Textural attributes of commercial biscuits. Effect of relative humidity on their quality

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Summary

Two commercial biscuits of semi-sweet type, ‘Marie’ and ‘Petit Beurre’ were used for investigating: (i) their texture variability as a function of the location and the side of puncturing and (ii) the influence of storage under different relative humidity on their texture, porosity and colour. Significant texture differences were found as a function of the location of puncturing (centre or periphery of biscuit area), as well as between the upper and the opposite side of a biscuit. At small relative humidity changes (11–32%) a distinct relationship between texture and moisture content was not noticed. In ‘Petit Beurre’ at \( a_{w} 0.32 \) a peak was observed in the puncture force values. In both biscuits porosity increased with their moisture content, accompanied by an area expansion. Significant differences in colour were mainly noticed between the upper and opposite side of the biscuits. Colour was less influenced by relative humidity changes.

Keywords

Colour, commercial biscuit, porosity, puncture, relative humidity.

Introduction

Hard dough, semi-sweet biscuits are produced from wheat flour dough with a moderate level of fat and sugar, approximately 200 and 150 g kg\(^{-1}\), respectively (Pedersen et al., 2004). Typical products of this group of biscuits are ‘Marie’, ‘Rich Tea’, ‘Osborne’ and ‘Petit Beurre’. These biscuits are harder than another popular type of biscuits: the short dough one, in which the typical fat and sugar levels are 320 and 290 g kg\(^{-1}\), respectively. As a result of a lower fat and sugar content, semi-sweet biscuits can be more attractive to consumers, who claim for less fat and sugar. As sales of biscuits continue growing in USA (Anonymous, 2001), and biscuit market is estimated to show an annual rate of increase of 1–2% (in quality terms) in the years 2003–2004 in Greece (ICAP, 2004), the quality of such products is obviously of paramount importance. To consumers, quality is a major factor for selecting a product and among the main characteristics related to quality are texture, taste and surface colour of a biscuit. In terms of texture, one can also include crumb structure, which because of a high ratio of open-air cells, can cause a series of cracks during biting, giving a ‘crunchy’ perception. For the crumb structure characterization, the porosity or the air volume fraction can be calculated. For fundamental measurements of one or more specific well-defined textural properties of biscuits, different types of measurements such as probing (puncture), compression, bending can be used for describing the multi-parameter nature of a biscuit (Gaines, 1991). Some literature references on texture measurements of biscuits are the three-point bending tests (Slade & Levine, 1995; Baltsvias et al., 1999; Ahmad et al., 2001), the Kramer shear tests (Zabik et al., 1979), the conical penetrometry (Maache-Rezzoug et al., 1998), the three-point break (known also as bending or snapping), combined with probing (puncture) tests (Gaines, 1991; Gaines et al., 1992) and finally the snapping, combined with compression tests (Manohar & Rao, 2002). Depending on the research tasks, one can use one or more of the above tests. Puncture is not so often used in biscuits, but it can give useful information about the variability of the texture in the same biscuit by puncturing at different locations, something that is not possible by the three-point bending test. Furthermore, the patterns of force generated by teeth pressing into the surface of the biscuit and then crushing a piece between the molars, may be estimated from the force-distance profile of the cracks produced as a probe is pressed through the food material. Therefore, the fracture profiles of a penetration test can be used for sources of adequate stimuli and

