you think?

Dislike Extremely (1)	Dislike Very Much (2)	Dislike Moderately (3)	Dislike Slightly (4)	Neither Like Nor Dislike (5)	Like Slightly (6)	Like Moderately (7)	Like Very Much (8)	Like Extremely (9)

Focusing only on the **smell/odour** of the product, what do you think?

Dislike Extremely (1)	Dislike Very Much (2)	Dislike Moderately (3)	Dislike Slightly (4)	Neither Like Nor Dislike (5)	Like Slightly (6)	Like Moderately (7)	Like Very Much (8)	Like Extremely (9)

Focusing only on the **taste/flavour** of the product, what do you think?

Dislike Extremely (1)	Dislike Very Much (2)	Dislike Moderately (3)	Dislike Slightly (4)	Neither Like Nor Dislike (5)	Like Slightly (6)	Like Moderately (7)	Like Very Much (8)	Like Extremely (9)

Focusing only on the **texture** of the product, what do you think?

Dislike Extremely (1)	Dislike Very Much (2)	Dislike Moderately (3)	Dislike Slightly (4)	Neither Like Nor Dislike (5)	Like Slightly (6)	Like Moderately (7)	Like Very Much (8)	Like Extremely (9)

Focusing only on the **overall level of appreciation** of the product, what do you think?

Dislike Extremely (1)	Dislike Very Much (2)	Dislike Moderately (3)	Dislike Slightly (4)	Neither Like Nor Dislike (5)	Like Slightly (6)	Like Moderately (7)	Like Very Much (8)	Like Extremely (9)

End screen

Do you have any comments on the samples to be added? Or perhaps some ideas for improvement?

Thank you very much for your participation!

Don't forget to press "submit" below to register your response.

Appendix 4: Photographs of 12 brioches studied.

Appendix 5: All the comments collected after the consumer test on the brioches.

JUDGE	COMMENT LINE
A0002	Overall, al the samples were a little dry. Some of them did not have a brown surface, was with a purpose or not
A0003	431, 613, 142: needs more salt or spices. Were a bit tasteless but might be delicious if combined with some source/ food 237: very saturating, I personally don't like too much oily taste in anything I loved 583 and 856 Thanks/ Aysu :)
A0004	Good job!
A0005	There are many plastic bags, but maybe no better ways to do the experiment. Thank you!
A0007	Too much bread maybe increases the fat and eggs to get more brioche feeling
A0008	sample 142 has its own good and delicious sides but in my opinion, it would be nice if a little bit of salt is added
A0009	Things were stored in unsealed packaging; this might have led to drier samples than expected.
A0010	Ok for all, but quite crumbly sometimes
A0011	I prefer the sweet breads!
A0012	237 and 583 I really loved these two masterpieces
A0013	Too sweet sometimes
A0014	Didn't like the texture on any of them.
A0015	Change add salt to them to get a rounder flavour
A0016	Need more sugar. Perhaps butter on Will taste better :-)
A0017	Improve the texture and juiciness the samples overall were to fare away from a brioche (too much bread)

A0018	The ones that I preferred had higher sweetness than the other. And also, a touch of caramel.
A0019	817 could be richer in taste 164 was my favorite
A0020	Good job!
A0021	Some samples are a bit too dry, and it crusted too easily. But overall, they’re really good.

Appendix 6: Table with all the data.

A- TPA

BRIOCHES FORMULATION		TPA																					
		Adhesive force (N)						Hardness (N)						Resilience						Cohesiveness					
	Cereals	Öland		Källunda		Helkorn		Öland		Källunda		Helkorn		Öland		Källunda		Helkorn		Öland		Källunda		Helkorn	
	Type	Crumb	Crust	Crumb	Crust	Crumb	Crust	Crumb	Crust	Crumb	Crust	Crumb	Crust	Crumb	Crust	Crumb	Crust	Crumb	Crust	Crumb	Crust	Crumb	Crust	Crumb	Crust
+B+S	Mean	0,2	0	0,1	0	0,2	0	14,5	13,3	12,3	8,6	16,9	5,1	0,3	0,2	0,3	0,1	0,3	0,1	0,5	0,4	0,6	0,3	0,5	0,2
	Sd	0	0	0	0	0	0	2,1	0,9	3	1,7	3,5	2	0	0	0	0	0,1	0	0	0	0	0	0,1	0
+B-S	Mean	0,1	0	0,1	0	0	0	11,7	9,4	15,3	13,8	20,4	9,9	0,3	0,2	0,3	0,2	0,2	0,1	0,5	0	0,6	0,4	0,5	0,3
	Sd	0,1	0	0	0	0	0	3,4	0,6	4	0,9	2	2,8	0	0	0	0	0	0	0,5	0,1	0	0	0,1	0
-B+S	Mean	0	0	0	0	0	0	17,8	10,2	17,6	21,2	20,5	6,7	0,3	0,2	0,3	0,2	0,3	0,2	0,6	0,3	0,6	0,4	0,6	0,4
	Sd	0	0	0	0	0	0	2,4	1,3	0,8	6,6	5	0,8	0	0,1	0	0	0	0	0	0,1	0	0	0	0
-B-S	Mean	0	0	0	0	0	0	37,3	27,3	35,6	36,6	44,7	30,5	0,4	0,2	0,4	0,2	0,4	0,2	0,7	0,5	0,7	0,5	0,7	0,3
	Sd	0	0	0	0	0	0	3,1	3,4	0,5	1,9	2,5	5,4	0	0	0	0	0,1	0	0	0	0	0,2	0,1	0

