Title: Literature Review on Bread Staling and Storage Conditions

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Student Declaration In Respect of Individual Work

I declare that the whole of this work is the result of my individual effort and that all quotations from other authors have been acknowledged.

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Signed:...........................................

Date:......................14/11/16......................
Introduction

Bread is a very important and highly consumed food, with a huge market worldwide. It can be produced and modified into various kinds of form and texture to suit the market preferences. Its primary ingredients include flour, water and salt. White bread, brown bread and wholemeal bread are made from flours produced from different stages of milling. Depending on the degree of milling, it will affect the nutritional content as well as flavour of the bread. White breads produced from white flour compared to wholemeal breads, has a lesser fibre content as the bran and germ removed during the milling process. Brown breads can simply be produced by using brown flour which is extracted from the wheat at a rate of between 70% to 100% (Edwards, 2007). This will retain some of the nutritional content from the wholemeal flour but also removes some of the flavour and texture which is not favoured by some individuals. However, manufacturers can also enhance the nutritional value of their bread by adding different kinds vitamins and minerals into the recipe.

The importance of bread in the individual’s diet reflects on the importance of proper bread storage. Freshly baked bread in ambient storage have a shelf life of around less than a week before changes in texture and flavour occurs (Brown, 2014). This process of texture and flavour deterioration can be referred as bread staling. The rate of staling
can be affected by many factors during pre-bake, baking and post-bake. Examples of these factors include the type and quality of flour used, the method of mixing, the ingredients used for the dough, proofing time and conditions, and any type of heat treatment (Chinachoti and Vodovotz, 2000). Storing the bread in different storage conditions may also affect the rate of staling. There 3 main types of conventional storage: ambient (25°C), chilled (5°C) and frozen (-18°C). By investigating the rate of staling of bread in conventional storage conditions over time, it may be possible to determine an ideal way of storage for bread to preserve its freshness as much as possible. This can have many benefits to the general public especially bread manufacturers and their customers. This includes reducing the economic losses and wastes disposal generated from expired bread and their packaging.

Food waste generation is a heavily discussed topic. According to the Food and Agriculture Organisation of the United Nations (FAO, 2016), a third of the global food produced for human consumption is wasted per year, which is about 1.3 billion tons. Around 7 million tons of this food waste is generated in the UK (FSA, 2016), where most of it could have be avoided in the first place. These wastes not only represent economic losses, but also represent an impact to the environment such as the emission of greenhouse gases (FAO, 2016). Among these wastes, it includes the packaging waste
that comes with the food product, which also contributes to filling up the landfills and producing greenhouse gases. Overall, this highlights the importance in preserving the freshness of bread to avoid wastage.

**Bread Staling**

The loss of crumb firmness and flavour resulting from bread staling are the major concerns of any consumer and food manufacturers. The reason for staling of bread can be explained from many approaches. The general justification for the deterioration of texture and flavour is starch retrogradation. The findings of a study by Miles *et al* (1985) explained this as a long-term process involving reversible crystallisation of amylopectin which increases the modules of starch gels. This is supported by a X-ray diffraction study (*Cuffini et al*, 2004), which concluded that the crystal structures formed by amylopectin contributes to its retrogradation and the firmness of bread. Both studies focused on amylopectin recrystallisation and justified it as one of the reason behind bread staling in storage. However, in a study of effects of water and its migration on starch retrogradation, Baik (2001) found that the increase of bread firmness may not necessary be directly related to amylopectin recrystallisation. The study suggests that dehydration and stiffing of amorphous domains may contributes to the hardening of
bread when glycerol was added to retard amylopectin recrystallisation. A similar study on bread storage temperature on bread crumb properties also concluded that water mobility in the crumb affects its firmness and elasticity (Bosmans et al, 2013). From these studies, it shows that there is a strong relationship between staling, starch retrogradation and moisture.