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can also be correlated to sensory analysis data (Gaines et al., 1992; Booth et al., 2003). The texture of commercial biscuits may vary even within the same biscuit. This happens mainly because of non-uniform moisture distribution in the product, something that it is inevitable in conventional drying (Burt & Fearn, 1983; Ahmad et al., 2001). Therefore, it seems that the biscuit moisture content is an important factor determining its quality. Strict regulation of moisture levels is important as moisture influences the product stability and its shelf-life (Faridi, 1994). Furthermore, sensory attributes such as the brittleness and crunchiness can be negatively affected when their moisture content increases. In spite of packaging (which is usually no sufficient), it is very important to store these products in a dry environment. However, in food retail or in household conditions, the atmosphere relative humidity may be often high, affecting the quality of biscuits. Storage under very high ambient humidity accelerates and induces stress development (Ahmad et al., 2001). This internal stress can cause visible or non-apparent cracks in a biscuit, a phenomenon known as ‘checking’. Commercial biscuits can often present quality fluctuations because of no uniformity of baking conditions, and/or to further storage and handling. In this study the textural properties (puncture measurements) of a random sample of two commercial brands of semi-sweet biscuits: ‘Marie’ and ‘Petit Beurre’ produced in Greece were investigated. This type of biscuits was selected, because it is popular to consumers in Greece. In the first part of this research, biscuits were punctured at precise but different locations on both area sides in order (i) to check if in the same biscuit or between biscuits of the same process there are textural variations between their two sides and (ii) for each biscuit to compare the texture between the upper and opposite side. Furthermore the above biscuits were stored under different relative humidity and its influence on the peak puncture force (‘apparent hardness’), on the peak deformation, the porosity and the colour was investigated. These samples were also compared with commercial, untreated samples. Samples were stored in most cases under relative humidity conditions of up to 67%. This value was selected for approximating the relative humidity values commonly found in ambient conditions of several retail shops.

Materials and methods

Commercial semi-sweet biscuits: ‘Marie’ and ‘Petit Beurre’ produced by a Biscuit and Food ware industry in Greece were used. ‘Marie’ has a circular and ‘Petit Beurre’ a rectangular shape. Their dimensions were measured out of twenty to thirty random samples and were as following: ‘Marie’ thickness: 0.60 ± 0.07 (cm) and diameter 6.7 ± 0.03 (cm), ‘Petit Beurre’ thickness 0.61 ± 0.01 (cm), great and small axis: 6.23 ± 0.07 (cm), 5.45 ± 0.06 (cm), respectively. Biscuit diameter was measured as the average value of two orthogonal diameters. Thickness was measured with a digital micrometer. For each measurement the average of two to three readings was recorded. All other measurements were performed by an image analysis programme (Image Proplus 1.3, Media Cybernetics, USA). The qualitative composition of these biscuits according to the manufacturer and quantitative data of the baked products are presented in Table 1. In the same table an

<table>
<thead>
<tr>
<th>Ingredients</th>
<th>Marie (literature data)* Per kilo of flour in grams</th>
<th>Petit Beurre</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat flour</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Refined vegetable oils</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Sugar</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Glucose</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Salt</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Full and skimmed milk powder (4%)</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Starch</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Sodium bicarbonate</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Ammonium bicarbonate</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Sodium pyrophosphate</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Emulsifier: soy lecithin</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Flavour: vanillin</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>In finished biscuit per kilo in grams</td>
<td>Carbohydrates 730 Sugar 159</td>
<td>750</td>
</tr>
<tr>
<td></td>
<td>Proteins 90</td>
<td>85</td>
</tr>
<tr>
<td></td>
<td>Fat 135</td>
<td>130</td>
</tr>
</tbody>
</table>

*Thacker (1994).
indicative composition of ‘Marie’ biscuits as found in literature (Thacker, 1994) is also presented. The composition of the ‘Petit Beurre’ is similar to that of the ‘Marie’. They vary in the type of the milk content (the ‘Marie’ has full and skimmed milk, while the ‘Petit Beurre’ only skim milk) and in the starch, sodium pyrophosphate content, which is only present in the ‘Marie’ biscuit. As indicated in Table 1 some variations were also observed in carbohydrate, protein and fat content of the finished biscuit, but they were small. From each brand several samples were bought, which had different lot numbers and expiration dates. From these samples biscuits were randomly selected for the experiments performed. The experiments included: (i) puncture tests in commercial products at both upper and opposite (down) side of the biscuit and (ii) equilibrating biscuits over salt solutions in desiccators at 35 °C ± 0.1 for 30 days for determining the way the moisture content affected puncture force, colour, porosity values and high humidity of storage. The values obtained were compared with those of commercial, untreated products. The salts used for creating constant relative humidity and the corresponding moisture content of samples after storage are presented in Table 2.

