

1           **EFFECT OF BAMBOO FIBRE AND GLUCOSE SYRUP AS NEW**  
2           **INGREDIENTS IN THE MANUFACTURE OF *AMARETTI* COOKIES**

3           EFFETTO DELLA FIBRA DI BAMBU' E DELLO SCIROPPO DI GLUCOSIO QUALI NUOVI  
4           INGREDIENTI NELLA PRODUZIONE DEI BISCOTTI *AMARETTI*

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13                           **ABSTRACT**

14           “Amaretti”, Sardinian almond-based cookies, have a shelf-life of about seven days, due to the  
15           quick hardening of the internal moist paste. To improve their overall quality, two different  
16           ingredients (bamboo fibre and glucose syrup), known as water-binding agents, were used  
17           separately to obtain two different recipes, in addition to the original one. To evaluate their effects,  
18           moisture content (wet basis) and  $a_w$  were measured. Sorption isotherms were determined and  
19           texture (by puncture test) and colour (as  $L^*$  parameter) evolution were monitored. Moreover, a  
20           formal sensorial evaluation was carried out. Moisture content and  $a_w$  evolution indicated that both  
21           ingredients are effective for preserving the softness of the internal paste for a longer time. After

1 ten days of storage, moisture loss from the internal paste was greater for the traditional cookies  
2 (61.2% fall) in comparison with fibre- and glucose syrup-based “Amaretti” (49.3% and 49.7%,  
3 respectively). However, sorption data and puncture test showed that bamboo fibre appears more  
4 suitable than glucose syrup for maintaining the typical difference between the external dry crust  
5 and the moist almond-based core, controlling water redistribution that takes place in the sugar-  
6 dominated formulation. Moreover, colour analysis showed a significant difference between the  
7 glucose syrup-based recipe ( $L^* \sim 53$ ) and the other ones ( $L^* \sim 75$ ): this added reducing sugar led  
8 to a burnt-like colour of the final product. Finally, the most important difference among the  
9 recipes assessed by the descriptive panel test, concerned the greater stickiness of the cookies made  
10 with glucose syrup, whereas fibre perception was not relevant.

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## RIASSUNTO

13 Gli “Amaretti”, dolci sardi a base di pasta di mandorle, possiedono una shelf-life di circa sette  
14 giorni, a causa dell’indurimento della pasta interna umida. Per migliorare la loro qualità sono stati  
15 utilizzati separatamente due nuovi ingredienti (fibra di bambù e sciroppo di glucosio), ben noti  
16 quali agenti in grado di legare l’acqua, ottenendo così due nuove ricette in aggiunta a quella  
17 tradizionale. Per valutare il loro effetto sui dolcetti si è deciso di misurare il contenuto umido,  
18 l’attività dell’acqua ( $a_w$ ) ed il colore, sono state costruite le isoterme di adsorbimento ed è stata  
19 monitorata l’evoluzione della texture nel tempo. Inoltre, è stata condotta una formale valutazione  
20 sensoriale dei diversi campioni. L’evoluzione del contenuto umido e dell’attività dell’acqua  
21 mostrano come entrambi gli ingredienti siano in grado di preservare per un tempo maggiore la  
22 morbidezza interna. In particolare, dopo dieci giorni di stoccaggio, la perdita di umidità dalla pasta  
23 interna è stata maggiore per gli “Amaretti” tradizionali (riduzione del 61.2%) rispetto a quelli a

1 base di fibra e sciroppo di glucosio (49.3% e 49.7%, rispettivamente). Tuttavia, la fibra di bambù  
2 sembra essere più adatta dello sciroppo di glucosio nel garantire la tipica differenza tra la secca  
3 crosta esterna e la morbida pasta interna, come evidenziato dalle isoterme di adsorbimento e dalla  
4 analisi tenderometrica. Inoltre, l'analisi colorimetrica ha evidenziato una differenza significativa tra  
5 la ricetta a base di sciroppo di glucosio ( $L^* \sim 53$ ) e le altre due ( $L^* \sim 75$ ): l'aggiunta di tale  
6 zucchero riducente ha determinato l'imbrunimento del prodotto finale. Infine, la principale  
7 differenza tra ricette derivante dal panel test descrittivo ha riguardato la maggiore appiccicosità dei  
8 dolcetti ottenuti mediante lo sciroppo di glucosio, mentre la percezione della fibra è stata non  
9 rilevante.

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11 -Keywords: cookies, hardening, humectant, sensory quality, shelf-life, texture, water binding agent

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# 1 **Introduction**

2 In Italy there are many sweets named “Amaretti”, but they may be different depending on the  
3 region of origin. The Sardinian “Amaretti” are well-known for their typical characteristics that  
4 make them unique. Unlike most Italian almond-based cookies, Sardinian ones are dome-shaped,  
5 have an intense bitter flavour and a rough, cracked external surface. The most important quality  
6 attribute noted by consumers arises from their texture; they have soft moist internal almond-paste,  
7 that contrasts with the thin, hard, dry external crust.

8 According to the definition of the term ‘traditional’ given by the COMMISSION OF THE  
9 EUROPEAN COMMUNITIES (2005) (‘Traditional means proven usage on the Community  
10 market for a period of at least equal to that generally ascribed to a human generation’) and by the  
11 EuroFIR working group (EUROPEAN FOOD INFORMATION RESOURCE NETWORK,  
12 2005) (that has defined the term traditional as ‘conforming to established practice or specifications  
13 prior to the Second World War), “Amaretti” can be cited as traditional regional cookies.  
14 Moreover, following the criteria for the definition of a food as traditional reported by  
15 TRICHOPOULOU *et al.* (2006), “Amaretti” are manufactured using traditional material,  
16 traditional formulation and traditional type of production and/or processing and despite the  
17 incorporation of technological progress, they are still produced and processed by traditional  
18 methods.

19 These regional cookies are usually made of sweet and bitter almonds, sucrose and egg white.  
20 Moreover, they are characterised by a moisture content (wet basis) of ~ 13-14% for the internal  
21 paste and of ~ 5-6% for the external crust; the  $a_w$  values are ~ 0.74 and ~ 0.40, respectively.  
22 Therefore, the Sardinian Amaretti are good examples of a multi-domain system, having two parts  
23 with different moisture content and  $a_w$ , in which a continuous moisture migration from one region

1 to another takes place. Multi-domain foods are quite common in all countries, particularly among  
2 medium shelf-life bakery products. Among the factors that control the amount and rate of  
3 moisture migration in multi-domain foods, the two most important are water activity equilibrium  
4 (thermodynamics) and factors affecting the diffusion rate (dynamics of mass transfer). As far as  
5 the “Amaretti” are concerned, these factors lead to a very serious problem that affects most  
6 cookies (MANLEY, 1988). After a few days (four to seven days), qualitative decay begins due to  
7 severe hardening of the internal almond paste that strictly limits the shelf-life of these cookies.  
8 Such a short shelf-life prohibits their exportation to countries far away from the traditional places  
9 of manufacturing. As reported previously (PIGA *et al.*, 2005; LABUZA, 2001), this hardening  
10 could be due to both the redistribution of water (that leads to sugar crystallisation) and loss of  
11 water into the surrounding environment. To control this migration, several tools can be utilised to  
12 inhibit the change in moisture, including the addition of an edible layer between domains, changing  
13 the water activity of the food ingredients, the effective diffusivity of the water, or the viscosity  
14 (molecular mobility) in the entrapped amorphous phases (LABUZA and HYMAN, 1998).  
15 Even if the general solutions for obtaining satisfactory multi-domain food items have already been  
16 well documented (BELL and LABUZA, 2000; GUILBERT *et al.*, 1996; KROCHTA *et al.*, 1994;  
17 LABUZA, 1985; ROCA *et al.*, 2006; THARANATHAN, 2003), to our knowledge there are no  
18 studies dealing with the use of different water-binding agents in typical regional cookies, in order  
19 to reduce the moisture migration between the different components (crust and paste) and,  
20 consequently, the rate of hardening. On the other hand, the need for a standardization of  
21 traditional foods, as well as the need to extend shelf life, is increasing, in order to maintain the best  
22 quality during a period of time that makes their marketing possible (TRICHOPOULOU *et al.*,  
23 2006). This kind of investigation, dealing with the optimisation and enhancing of traditional food  
24 products, has a huge potential for the useful transfer of knowledge and technology in food sectors

1 of great importance in some less-developed regions. Moreover, they can contribute to the  
2 transmission of precious aspects of cultural heritage related to particular food products.