Besides moisture migration in bread during storage, various factors in the pre-bake stage can also contribute to the rate of staling. In the study of improvement of bread quality and shelf-life by enzyme combination, Caballero et al (2006) found that depending on the type of enzyme, it can affect bread staling rate both positively and negatively. This supports the earlier study by Brathen and Sahlstrom (1996) on the effects of enzyme preparation on bread quality and staling, which also found that different enzymes are able reduce the bread firming rate during storage to different degrees. The reason behind this is also suggested in a review of enzymes and quality of cereal (Poutanen, 1997). The review stated that enzyme activity in the bread hinders the amylopectin recrystallisation by producing low molecular weight branched-chain starch polymers during hydrolysis. These studies have shown that the application of enzymes may be able to help manufacturers in producing bread products which can last longer in terms of their texture.
In correlation of the usage of enzymes, emulsifiers are another popular alternative to delay the rate of staling in bread. In the study of the effects of the emulsifiers lecithin, E471 and E472 on Taftoon bread, Karimi et al (2006) have concluded that the emulsifiers were able to reduce the bread firmness after 72 hours of storage. This is supported by another study on the usage of emulsifier which showed that sodium stearoyl lactylate treated pan bread has better sensory qualities after 10 days compared to the ones without treatment (Almeida et al, 2012). Another recent study on the effects of hydrocolloids and emulsifiers on bread had also showed positive results for both bread quality and shelf-life (Ahrne et al, 2016). Although in all of these studies the type of bread used the experiments are different, it shows that emulsifier can help increases the shelf-life of a bread to a certain extent.

Storage conditions & Packaging

Different storage conditions on bread may affect the rate of starch retrogradation and its losses in moisture. Ambient (25°C), chilled (5°C) and frozen (-18°C) are the main storage conditions which are available to the general public and are also the common storage options for bread in households. Studies have shown that these conditions may slow down or even speed up the rate of staling. In the study of baking conditions and
storage temperature on staling in Sangak bread, Hamdami et al (2014a) found that by placing the bread into frozen storage of -18°C immediately after baking, bread staling was prevented compared to the other two storages at 20°C and 4°C. There was an increasing rate of unfreezable water when stored at 20°C than at 4°C, which the rate of staling is faster when stored at ambient temperatures. A study on staling of a similar type of bread by Kelekci et al (2003) had also shown similar findings. In a 25 days period, the wheat flour tortillas staled more at 22°C than at 4°C and 0°C. However, in contrast, a study by Felicidad and Yrjo (2011) on the staling of fresh and frozen gluten-free bread had shown a faster rate of staling at a chilled temperature at 4°C compared to an ambient temperature at 20°C. A review on improving the control of staling in frozen bakery products also supports this argument on the rate of staling increases as the storage temperature decreases (Cauvain, 1998). However, the review also concluded that staling decreases again after the bread temperature has passed below 4°C. Similar to the study by Hamdami et al (2014a) and Kelekci et al (2003), the study by Felicidad and Yrjo (2011) showed that the bread stored in frozen temperate at -28°C retained similar sensory qualities to that of a fresh bread. This shows that there may be a relationship in the difference in bread type and staling rate for ambient storage at around 20°C and chilled storage at 4°C.
Breads are commonly packed in ambient conditions in plastic and tapped to sealed the opening but are not air-tight. Although vacuum and modified atmosphere packaging (MAP) are generally used to inhibit the mold growth to extend the shelf-life of the bread (Hamdami et al., 2014b), it may also be able to retain a certain amount of moisture. As starch retrogradation may be linked to moisture migration during storage, the packaging used for the bread may, to a certain degree, also have effect on the rate of staling. In a study of changes in the physical properties of baguettes during storage in vacuum containers and polyethylene foils over 5 days, Fortuna et al. (2012) concluded that the breadcrumbs packed with the polyethylene foil was firmer than the ones packed in the vacuum containers. This is further supported by the findings by Hu et al. (2016) in the study of thermal-vacuum packaged steamed buns. It was found that vacuum packaging allowed moisture to migration from crust to the center which significantly slowed down the starch retrogradation of the steamed buns. However, Fortuna et al. (2012) have found that there were insignificant changes in the level of moisture content between both packaging over 5 days and both packages did not prevent the staling of the baguette. This may suggest that different types of bread will perform differently in similar atmosphere due to their original moisture content. In contrast with the positive findings in those two studies, Hansen and Rasmussen (2001) in the study on the use of MAP on
wheat bread has shown no correlation between the packaging and rate of staling. The storage of MAP wheat bread in 100% CO₂ for a 7 and 14 days period at 20°C had shown no significant differences in bread firmness compared to the control sample. Although the findings of these authors are solely directed to their own type of bread, this may still suggest that vacuum packaging may be effective in retaining the moisture in the crumb compared to MAP inflated with inert gases such as CO₂. However, the type of the bread must also be taken into account in this argument. For example, steamed buns used in the study by Hu et al (2016) have a higher available water content compared to other breads such as the wheat breads used in the study by Hansen and Rasmussen (2001). This may also suggest that, due to their own nature, some types of bread retain more moisture and have a lower rate of staling compared to the others.