**Puncture tests**

Biscuits were placed between two aluminium plates secured by their sides with 5 mm holes each enabling the pass of the plunger as it travelled through the biscuits. Biscuits were punched through, completely. Nine holes per biscuit were punched in a modification of a pattern of Gaines et al. (1992) as it is shown in Fig. 1 for ‘Marie’ biscuits: one in the centre, and eight holes at two-third of their radius. For ‘Petit Beurre’ one hole was punched in the centre and eight in diagonal and central axis of these rectangular biscuits in positions similar to those of ‘Marie’ biscuits. Force-deformation curves were recorded and stored electronically; computer analysis resulted in peak force F (N) and peak deformation values. Peak force was recorded, referred according to Gaines et al. (1992) as ‘apparent hardness’. The force/deformation ratio (i.e. F/L) was also calculated in some cases, because it may indicate hardness better (Gaines, 1991). For each measurement seven to eight different biscuits, randomly selected, were used. Biscuits were puncture tested at a deformation speed of 300 mm min⁻¹ using a 4 mm diameter flat-ended cylindrical probe attached to a Universal Testing Machine (Instron 1011, MA, USA) equipped with a 50N load cell. As in most cases, differences among the one to eight positions (Fig. 1a) were not observed and an average value for both, peak puncture force and deformation at peak force was calculated and then compared with the respective value in the centre of the sample. Puncture experiments were performed in both biscuit sides: in the upper, rough in which the name of the biscuit is stamped (combination 1) and in the down, flat one (combination 2; Fig. 1b).

**Moisture content determination**

The moisture content of all samples was quoted according to AACC (2000) method 44–15A on a dry basis (d.b.) and the average value was calculated for a number of four to ten biscuits each time, for untreated and stored samples.

**Table 2** Saturated salts used and respective biscuit moisture after storage

<table>
<thead>
<tr>
<th>Saturated salt solutions</th>
<th>Relative humidity at 35 °C (%)</th>
<th>Moisture content of biscuits (d.b. %)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LiCl</td>
<td>11.25</td>
<td>Marie: 0.43 (0.02); Petit Beurre: 1.54 (0.09)</td>
</tr>
<tr>
<td>–</td>
<td>–</td>
<td>Marie: 1.36 (0.07); Petit Beurre: 3.02 (0.18)</td>
</tr>
<tr>
<td>MgCl₂</td>
<td>32.05</td>
<td>Marie: 2.99 (0.14); Petit Beurre: 3.50 (0.33)</td>
</tr>
<tr>
<td>K₂CO₃</td>
<td>43.15</td>
<td>Marie: 3.49 (0.05); Petit Beurre: 4.05 (0.19)</td>
</tr>
<tr>
<td>Mg(NO₃)₂</td>
<td>49.91</td>
<td>Marie: 5.92 (0.19); Petit Beurre: 6.80 (0.12)</td>
</tr>
<tr>
<td>NaBr</td>
<td>54.55</td>
<td>Marie: 6.42 (0.34); Petit Beurre: 8.08 (0.18)</td>
</tr>
<tr>
<td>KJ</td>
<td>66.96</td>
<td>Marie: 10.26 (0.26); Petit Beurre: 11.26 (0.21)</td>
</tr>
<tr>
<td>NaCl*</td>
<td>74.87</td>
<td>Marie: 12.98 (0.11); Petit Beurre: 13.02 (0.15)</td>
</tr>
<tr>
<td>KCl*</td>
<td>82.95</td>
<td>Marie: 13.88 (0.22); Petit Beurre: 13.96 (0.19)</td>
</tr>
</tbody>
</table>

*a*Used only in colour experiments.

*b*Moisture content of commercial, untreated products.