3 The purpose of this research was to test the applicability and effects of glucose syrup and bamboo  
4 fibre as water-binding ingredients on “Amaretti” cookies, by a multi-analytical approach.  
5 Particular attention was paid to the changes in the typical sensorial characteristics such as the  
6 different textures between the internal paste and the external crust, which is the quality attribute  
7 most appreciated by consumers.

8

## 9 **Materials and methods**

### 10 **“Amaretti” manufacturing**

11 “Amaretti” cookies were made in the department pilot plant, using traditional ingredients in the  
12 following amounts:

- 13 - Sweet almonds (650 g)
- 14 - Sucrose (650 g)
- 15 - Fresh liquid egg white (255 g)
- 16 - Bitter almond aroma (5 mL)

17 The sweet almonds (purchased in a local market) were ground into tiny pieces with a mincing  
18 machine (SIMAC, Bravo chef 750, Veldhoven, Holland). Two sieves (Analysensieb – RETSCH,  
19 D-42759 Haan / Germany) both certified in conformity with DIN-ISO 3310/1 standard, were used  
20 to obtain two different sized particles, the first with a diameter < 1.0 mm (350 g) and the second  
21 with a diameter of 3.55 mm and 2.36 mm (300 g), respectively. Both fractions were put in a small  
22 bowl and all the sugar and most of the egg white (165 g) were added. The ingredients, left  
23 unmixed, were placed in a climatic chamber (Heraeus Vötsch, mod. HC 0020 –Balingen /

1 Germany) at  $15 \pm 0.5$  °C and  $40 \pm 2$  % RH for 24 h. This pre-mixture was then put in a refiner  
2 machine (Steno, f.lli Nazzari, mod. R2 – Italy) to obtain a more homogeneous matrix, which was  
3 subsequently mixed for 3 min at low speed with a vertical axis planetary mixer (Hobart  
4 Corporation, mod N-50, Troy, OH 45374) with a stainless steel paddle. The remaining part of the  
5 egg white (90 g) and the bitter almond aroma were added at this point. The ingredients were then  
6 mixed for 5 min at medium speed. The mixture was then used to form the cookies on a baking  
7 pan. To shape the cookies as uniform as possible, small steel discs of about 5.5 cm in diameter  
8 were used, the paste was put into the forms ( $40.0 \pm 0.5$  g) by using a typical confectionery cloth-  
9 bag with a stainless steel tip of 1.3 cm in diameter. Baking was carried out in a ventilated electric  
10 oven (Moretti Forni s.r.l., mod. Mikro - Italy) for 20 min at 200 °C. Finally, 38 “Amaretti”  
11 cookies ( $37 \pm 0.5$  g) were obtained (Fig. 1), which were then cooled in a climatic chamber at  $25 \pm$   
12  $0.5$  °C and  $40 \pm 2$  % RH for two h.

13

## 14 **Ingredients**

15 To test the effects of the two different water binding agents, the “Amaretti” were also produced  
16 adding 30 g ( $\sim 2\%$  w/w) of glucose syrup (D.E.= 47), provided by a local confectioner’s shop, and  
17 30 g ( $\sim 2\%$  w/w) of bamboo fibre (Chimab S.p.a., Campodarsego (PD) – Italy) before starting the  
18 mixing. The amounts of these ingredients were selected for two reasons: first, larger amounts of  
19 ingredient would affect food-processing, leading to a paste that would be hard to handle  
20 particularly during mechanical mixing. Second, the above-mentioned amount should not affect the  
21 original quality characteristics of these regional cookies and hence their “traditional” attribute.  
22 Glucose syrup was chosen as the conventional sugar used in the confectionery industry  
23 (GUILBERT, 2002), and is characterised by low cost, ready-availability on the internal market  
24 and, from a legal point of view (DIRECTIVES 2000/13/EC and 2003/89/EC), it is considered a

1 food ingredient. In this work, the glucose syrup used had an average D.E. value (D.E.= 47). The  
2 viscosity of the syrup is a parameter that influences the dynamics of mass transfer by reducing the  
3 moisture migration between the internal paste, crust and surrounding environment. In fact, the rate  
4 of water diffusion is controlled by the local viscosity of the system. The higher the local viscosity,  
5 the less molecular movement is noted with respect to rubbery and glassy states (LABUZA and  
6 HYMAN, 1998). Moreover, glucose syrup is recognised as a humectant agent thanks to its  
7 colligative properties (BELL and LABUZA, 2000). Bamboo fibre is a new cellulose-based  
8 ingredient derived from the shoots of bamboo plants. This is a purified fibre (total fibre content >  
9 99% on dry basis). In addition, it is characterised by a high pectin and hemicellulose content. It is  
10 about 0.25 mm long, has a density of about 120 g / L and a *WHC* (water holding capacity) of 8.7 g/g  
11 fibre, calculated after centrifugation. With these characteristics, the fibre can retain water, not only  
12 by capillary forces, but also by specific bonds (data provided by the supplier). For these reasons,  
13 the addition of this fibre enables the moisture loss to be reduced considerably; it can also improve  
14 textural properties, since it is also considered to be a texturising agent. Moreover, the fibre has  
15 zero calories, is inert, tasteless and white in colour. Their functional properties are no less  
16 important; more than 90% of the water-insoluble fibre bulks in the stomach, removes undesired  
17 metabolic by-products and shortens intestinal transit time. Dietary fibre is essential for keeping the  
18 digestive tract healthy and has also been related to a variety of beneficial effects, such as  
19 contributing to weight management (RODRIGUEZ *et al.*, 2006). Due to consumer interest in  
20 health foods and beverages, fibre-fortified foodstuffs is a category with potential for fast-growth.  
21 Another important aspect is that any plant fibre, including that from bamboo can be labelled simply  
22 as plant fibre under the listing of food ingredients and not as an additive (as noted above for  
23 glucose syrup).

24 From now on, the three different typologies of “Amaretti” will be indicated as follows:



1  $T$ = traditional;  $S$ = syrup;  $F$ = fibre.

2

### 3 **Storage conditions of “Amaretti” cookies**

4 For each trial the “Amaretti” were divided into three lots: one for the determination of the  
5 sorption isotherms, one for textural analysis and the last for the evaluation of the  $a_w$ , moisture  
6 content (wet basis) and colour. The cookies were then stored under controlled temperature-  
7 humidity conditions ( $25 \pm 0.5$  °C and  $40 \pm 2$  % RH, similar to those of the typical outlets for  
8 “Amaretti”), for ten days and analysed after 1, 2, 4, 6, and 10 days. This storage time was selected  
9 to verify the single effect of the added ingredients on “not-packaged Amaretti” after a period of  
10 time slightly longer than the typical shelf-life of “packaged Amaretti”.