Methodology

Staling may be caused and be affected by various internal and external factors during bread production. The main post-bake contributing factors are starch or more specifically amylopectin retrogradation, and moisture content or water availability which are both affected by the bread storage conditions (Cauvain, 1998). Therefore, by measuring and comparing the effects of amylopectin retrogradation and the losses in
moisture on controlled and modified samples, the rate of staling can be determined.

Storage and sampling methods during the experiment can be fairly similar among existing studies. Bosmans et al (2013) in the study stored the bread samples in sealed nuclear magnetic resonance (NMR) tubes at 4°C and 25°C for up to 7 days. Another short study by Al-Hajji et al (2016) on starch retrogradation in Arabic flat bread stored the bread in a zip-lock bag at ambient temperature for only a period of 3 days. In comparison, the study by Hu et al (2016) on steamed buns stored the samples in vacuum packaging up to a 90 days period. Both the samples from Bosmans et al (2013) and Al-Hajji et al (2016) have a lower water availability value compared to the steamed buns from Hu et al (2016). It is clear that the storage and sampling methods which will be used in the experiment will depend on the nature of the sample and the analysing methods.

For measuring amylopectin retrogradation, various but similar creditable methods and technology were used by the authors to obtain the data. In the study by Al-Hajji et al (2016), a differential scanning calorimetry (DSC) model was used to determine the enthalpy of the retrogradation. Similar to Bosmans et al (2013), the study also uses a DSC model to obtain the enthalpy and temperature data corresponding to the melting of the amylopectin crystals. However, the study also included a crumb texture analysis to
further address the differences in the changes of sensory quality. This was performed by using a texture analyser which measures the resilience of the crumb to produce a stress-strain curve. Lastly, the NHR spectrometer was also used to examine both the retrogradation and crumb firmness. Texture analyser was also used in the study by Caballero et al (2006) which also included a digital image analysis (DIA). It was used to further examine the cell wall thickness of the crumb grain. Addition methods used by Bosmans et al (2013) and Caballero et al (2006) allowed more data to be generated to accurately support other findings and arguments in the studies. In contrast, the study by Cuffini et al (2004) only used X-ray diffraction to measure the retrogradation. The total mass crystallinity and relative crystallinity of the amylopectin crystals were measured to determine a relationship with bread firmness and storage time. However, the study only focuses on this relationship therefore lesser methods were required to generate data for the argument. The methodology from these studies have showed that the number methods for measuring retrogradation shall depend on the focus of the experiment, but having additional methods may provide more data for an accurate finding.

The measurement for moisture content were also fairly similar within the reviewed studies. The Oven-drying method approved by the American Association of Cereal Chemists (AACC, 2016) were used in the studies by Hu et al (2016), Felicidad and Yrjo
(2011) and Hamdami et al (2014a). A certified and approved method helps to ensure accurate and standardised date to be produce among most study.

Statistical analysis was used in all of the reviewed studies to analyse the significance in difference between the raw data. The common analytical software used were the Statistical Analysis System (SAS, 2016), Statistical Product and Service Solutions (IBM, 2016) and Statgraphics (2016). However, results were analysed differently between the reviewed studies. Both the study by Hamdami et al (2014a) and Caballero et al (2006) uses the Fisher’s least significant differences (LSD) test, while the study by Brathen and Sahlstrom (1996) and Ahrne et al (2016) used the Tukey’s honesty significant difference (HSD) test. Both tests were used to detect the significant differences between the data at a confidence level of 95%. Tukey’s HSD test compared to Fisher’s LSD test, can adapt to unequal sample sizes (UOG, 1999) which may be a better option for the bread experiments. Results were also evaluated using Analysis of Variance (ANOVA) methods such as the one-way and two-way procedure used by Ahrne et al (2016) and Bosmans et al (2013) respectively.
Conclusion

The reviewed studies on bread staling have demonstrated different ideas and arguments which may help preserve the quality bread and providing a longer shelf-life. Various methodology between the studies were also compared and discussed to help decide proper methods which can be used in the intended study of this literature review.

Aim: To study the rate of staling between brown and wholemeal tin bread in ambient (25°C) and frozen (-18°C) storage treated conditions.

Objective:

1. To investigate the changes in texture of both types of bread by comparing the texture analysis results

2. To examine the relationship between the changes in texture and the type of bread by comparing their texture analysis results.

3. To investigate the amount of loss in moisture in both types of bread by comparing the moisture content results from the start and end date of the experiment.

4. To examine the relationship between the loss in moisture and the type of bread by comparing their moisture content results.

5. To determine the best storage conditions for both types of bread for the set period of time in this study.
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