B- Colour

BRIOCHES FORMULATION		COLOUR																	
		L*						a*						b*					
	Cereals	Öland		Källunda		Helkorn		Öland		Källunda		Helkorn		Öland		Källunda		Helkorn	
	Type	Crumb	Crust	Crumb	Crust	Crumb	Crust	Crumb	Crust	Crumb	Crust	Crumb	Crust	Crumb	Crust	Crumb	Crust	Crumb	Crust
+B+S	Mean	47,3	42,3	29,1	30,5	34,5	28,8	15,1	17,1	17,4	17,9	17,8	16	34,3	34,3	27,6	30,7	26,1	25,2
	Sd	1,2	2	1,2	1	0,1	1	1	0,5	0,9	0,2	0,1	1,9	2,2	0,5	2,7	2,9	0,4	1,8
+B-S	Mean	47,4	51,3	52,7	49,4	52,8	48,2	9,2	8	8,4	8,4	8,1	7,6	27,6	26,9	29,6	27,7	26,4	26,3
	Sd	0,7	1	1,7	0,5	2,2	1,1	0,1	0,3	0,7	0,2	0,2	0,2	0,6	0,5	0,4	1,1	0,5	1,1
-B+S	Mean	52,8	34,5	52,7	29,1	51,2	46,9	8,1	17,8	8,4	17,4	8,3	15,5	26,4	26,1	29,6	27,6	26,9	36,6
	Sd	2,2	0,1	1,7	1,2	0,6	0,5	0,2	0,1	0,7	0,9	0,4	0,9	0,5	0,4	0,4	2,7	0,4	1,2
-B-S	Mean	48,6	48,8	48,1	43,2	47,4	47,3	8,5	13,8	9,6	16,5	9,2	15,1	28,8	34	30,3	35,5	27,6	34,3
	Sd	1,6	0,6	0,5	0,6	0,7	1,2	0,2	0,1	0,5	0,3	0,1	1	0,6	0,9	1,4	1,6	0,6	2,2

C- Consumer test

BRIOCHES FORMULATION		CONSUMER TEST														
		Appearance			Smell/odour			Taste/flavour			Texture			Overall level of appreciation		
	Cereals	Öland	Källunda	Helkorn	Öland	Källunda	Helkorn	Öland	Källunda	Helkorn	Öland	Källunda	Helkorn	Öland	Källunda	Helkorn
	Type															
+B+S	Mean	6,8	6,7	6,4	7	6,9	6,9	7,2	7,1	7,1	6,8	6,2	6,2	7,1	6,8	6,7
	Sd	1,7	1,3	1,7	1,3	1,5	1,6	1,5	1,7	1,6	1,7	2	2	1,6	1,6	1,6
+B-S	Mean	6,4	6,3	6	6	5,9	5,8	4,6	4,3	4,4	5,2	4,9	5,3	4,8	4,8	4,8
	Sd	1,3	1,5	1,3	1,6	1,7	1,4	1,8	2,1	1,5	1,9	2,2	1,7	1,4	1,9	1,3
-B+S	Mean	6,8	6,5	6,4	6,7	6,5	6,4	7,2	6,9	6,6	6,8	5,8	6,3	7,2	6,4	6,6
	Sd	1,5	1,6	1,4	1,5	1,6	1,5	1,5	1,2	1,5	1,6	1,9	1,5	1,2	1,5	1,4
-B-S	Mean	5,4	5	4,9	5	5	5	4,2	3,5	3,9	4,3	4,1	4,1	4,3	3,9	4
	Sd	1,7	2,1	2	1,5	2,1	2,2	1,9	2	2,2	2,1	2	1,9	1,5	1,8	2,1

Appendix 7: Table of correlations for the Crumbs.