11

### 12 **Water activity and moisture content**

13 Water activity was measured on three “Amaretti” at a time with an electronic hygrometer (Aqua  
14 Lab Series 3 mod. TE – DECAGON DEVICES, Inc. Pullman, Washington USA), previously  
15 calibrated with a standard solution of NaCl of known activity (prepared by High-Purity Standards  
16 for DECAGON DEVICES, Inc). Gravimetric analysis was performed in triplicate to determine  
17 water content (% H<sub>2</sub>O on wet basis) using an oven at  $130 \pm 2.0$  °C for 90 min, long enough to  
18 guarantee the total drying of the samples. The measurements were performed separately on the  
19 whole cookie (paste and crust) and on the internal paste. In the first case,  $5 \pm 0.5$  g of “Amaretti”  
20 were cored with a spoon soil auger, whereas in the second case,  $5 \pm 0.5$  g were sampled from the  
21 inner part of the almond paste filling with a laboratory spatula.

22

### 23 **Moisture sorption data**

1 Moisture sorption data were collected according to the procedures reported in the COST project  
2 of European Cooperation in the field of Technical and Scientific Research (WOLF *et al.*, 1985)  
3 and the principles described by BELL and LABUZA (2000). In particular, whole “Amaretti” were  
4 used because it was impossible to separate in a proper way the external crust from the internal  
5 paste. Even though the term “sorption isotherm” is here used, the more precise term is “working  
6 isotherm”, i.e. a combined adsorption/desorption isotherm (LABUZA, 1985). Triplicate samples  
7 were placed in sealed glass jars with an internal inert platform used to raise the samples off the  
8 floor. Each jar containing saturated salt slurries in the  $a_w$  range of 0.11 to 0.81 were stored in a  
9 climatic chamber at 25 °C. At high water activities ( $a_w > 0.75$ ), a small amount of toluene (1 g)  
10 was placed in a capillary tube fixed in the jar to prevent microbial spoilage. Salts (LiCl anhydrous,  
11 CH<sub>3</sub>COOK, MgCl<sub>2</sub> hexahydrate, K<sub>2</sub>CO<sub>3</sub> anhydrous, Mg(NO<sub>3</sub>)<sub>2</sub> hexahydrate, CH<sub>3</sub>COOLi  
12 dihydrate, NaCl, (NH<sub>4</sub>)<sub>2</sub>SO<sub>4</sub>) used to obtain constant water activity environments were reagent  
13 grade (Sigma Aldrich Srl, via Gallarate 154, 20151 Milano). For all samples, equilibrium was  
14 reached in three weeks.

15

## 16 **Texture analysis**

17 Hardness was evaluated in cooled, freshly baked “Amaretti” and after 2, 4, 6 and 10 days by using  
18 a food texture analyser (mod. Z005, Zwick Roell, Ulm, Germany). The software “TestXpert  
19 V10.11 Master” was used for the data analysis. Textural determination was made on 15  
20 “Amaretti” per each storage time by using a 4 mm diameter cylinder probe for a puncturing test  
21 (BOURNE, 2002). “Amaretti” were punctured in the center up to 9 mm in depth, in order to  
22 check whether any different structural characteristics were present inside or on the surface. These  
23 analyses were carried out by using two different cell loads, depending on the time of analysis: a  
24 100 N cell load for the first three trials (after 0, 1, and 2 days of storage) and a 5 kN cell for the

1 last three (4,6 and 10 days). The parameters for the puncturing test were: pre-test speed: 100 mm  
2 min<sup>-1</sup>; pre-load: 0.01 N (with a 100 N cell load) and 2 N (with a 5 kN cell load); pre-load speed: 4  
3 mm min<sup>-1</sup>; test speed: 10 mm min<sup>-1</sup>; post-test speed: 700 mm min<sup>-1</sup>; distance: 15 mm; probe: 4 mm  
4 diameter cylinder. “Amaretti” were selected with a diameter of  $55 \pm 2$  mm and a thickness of  $25 \pm$   
5 1 mm, in order to have standardised samples. Hardness measurements of samples by puncturing  
6 involved plotting force (N) versus deformation (mm) and calculation of three parameters: (a)  
7 maximum force (N) as an index of the hardness of the crust ( $F_{\max}$ ); (b) elastic modulus (Nmm<sup>-1</sup>) as  
8 an index of the stiffness of the crust ( $E_{\text{mod}}$ ); (c) area under the curve (Nmm) up to 9 mm as an  
9 index of global hardness of the cookie ( $W_{\text{tot}}$ ).

10

## 11 **Colour measurement**

12 The external colour of “Amaretti” was measured using a reflection colorimeter (MINOLTA  
13 Chroma Meter mod. CR 210, Osaka, Japan). Cookies were placed on a white standard plate ( $L^* =$   
14 100) and the *CIE L\*a\*b\** coordinates were measured, using D65 illuminant/10° observer. Colour  
15 analysis was carried out only on freshly baked “Amaretti” (30 replicates for each lot).

16

## 17 **Sensory evaluation**

18 A sensory evaluation was carried out to check the texture evolution during storage time and the  
19 difference between recipes. In particular, a descriptive test was used in which nine trained  
20 panellists (5F, 4M, age range 21–58 yrs) described the evolution of the cookies through four  
21 attributes: resilience, external crispness, internal stickiness and fibre perception. For each of the  
22 five times of analysis (freshly baked “Amaretti” and after 2, 4, 6 and 10 days of storage), the  
23 sensory test was carried out using six “Amaretti” (two for each formulation), presented to the

1 panel in two separate sessions. An unambiguous alphanumeric code was given to each recipe, to  
2 avoid that the panellists underwent any kind of possible influence. To best assess the sensations  
3 from the products, this chronological order was followed: first a general look at the product, then  
4 touch (resilience), then take the first bite (external crispness) and then further chew the cookie  
5 (internal crispness and fibre perception). The panellists attributed a value between 1 (minimum)  
6 and 9 (maximum) for each of these parameters.

7

## 8 **Statistical analysis**

9 The data were subjected to one-way analysis of variance (ANOVA) using Statgraphics Plus 4.0  
10 software. In particular, the data were grouped by lots (the three different recipes: T, S and F) to  
11 assess the differences for each recipe. The mean values, when appropriate, were separated by  
12 LSD's multiple range test at  $P \leq 0.05$ .

13

## 14 **Results and discussion**

### 15 **Moisture content and water activity**

16 The two added ingredients gave rise to different moisture content and  $a_w$  values of the internal  
17 paste (Table 1). Cookies with syrup had a higher moisture content, in comparison to the other two  
18 recipes, due to its composition (water/sugar solution), whereas the  $a_w$  value of the internal paste of  
19 S freshly baked "Amaretti" was not statistically different from the  $a_w$  value of the traditional  
20 cookies, in contrast to cookies with fibre, that had the lowest  $a_w$  value. Although fibres are not  
21 classified as humectants because they do not lower water activity, nevertheless this result could  
22 somehow be related to their great capacity to hold water. All the pastes had a water activity  
23 around  $0.72 \pm 0.02$ . With regard to the evolution of the above-mentioned parameters (Fig. 2), on

1 the last day of storage the loss of moisture from the internal paste was particularly evident in T  
2 (61.2% decrease) and less pronounced in S and F (49.3% and 49.7%, respectively). The same  
3 behaviour was observed for the  $a_w$  values. In fact, all of the types of “Amaretti” underwent a  
4 progressive decrease in  $a_w$ , but it was sharper in T than in the other two. In the case of fibre, this  
5 trend could again be linked to the *WHC*. Regarding glucose syrup, the delayed moisture loss is  
6 linked to its colligative properties and to the increased internal viscosity of the system.