Standard deviation values in parentheses (n = 4–10).
Porosity measurements

For porosity measurements, samples from random locations in a biscuit avoiding the exterior ring part for ‘Marie’ and the part near the edges for ‘Petit Beurre’ were taken from all investigated samples. The volume of solids \( V_S \), cm\(^3\) was measured with a gas pycnometer (Stereopycnometer SPY-3; Quantachrome, Syosset, NY, USA) using helium as displaying fluid for volume measurements. The bulk volume \( V_b \), cm\(^3\) was measured by water displacement. Porosity can be described as the ratio between the volume of the pores \( V_S - V_b \) and the total volume of the product \( V_b \) and it is given by the equation:

\[
e = 1 - \frac{V_S}{V_b}.
\]

For avoiding water absorption, before putting the samples in water and measuring the displaced volume of water, samples were coated with a mixture of vaseline and toluene (specific gravity: 950 g kg\(^{-1}\) water) and were put in a refrigerator \( (t = 6 ^\circ C) \) for 1 h. They were weighed before and after coating and from the displaced volume, the volume of coating was subtracted, as its specific gravity was known. Coating was viscous enough and was not absorbed by the samples. Furthermore, it has been checked that there was no water diffusion through it. For each measurement seven to eight different samples were used, each measured four times.

Colour and area measurements

The colour of the surface of the biscuits was measured using an image analysis programme (Image Proplus 1.3; Media Cybernetics, Silver Spring, MD, USA) and Red \( (R) \), Green \( (G) \) and Blue \( (B) \) values were calculated at both sides of biscuits: upper and down in samples of different treatments. From the above measurements \( r, g, b \)-values were also calculated according to the equations:

\[
r = \frac{R}{R + G + B},
\]

\[
g = \frac{G}{R + G + B},
\]

and

\[
b = \frac{B}{R + G + B}.
\]

Finally the parameter \( C \) was calculated from the equation:

\[
C = r \cdot R + g \cdot G + b \cdot B.
\]

The area of the biscuit was traced by using the above image analysis programme and values obtained in pixels were converted into centimetre.

Statistical analysis

Statistical analysis was performed using the Statgraphics Statistical Graphics System, Version 2.1 (Statgraphics, Rockville, MD, USA). Fisher’s least significant difference (LSD) was used to determine significant differences among the means of the samples. A \( P \)-value of less than 0.05 was considered significant.

Results and discussion

Textural attributes of commercial, untreated biscuits

Concerning the punctured area, for the first type of biscuits ‘Marie’, in combination 1 (i.e. the upper rough part faced to the plunger) significant differences in peak force values between periphery locations and central area were not noticed (Fig. 2a). However, the deformation corresponding to the peak force was higher in the central area of the biscuit and differed significantly from it in the periphery \( (P < 0.05) \). A high variation of deformation values was also observed (Fig. 2b). Just the opposite occurred in combination 2 (i.e. the down, flat area faced to the plunger). In this case the periphery peak force values differed from the values in the centre \( (P < 0.05) \), but in both case the deformations at peak force were relatively low \((1.8–2.2 \text{ mm}; \text{Fig. 2a,b})\).

Comparing the ratio of peak force to the deformation at the peak force \((F/L)\), which indicates the hardness of the biscuits, the samples that were punctured by the combination 2, showed higher values. In the central position the observed values were twofold than those of combination 1. It is obvious that there is a difference in the resistance behaviour, according to the side of puncturing. This indicates that the area of placing the biscuit (rough or flat) can result in differences in the way that a biscuit of the investigated type withdraw the forces applied on it. This could be especially useful in packaging, where samples built columns. Placing them with the flat side in the upper position can reduce the total number of fragments during transfer and further handling. Concerning the quality of the biscuit, it can be regarded that the texture of ‘Marie’ biscuit fluctuated especially in the central area of the biscuit, something that may be commercially important. In combination 1 ‘Petit Beurre’ showed similar behaviour to ‘Marie’ concerning the peak force values (Fig. 2c). Deformation values were similar in the periphery and in the centre \( (P < 0.05) \) but were lower than in case of ‘Marie’ (Fig. 2d). In combination 2 peak force values were relatively low in comparison to those observed in ‘Marie’ and this was especially evident in the central area. Centre seems to withdraw lower forces, which were significantly different from those in the periphery. Deformation values on the other hand, were relatively high and consequently lower \( F/L \) ratio values were
observed than in case of combination 1. In conclusion, ‘Petit Beurre’ behaved in a different way than ‘Marie’ biscuits did. ‘Marie’ biscuits indicated higher hardness (F/L ratio) in combination 2, just the opposite occurred in ‘Petit Beurre’.