	Type	Sugar	Butter	Sug+butter	Type+Sug+Butter	Adhesive force	Hardness	Resilience	Cohesiveness	L	a	b	Appearance	Smell	Taste	Texture
Sugar	0															
Butter	0	0														
Sug+butter	0	0,572182	0,820127													
Type+Sug+Butter	0,068087	0,579752	0,811652	0,997381												
Adhesive force	0,042291	0,401418	0,755357	0,8491723	0,84714648											
Hardness	-0,20773	-0,52289	-0,65855	-0,839285	-0,847047257	-0,560517349										
Resilience	0,092954	-0,47289	-0,63636	-0,792478	-0,780324728	-0,49217075	0,871276									
Cohesiveness	0,100062	-0,42795	-0,70029	-0,819193	-0,806857588	-0,552577868	0,802137	0,973813								
L	0,143683	-0,33879	-0,42665	-0,543754	-0,532590126	-0,653155626	0,194674	0,063005	0,144106316							
a	-0,06871	0,510112	0,554006	0,7462314	0,743627256	0,85761298	-0,34784	-0,24549	-0,32476059	-0,89598						
b	0,465363	0,023732	0,070695	0,0715577	0,110843028	0,149142168	-0,00742	0,162373	0,172329169	0,168073	0,125658					
Appearance	0,262537	0,732725	0,454705	0,7921674	0,808965598	0,488521359	-0,93449	-0,83081	-0,77570262	-0,16408	0,343437	0,007203				
Smell	0,08195	0,869851	0,443001	0,8610301	0,867946776	0,633932944	-0,84357	-0,77339	-0,74099388	-0,35927	0,572159	0,013371	0,93393829			
Taste	0,080436	0,979473	0,142675	0,6774478	0,688761138	0,487087362	-0,63616	-0,59288	-0,56457251	-0,34926	0,535772	0,005017	0,82870979	0,934477		
Texture	0,139174	0,893584	0,273757	0,7358077	0,748852898	0,491458753	-0,74836	-0,72229	-0,69627405	-0,21019	0,437251	0,004843	0,90802533	0,955157	0,946016	
Overall	0,109107	0,958862	0,183612	0,6992286	0,712394937	0,473374397	-0,68949	-0,63859	-0,60594081	-0,28478	0,487646	0,009297	0,87554366	0,952981	0,989265	0,978727

Appendix 8: Table of correlations for the Crusts.

	Type	Sugar	Butter	Sug+butter	Type+Sug+Butter	Adhesive force	Hardness	Resilience	Cohesiveness	L	a	b	Appearance	Smell	Taste	Texture
Sugar	0															
Butter	0	0														
Sug+butter	0	0,572182	0,820127													
Type+Sug+Butter	0,068087	0,579752	0,811652	0,997381												
Adhesive force	-0,12958	0,423207	0,070535	0,2999988	0,288040205											
Hardness	0,083295	-0,52503	-0,60903	-0,799893	-0,787538963	-0,496312591										
Resilience	0,779369	-0,38414	-0,27549	-0,445738	-0,394016488	-0,270130087	0,401497									
Cohesiveness	0,05058	-0,02354	-0,45806	-0,389142	-0,365162641	-0,143186819	0,563615	0,267937								
L	0,070456	-0,77257	0,005316	-0,437691	-0,441212346	-0,153835002	0,228002	0,570899	0,044510034							
a	0,06579	0,712782	-0,46357	0,0276554	0,045837844	0,196076921	0,173125	-0,17866	0,376946013	-0,70866						
b	-0,02859	-0,09098	-0,47364	-0,440501	-0,435506918	0,163525065	0,525441	0,341958	0,619491243	0,35292	0,345713					
Appearance	0,262537	0,732725	0,454705	0,7921674	0,808965598	0,423905729	-0,84194	-0,15588	-0,3224966	-0,45348	0,120844	-0,47191				
Smell	0,08195	0,869851	0,443001	0,8610301	0,867946776	0,391562635	-0,79627	-0,38595	-0,29864702	-0,64803	0,342249	-0,41126	0,93393829			
Taste	0,080436	0,979473	0,142675	0,6774478	0,688761138	0,400622985	-0,63683	-0,36754	-0,13916264	-0,75293	0,601429	-0,23236	0,82870979	0,934477		
Texture	0,139174	0,893584	0,273757	0,7358077	0,748852898	0,420797568	-0,76775	-0,27076	-0,19834875	-0,56638	0,401643	-0,2898	0,90802533	0,955157	0,946016	
Overall	0,109107	0,958862	0,183612	0,6992286	0,712394937	0,425943645	-0,69378	-0,3233	-0,13205236	-0,6834	0,534066	-0,24809	0,87554366	0,952981	0,989265	0,978727