7

### 8 **Moisture sorption data**

9 Moisture sorption data were obtained to assess the different effects of the two new ingredients on  
10 the whole cookie (BELL and LABUZA, 2000). Fig. 3 shows the sorption isotherm data obtained  
11 from the three different recipes of freshly baked “Amaretti” after an equilibrium time of 3 weeks at  
12 25°C. Each data point is the average of three samples (Table 2).

13 The shape of the isotherms is different from a typical sigmoid curve. In fact, the latter is a smooth  
14 curve in the 0.30-0.52  $a_w$  range, while the three experimental isotherms exhibit a slight  
15 discontinuity, probably due to sucrose crystallisation, as reported in previous papers (PIGA *et al.*,  
16 2005; SALTMARCH and LABUZA, 1980) but further study is needed to confirm this hypothesis  
17 (e.g., MRI). The imperfect coincidence of the curves is quite evident, especially for some  $a_w$   
18 values; there is no statistically significant difference among the first three  $a_w$  values (i.e., 11%, 23%  
19 and 32% relative humidity equilibrium, ERH). The three different lots of “Amaretti” lost the same  
20 amount of water. This moisture loss at the lowest  $a_w$  levels was assumed to be due to desorption.  
21 At 0.44  $a_w$  there was a statistically significant difference between S on the one hand and T and F  
22 on the other. As noted above, sugar crystallization probably took place more rapidly in S than in  
23 the other two recipes. Generally, a sugar mixture is expected to prevent this phenomenon but in  
24 this sugar-dominated formulation, both saccharose and glucose are in an amorphous form (highly

1 hygroscopic), which promotes water redistribution at the molecular level (e.g., water in different  
2 regions such as sugar and protein). At 52% ERH, a significant difference was observed between S  
3 and T on the one hand and F on the other, since at this  $a_w$  value the effect of crystallisation was  
4 less evident. The water mobility (and consequent water redistribution between components) was  
5 less due to the high water binding capacity of the fibre. At 70% ERH, there was a significant  
6 difference between T and F, whereas at  $a_w$  value of 0.75 there was a difference between T on the  
7 one hand and S and F on the other. This result reflects the water-binding affinity of the different  
8 matrices. At the highest  $a_w$  value there were no statistically significant differences between lots;  
9 this is because the “Amaretti” took moisture from the surrounding air very easily, when the  
10 humidity was high. This moisture gain at the highest  $a_w$  levels was assumed to be due to sorption.  
11 Based on this, the discontinuities exhibited by the isotherms would be the result of the loss of  
12 moisture due to sugar crystallisation. At high  $a_w$  values, i.e.,  $\sim 0.70$  and above, there would be  
13 losses of moisture over time during the equilibration period as a result of continued sugar crystal  
14 growth, but this would not be reflected in the isotherms which would show a smooth curve with  
15 increasing  $a_w$  because the different components within the matrix (protein) can hold more water  
16 (SALTMARCH and LABUZA, 1980). In this case, moisture uptake exceeds moisture losses from  
17 sugar crystallisation.

18

## 19 **Texture evolution**

20 The curve resulting from the puncturing test on freshly baked “Amaretti” is characterised by an  
21 initial increase, a maximum point and a final decrease that corresponds, respectively, to an  
22 increasing force recorded at the onset of penetration, the maximum force recorded when the probe  
23 penetrated the cookie and the penetration of the internal paste. This shape is typical for food  
24 systems characterized by an outer surface (the external crust, in this case) that is harder than the

1 remaining part (the internal paste). The profiles of the three mean curves of freshly baked  
2 “Amaretti” is similar (Fig. 4); T had an external crust that was little harder and stiffer than the  
3 other two, as can be seen from the maximum force and Young’s modulus values, respectively  
4 (Table 3). The three curves are almost coincident in the final tract, indicating that the internal  
5 paste had the same, if not equal consistency, even if not equal. This was confirmed by the overall  
6 hardness (see the area under the curves and the corresponding  $W_{tot}$  values in Table 3). There was a  
7 significant difference between S “Amaretti” on the one hand and T and F on the other. This was  
8 due to the viscosity of the internal paste, which gave a slightly upwards shifted curve. After 2 days  
9 of storage (Fig. 5), the curve related to S was flatter than that of the previous day; moreover, the  
10 peak due to the crust penetration was absent. This could be due to the water redistribution  
11 between components within the matrix, i.e. the water moves to the hygroscopic sugar in the  
12 amorphous form and from the paste to the crust, due to the  $a_w$  gradient. Finally, the crust lost its  
13 crispness as can be seen from the maximum force and Young’s modulus values (Table 3). The F  
14 curve was similar to that of S in the final part, but very different in the first; in fact, the F  
15 “Amaretti” had a hard, crumbly crust that was still differentiated from the internal soft paste. The  
16 T cookies had a crust that was as stiff as F (no significant difference concerning Young’s  
17 modulus), but harder (higher maximum force). Moreover, it is interesting to observe that the  
18 descending tract of the T curve was slightly shifted over the other two, indicating that after two  
19 days, the internal paste of T had already lost a little more moisture. The above-described trend  
20 becomes more evident after 4 days (Fig. 6). T “Amaretti” underwent a severe hardening; the area  
21 under the curve as well as the maximum force increased dramatically (Table 3) and there was no  
22 difference between the texture of the paste and that of the crust. The curve of the S cookies had a  
23 flat profile, indicating that the applied force was the same throughout the whole thickness of the  
24 “Amaretti”. This means that the moisture redistribution continued, leading to a structural change

1 of the crust. In the cookies with added fibre, there was only a slight hardening of the internal  
2 paste. On the sixth day of analysis (Fig. 7) the hardening also began to affect S; the moisture loss  
3 exceeded the moisture redistribution between the components. The original difference in texture  
4 between paste and crust was observed in F, where the effect of the fibre was very noticeable (it  
5 should be noted that the water binding capacity of the fibre used in this work was 8.7 g/g fibre).  
6 However, these “Amaretti” were harder than those analysed in the previous time period as can be  
7 deduced by observing the value of the area under the curve (Table 3). On the last day (Fig. 8), it is  
8 interesting to observe that only the T “Amaretti” broke into pieces during the test, due to the  
9 porous structure previously occupied by water. In contrast, the other two recipes did not break  
10 apart because water was still present in the matrix. The different textures between paste and crust  
11 were still evident in both S and F. The overall hardness was higher in F (value of maximum force  
12 under the curve), whereas the crust of S was stiff but not as hard as can be seen from the  
13 maximum force values (Table 3).

14

## 15 **Colour measurement**

16 The results of the colour analysis are reported in Table 4. Regarding the *CIE L\*a\*b\** parameters  
17 for S “Amaretti”, the *a\** parameter value was the highest indicating a hue of redness/brownness.  
18 At the same time they had the lowest *L\** value, indicating a greater overall darkness of these  
19 cookies. This was due to the Maillard reaction, that proceeded more intensely in S due to a higher  
20 amount of reducing sugar. The values of the *CIE L\*a\*b\** parameters for F exhibited the highest  
21 *L\** value and the lowest *a\** and *b\** values, indicating an overall lighter colour and less brownness in  
22 the cookies.