**Textural attributes of biscuits in relation to relative humidity**

In Fig. 3a the influence of moisture content on the peak force of ‘Marie’ biscuits at both positions: in the periphery and in the centre is presented. Samples were compressed with their upper part faced to the plunger (combination 1). At the range of low moisture content, similar values in puncture force values among biscuits were observed. Thus, puncture force values in the periphery of samples having 0.43% and 2.99% moisture content did not differ significantly, but comparing this force to that in the centre, differences were observed ($P < 0.05$). Furthermore, in the same sample there was a relatively great variability in values, which can reach the 20%. According to Burt & Fearn (1983) during baking heat is penetrating unevenly in a biscuit creating longer residence of moisture in the centre and allowing greater amounts of starch to gelatinize there. This can result in a more open crumb cell structure in the centre, which can be considered to contribute to a ‘softer’ product area. This fact justifies the lower values obtained in the central area of a biscuit. Ahmad et al. (2001), who investigated the breaking stress of biscuits in bending test, considered that it is difficult to determine the sensitivity of breaking stress experiments when moisture content changes are small (e.g. 0.5–2%). However even at higher moisture content (3–5% d.b.) it can not be noticed a distinct relationship between breaking stress and moisture content. Commercial, untreated products showed slightly lower peak force values in the periphery than in the adjacent samples. In the centre, similar values were observed for all samples in the moisture range of 0.4–3.0% ($a_w$ 0.11–0.32). Concluding, biscuits of a low moisture content (0.4–3%) indicated similar behaviour and differences were usually not significant. As the moisture content in biscuits increased as expected, puncture force values dropped down. Deformation generally did not change with the moisture content of the samples (Fig. 3b), although at high moisture content, biscuits exhibited a rubbery behaviour, as the water acts as a plasticizer, decreasing thereby the glass transition temperature (Zabik et al., 1979). According to puncture tests, the central area of the samples was generally ‘softer’. Therefore the central area of each biscuit can sustain a greater deformation before breaking. However, in most cases no significant differences ($P < 0.05$) between centre and periphery were noticed. In untreated products, the deformation was rather high as it was

![Figure 2](image-url)
also the variability in values, which could reach 25% (for the deformation at periphery position), indicating a no uniform texture. Because of this great variability the deformation values differed from those samples of vicinal moisture content. Especially for these products, considering both peak force and deformation at peak force values, it can be concluded that biscuits can ‘tolerate’ higher moisture content (up to 3–4%) without any significant change of F/L ratio. In ‘Petit Beurre’ a peak force value was observed at 4% a moisture content (\(a_w\) 0.32; Fig. 3c). This peak was not observed in case of the ‘Marie’ biscuits. After this peak point, a gradual decrease in puncture force was observed, as the moisture content increased. The periphery of biscuits generally indicated greater puncture forces than the centre of the biscuit. Significant differences between periphery and central area were noticed at low (1.5–3%) and at high (6.8–8%) moisture contents. Concerning the deformation at peak force significant differences in deformation values were observed only between the untreated products and the samples with the high moisture content (\(P < 0.05\)). This was observed in both cases: in periphery and in central area of the biscuit (Fig. 3d). Commercial, untreated ‘Petit Beurre’ biscuits can also ‘afford’ greater moisture content (up to 4%) without any influence on their texture. ‘Marie’ seems to be more ‘sensitive’ in moisture changes, as at high moisture content, a sudden loss of their ‘apparent hardness’ occurs.