23

## 24 **Sensory evaluation**



1 The panellists who took part in the sensory evaluation had the task of detecting any changes in the  
2 texture that occurred in the “Amaretti” during the storage time (ten days). In particular, four  
3 parameters that can be well described by the human senses were taken into consideration. The  
4 parameters correlated to the senses of odour and flavour were not taken into account, but only  
5 those related to the texture evaluation. Resilience (Fig. 9), was considered as the tendency of the  
6 crust to return to its original shape after the removal of a stress (the slight pressure of the index  
7 finger in this case) that produced elastic strain. In this case, the panellists confirmed the results  
8 previously obtained with the puncture test. In the first few days after baking, this attribute was  
9 perceived more clearly in the S “Amaretti” than the F ones. The former underwent a water  
10 redistribution between the paste and crust that led to a soggy, elastic crust; the panellists perceived  
11 this sensation up to the sixth day of storage, after which there was moisture loss from the external  
12 crust to the surroundings. In T, a low resilience was perceived in the first days, which disappeared  
13 after three days due to a quick hardening of the crust. As regards the external crispness (Fig. 10),  
14 the lowest scores were given to S because the crust began to pick up water, became less crisp  
15 (particularly evident on the third day of analysis). This led to quality decay of the “Amaretti”, in  
16 which crispiness is an essential characteristic that influences consumer acceptance. This parameter  
17 was perceived later in T and F, where the moisture redistribution was less intense than in S. On the  
18 last day of analysis, the external crispiness scores were lower than the initial days for all three lots,  
19 because of the hardening of the crust due to the loss of moisture into the surrounding  
20 environment. With regard to internal stickiness (Fig. 11), the panellists perceived S to be stickier  
21 than the other two lots. This was certainly due to the addition of glucose syrup; its thickness was  
22 perceived as sticky by the panellists. While this ingredient reduced moisture migration from the  
23 internal paste, it also affected the original texture of the final product. With regard to fibre  
24 perception (Fig. 12), the panellists were not able to distinguish the presence of fibre among the

1 different lots of “Amaretti”. This result is very important because it indicates that the addition of  
2 the fibre did not cause a change in the original mouthfeel of the internal paste of the cookies.

3

## 4 **Conclusions**

5 Two different ingredients were tested in the traditional recipe of “Amaretti” cookies. Glucose  
6 syrup and bamboo fibre, with known water binding properties, acted differently on the product.  
7 Although the glucose syrup obviously reduced moisture loss during the ten days of storage, it  
8 caused some modifications of the original characteristics of this regional product. The use of  
9 glucose seemed to promote water redistribution between the components of the matrix and hence  
10 sugar crystallization, which softened the crust during the first 3-4 days of storage, as pointed out  
11 by sensory analysis and the textural test. The textural analysis, showed that the crust lost its  
12 crispness, probably due to water migration from the paste to the crust (due to the  $a_w$  gradient) and  
13 from the protein to the large amount of hygroscopic sugar in the amorphous form (water  
14 redistribution). In contrast, the fibre had a positive water-holding effect which limited sugar  
15 crystallisation (the discontinuity of the sorption isotherm obtained from F “Amaretti” was less  
16 pronounced than in the other two recipes). Finally, the large amount of sugar caused a more  
17 intense Maillard reaction, as shown by the colour analysis. The added fibre promoted water  
18 retention in the matrix for a longer time than the traditional recipe which helped maintain the  
19 textural differences between crust and paste. Only a small difference in colour was detected; this  
20 could be easily compensated with a small change in the time-temperature conditions during  
21 baking. The addition of these ingredients could help control moisture loss (and consequently  
22 extend the shelf-life) in high and intermediate-moisture foods. In order to get the best results, the  
23 addition of glucose and fibre should be combined with others aspects such as finding a suitable

1 packaging solution and/or applying an edible layer between the crust and paste. Finally,  
2 experiments should be designed specifically to obtain a new optimised recipe with the best  
3 combination of factors, that would provide a partial standardization of traditional food  
4 manufacturing and extend their shelf life, while maintaining as many of the original characteristics  
5 of these typical cookies as possible.

6  
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1 **Legends to Tables**

2

3 Table 1 - Moisture content (%) and  $a_w$  values of the three different recipes of freshly baked “Amaretti”.

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5 Table 2 - Sorption isotherm data obtained for the three different recipes.

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7 Table 3 - Mean values of the three parameters arising from texture analysis of freshly baked and after storage “Amaretti”.

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9 Table 4 - *CIE L\*a\*b\** parameters for the three different recipes.

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## 1 **Legends to Figures**

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3 Fig. 1 - Section of a typical “Amaretti” cookie (left) and its section (right).

4 Fig. 2 - Change of moisture content (%) and  $a_w$  in the three different recipes of “Amaretti” stored at  $25 \pm 0.5$  °C and  $40 \pm 2$  %  
5 RH.

6 Fig. 3 - Experimental sorption isotherm curves for the three different recipes.

7 Fig. 4 - Three mean curves of freshly baked “Amaretti”.

8 Fig. 5 - Three mean curves of “Amaretti” after 2 days of storage.

9 Fig. 6 - Three mean curves of “Amaretti” after 4 days of storage.

10 Fig. 7 - Three mean curves of “Amaretti” after 6 days of storage.

11 Fig. 8 - Three mean curves of “Amaretti” after 10 days of storage. The “breaking-point” for the traditional formulation is well  
12 evident .

13 Fig. 9 - Sensorial analysis: resilience evolution during 10 days of storage.

14 Fig. 10 - Sensorial analysis: external crispness evolution during 10 days of storage.

15 Fig. 11 - Sensorial analysis: internal stickiness evolution during 10 days of storage.

16 Fig. 12 - Sensorial analysis: fibre perception evolution during 10 days of storage.

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## Figures

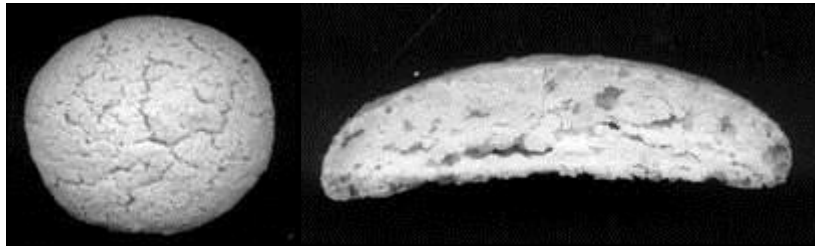


Fig. 1 - Section of a Typical "Amaretti" cookie (left) and its section (right).

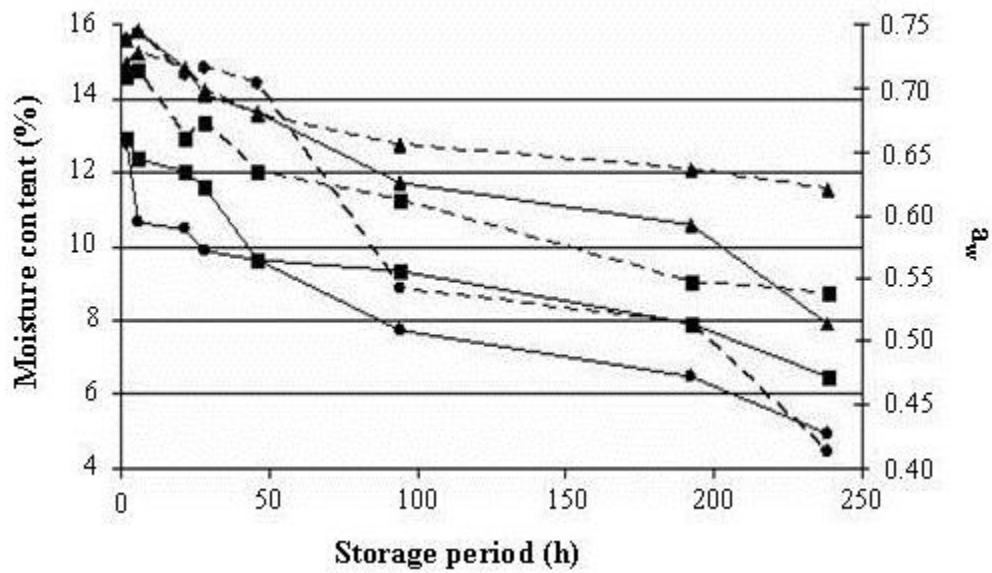


Fig. 2 - Change of moisture content (%) and  $a_w$  of paste in the three different recipes of "Amaretti". Data are the means of three determinations.

Legend: - - - -  $a_w$  ——— moisture content (%)

● T ▲ S ■ F



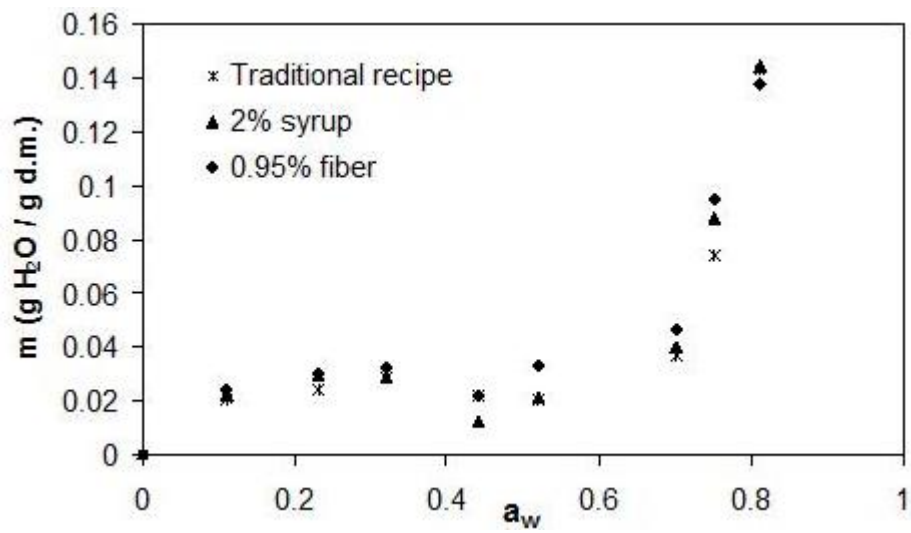


Fig. 3 - Experimental sorption isotherm curves for the three different recipes.

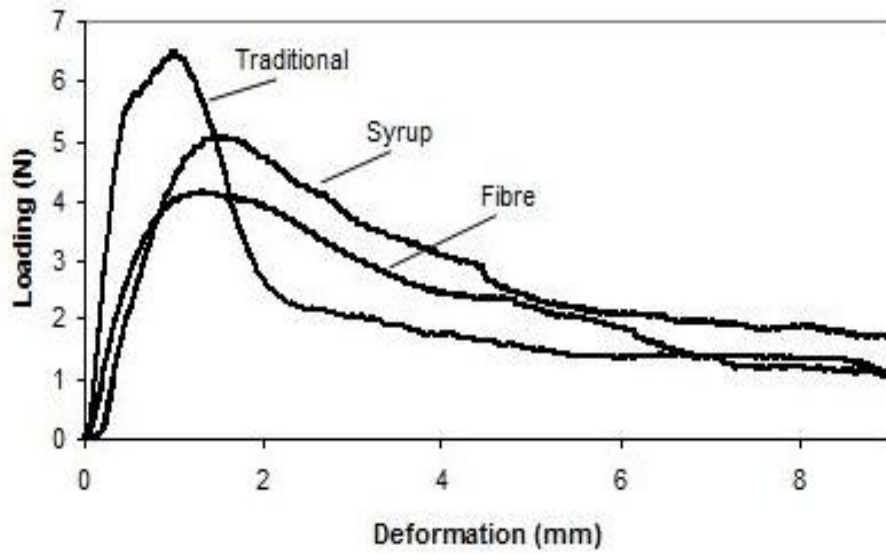


Fig. 4 - Three mean deformation curves of freshly baked "Amaretti".

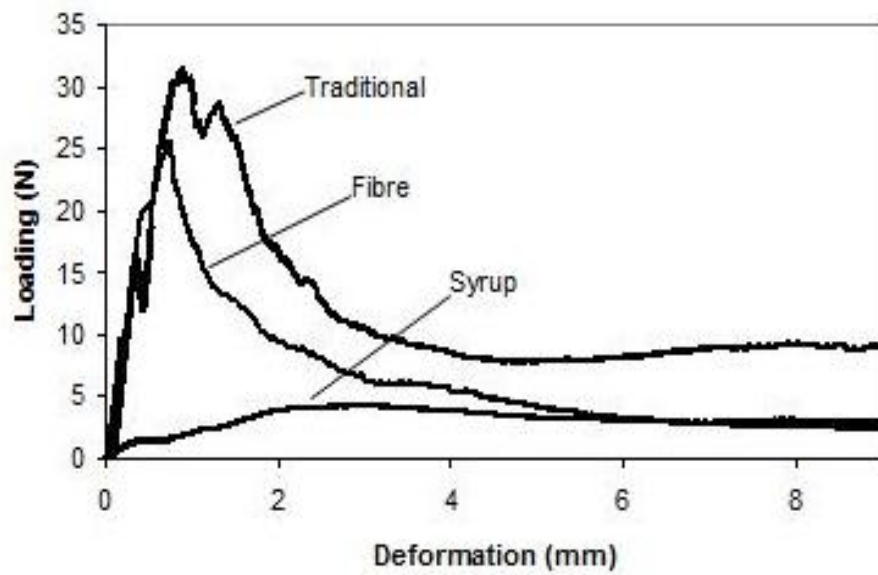


Fig. 5 - Three mean deformation curves of "Amaretti" after 2 days of storage.

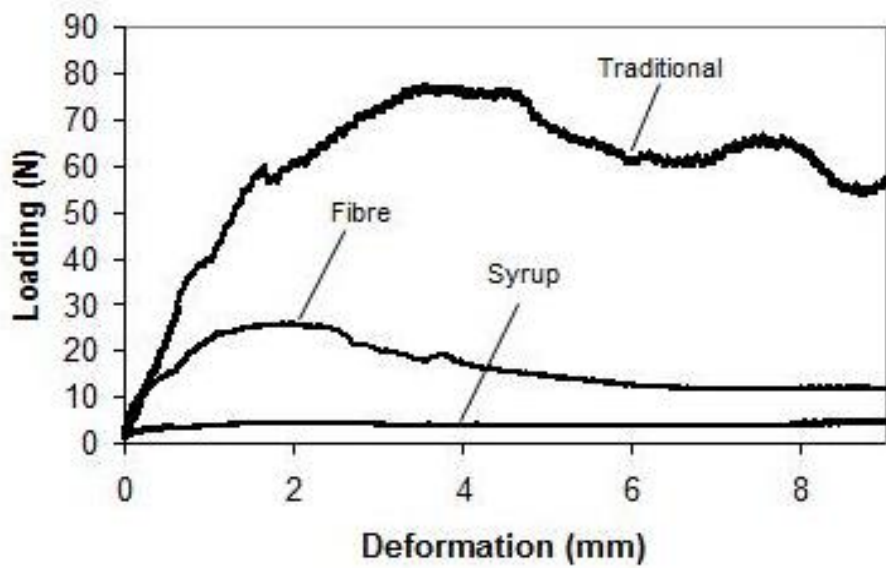


Fig. 6 - Three mean deformation curves of "Amaretti" after 4 days of storage.