Porosity

At low moisture content range (0.44–3.00% for ‘Marie’ and 1.50–4.00% for ‘Petit Beurre’) untreated samples had higher porosity than samples of lower moisture (significant difference at \(P < 0.05\)). However it is remarkable that at high moisture content, porosity generally increases (Fig. 4). In Table 3 the area change of biscuits can be seen, which is proportional to volume change. This change is also related to the moisture content. At high moisture content, (10.2 for ‘Marie’ and 11.2% for ‘Petit Beurre’ biscuits), the area increased by 6.4% and 7.2%, respectively. This increase can be ascribed to a sudden swelling by water absorption. Baltsalias et al. (1999) refer that the air volume fraction of short-dough biscuits did not change in a water activity range of 0.11–0.57, as at \(a_w\) 0.33 the mechanical properties did change and the biscuits underwent a glass transition. In the present work, porosity increased at \(a_w\) 0.32 for ‘Marie’ biscuits and \(a_w\) 0.50 for ‘Petit Beurre’ biscuits (2.99 and 6.80 moisture content d.b., respectively), as a significant area increase occurred at relatively low water activity equal.
to 0.43. At this water activity the mechanical properties (peak force values) of both biscuits changed as well.

**Colour**

The colour of ‘Marie’ biscuits stored in salts was generally greater than that of the untreated samples. Just the opposite occurred in case of ‘Petit Beurre’ (Fig. 5a,b). Generally the down side had greater colour values than the upper one and significant differences to the upper side were noticed ($P < 0.05$), indicating uneven baking. This was observed in both brands of biscuits. Comparing samples of different moisture content, at high biscuit moisture content similar colour values were observed in most cases for samples stored at different relative humidity. This was evident for both upper and opposite side and it was also observed in both brands of biscuits. Concluding, colour changes in relation to moisture content were not significant for both types of biscuits. Therefore they can not be used as quality indicator. However, untreated ‘Petit Beurre’ biscuits (moisture content: 3.0%) had higher colour values as untreated samples than those that acquired higher humidity because of storage in relative humidity higher than 43%.

**Conclusions**

Two different brands ‘Marie’ and ‘Petit Beurre’ of semi-sweet biscuits were analysed in order to assess the variability in texture of commercial, untreated biscuits and to investigate the influence of relative humidity on their quality. The area of puncturing influenced the textural properties of the two products in a different way. When ‘Marie’ biscuits were punctured with the down area faced to the plunder indicated a high ‘apparent hardness’ and great rigidity. On the contrary, in this way of puncturing, ‘Petit Beurre’ indicated lower rigidity and hardness in the centre of their area. The influence of the relative humidity was not the same accordingly to the biscuit investigated. When laying in the same relative humidity ‘Marie’ biscuits had lower moisture content than ‘Petit Beurre’. In these biscuits at $a_w$ greater than 0.32 a gradual drop in peak puncture force occurred. At the same $a_w$ a peak was observed in puncture force of ‘Petit Beurre’. Differences in force and deformation values obtained in the centre and the periphery of the area of the same biscuits were mainly observed at low relative humidity. There was also a difference in colour of two brands. ‘Petit Beurre’ stored in salts indicated lower colour values than ‘Marie’, but as untreated commercial samples they had higher colour.
values. Porosity increase can be attributed to volume swelling, which occurs when biscuits are extended in an environment of high relative humidity and absorb water. It seems that commercial biscuits present texture variations, at both the centre and the periphery or upper and down side, at a level that may be commercially significant. This should be further investigated including also a sensory analysis. On the contrary even at common relative humidity storage texture, porosity and in a less extent colour may change meaning the end of the acceptability of such products.

References