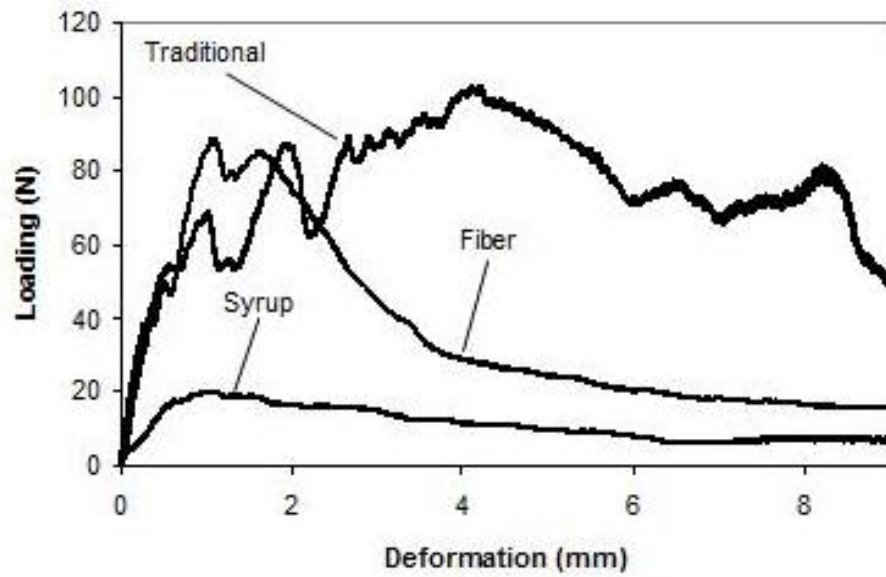


Fig. 7 - Three mean deformation curves of "Amaretti after 6 days of storage.

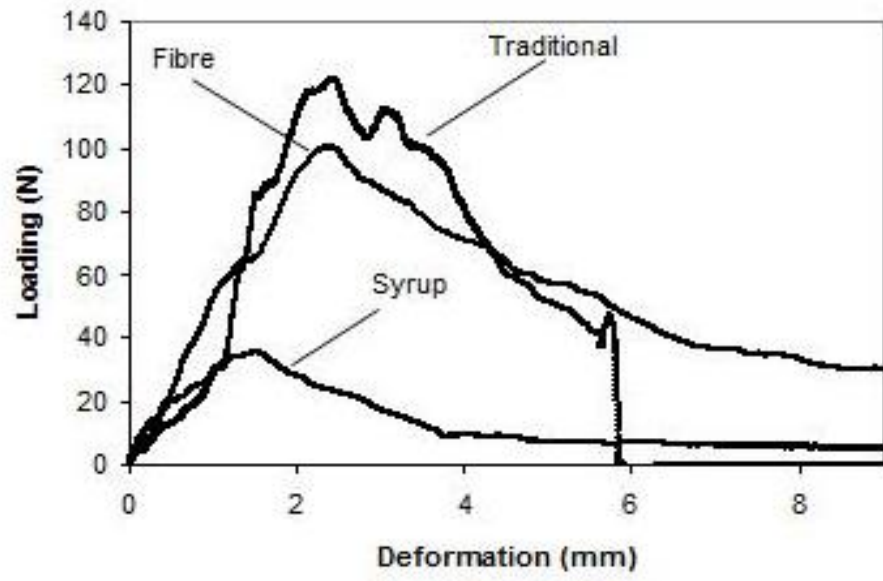


Fig. 8 - Three mean deformation curves of "Amaretti" after 10 days of storage. The "rupture-point" for the traditional formulation is well evident.

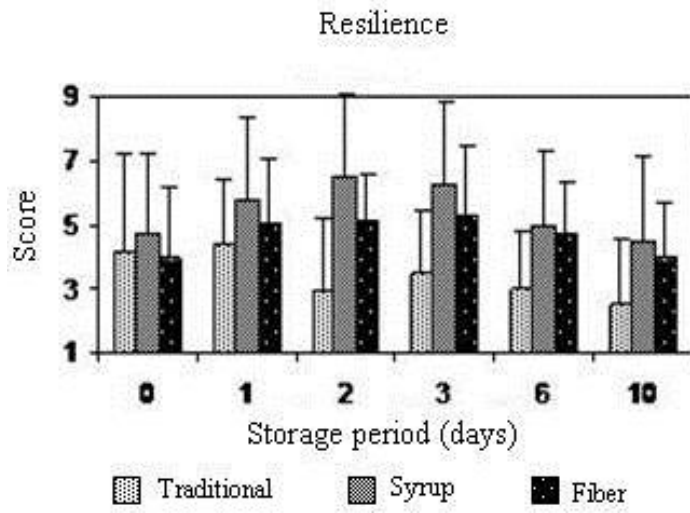


Fig. 9 - Sensorial analysis: resilience evolution during 10 days of storage.

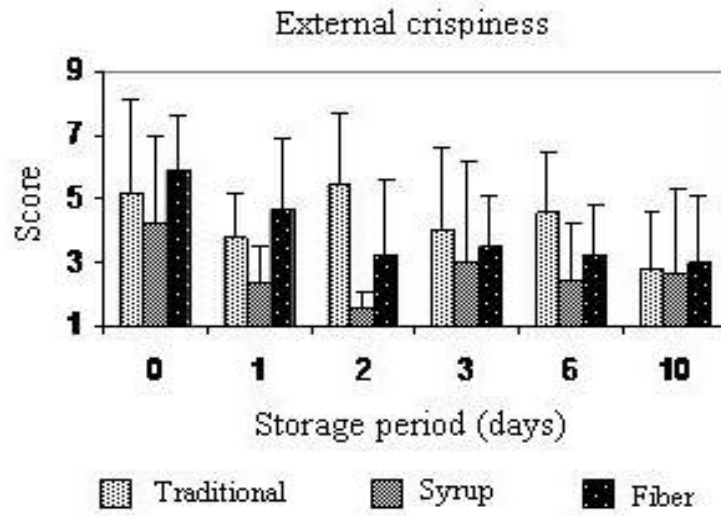


Fig. 10 - Sensorial analysis: external crispiness evolution during 10 days of storage.



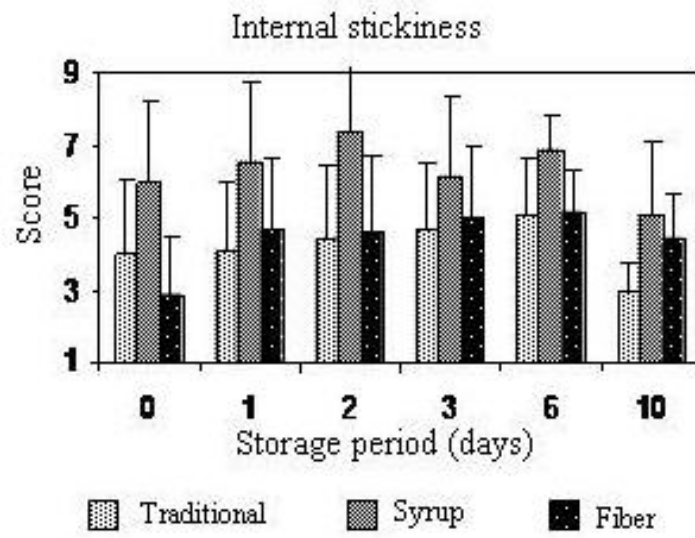


Fig. 11 - Sensorial analysis: internal stickiness evolution during 10 days of storage.

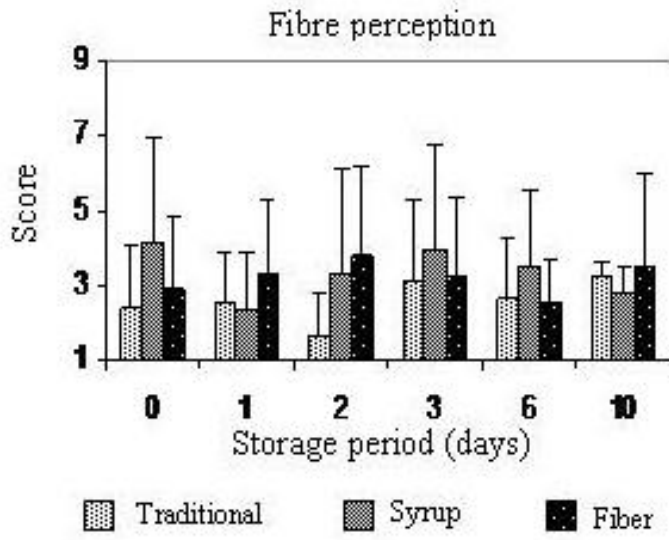


Fig. 12 - Sensorial analysis: fibre perception evolution during 10 days of storage.

## Tables

Table 1 - Moisture content (%) and  $a_w$  values of the three different recipes of freshly baked "Amaretti"

Moisture content (%)	Traditional		Syrup		Fibre	
	Paste	Paste + crust	Paste	Paste + crust	Paste	Paste + crust
	12.82 <sup>a</sup> (±1.36)	7.56 <sup>c</sup> (±1.09)	15.61 <sup>b</sup> (±1.18)	8.81 <sup>c</sup> (±1.45)	12.90 <sup>a</sup> (±0.94)	8.22 <sup>c</sup> (±1.62)
$a_w$	0.74 <sup>d</sup> (±0.025)	0.57 <sup>f</sup> (±0.011)	0.72 <sup>d</sup> (±0.013)	0.55 <sup>f</sup> (±0.020)	0.70 <sup>e</sup> (±0.025)	0.54 <sup>f</sup> (±0.018)

Standard deviation is reported in brackets.

Different letters denote statistically significant differences ( $P \leq 0.05$ ) among recipes for each moisture content and  $a_w$  value (internal paste and paste + crust).

Table 2 – Sorption isotherm data obtained for the three different recipes.

<i>Recipe</i> \ $a_w$	0.11	0.23	0.32	0.44	0.52	0.70	0.75	0.81
<i>Traditional</i>	0.020493 <sup>a</sup> (±0.00387)	0.024408 <sup>a</sup> (±0.00099)	0.029104 <sup>a</sup> (±0.00348)	0.022151 <sup>a</sup> (±0.00479)	0.020516 <sup>a</sup> (±0.00159)	0.036925 <sup>a</sup> (±0.00564)	0.074292 <sup>a</sup> (±0.00280)	0.142684 <sup>a</sup> (±0.00646)
<i>Syrup</i>	0.022206 <sup>a</sup> (±0.00636)	0.02942 <sup>a</sup> (±0.00925)	0.029039 <sup>a</sup> (± 0.00291)	0.012856 <sup>b</sup> (± 0.00303)	0.021116 <sup>a</sup> (±0.00574)	0.040126 <sup>ab</sup> (±0.00303)	0.087975 <sup>b</sup> (±0.00795)	0.144599 <sup>a</sup> (±0.00795)
<i>Fibre</i>	0.024278 <sup>a</sup> (±0.00452)	0.030402 <sup>a</sup> (±0.00579)	0.032457 <sup>a</sup> (±0.00290)	0.022109 <sup>a</sup> (±0.00116)	0.032976 <sup>b</sup> (±0.00484)	0.046681 <sup>b</sup> (±0.00518)	0.094931 <sup>b</sup> (±0.00331)	0.137724 <sup>a</sup> (±0.01639)

Standard deviation is reported in brackets.

Different letters indicate statistically significant differences ( $P \leq 0.05$ ) among recipes for each  $a_w$  value.

Table 3 – Mean values of the three parameters arising from texture analysis of “Amaretti” freshly baked and after storage.

Days of aging	E <sub>mod</sub> (Nmm <sup>-1</sup> )			F <sub>max</sub> (N)			W <sub>tot</sub> (Nmm)		
	Traditional	Syrup	Fibre	Traditional	Syrup	Fibre	Traditional	Syrup	Fibre
	<i>X (±s.d.)</i>	<i>X (±s.d.)</i>	<i>X (±s.d.)</i>	<i>X (±s.d.)</i>	<i>X (±s.d.)</i>	<i>X (±s.d.)</i>	<i>X (±s.d.)</i>	<i>X (±s.d.)</i>	<i>X (±s.d.)</i>
0	21.54 <sup>a</sup> (±6.35)	7.85 <sup>fn</sup> (±1.15)	8.98 <sup>in</sup> (±2.89)	6.01 <sup>a</sup> (±0.70)	5.18 <sup>f</sup> (±0.35)	4.49 <sup>i</sup> (±0.28)	17.18 <sup>an</sup> (±2.88)	21.60 <sup>d</sup> (±3.34)	18.41 <sup>gn</sup> (±2.60)
2	97.96 <sup>abo</sup> (±46.18)	4.94 <sup>f</sup> (±2.01)	122.74 <sup>io</sup> (±21.10)	42.90 <sup>b</sup> (±11.07)	4.20 <sup>f</sup> (±0.52)	25.46 <sup>l</sup> (±2.34)	94.74 <sup>a</sup> (±19.13)	26.32 <sup>d</sup> (±3.49)	62.19 <sup>h</sup> (±10.87)
4	202.83 <sup>bc</sup> (±151.61)	8.42 <sup>fp</sup> (±2.34)	33.22 <sup>lp</sup> (±8.72)	80.19 <sup>c</sup> (±10.76)	5.22 <sup>f</sup> (±1.14)	25.12 <sup>l</sup> (±3.32)	445.07 <sup>b</sup> (±91.01)	32.75 <sup>d</sup> (±5.08)	132.05 <sup>i</sup> (±22.34)
6	283.10 <sup>cd</sup> (±160.14)	33.22 <sup>sq</sup> (±6.65)	226.28 <sup>lq</sup> (±28.83)	121.01 <sup>d</sup> (±20.06)	22.29 <sup>g</sup> (±2.60)	86.16 <sup>m</sup> (±6.03)	666.48 <sup>c</sup> (±133.00)	98.05 <sup>e</sup> (±14.80)	286.58 <sup>l</sup> (±47.91)
10	368.47 <sup>de</sup> (±207.33)	90.32 <sup>hr</sup> (±51.75)	136.45 <sup>mr</sup> (±76.73)	139.89 <sup>e</sup> (±28.88)	39.82 <sup>h</sup> (±11.10)	100.27 <sup>n</sup> (±8.33)	606.53 <sup>c</sup> (±157.8)	131.86 <sup>f</sup> (±36.03)	499.09 <sup>m</sup> (±68.09)

Standard deviation is reported in brackets.

Different letters indicate statistically significant differences ( $P \leq 0.05$ ) within formulation and among recipes for each texture index.

Table 4 - *CIE L\*a\*b\** parameters for the three different recipes.

<i>CIE L*a*b*</i> parameters	Traditional	Syrup	Fibre
<i>L*</i>	+73.72 ( $\pm 1.30$ ) <sup>c</sup>	+53.08 ( $\pm 2.32$ ) <sup>d</sup>	+78.35 ( $\pm 0.7$ ) <sup>e</sup>
<i>a*</i>	+5.05 ( $\pm 0.13$ ) <sup>f</sup>	+15.54 ( $\pm 0.50$ ) <sup>g</sup>	+2.79 ( $\pm 0.01$ ) <sup>h</sup>
<i>b*</i>	+27.28 ( $\pm 0.58$ ) <sup>i</sup>	+26.85 ( $\pm 2.29$ ) <sup>i</sup>	+23.49 ( $\pm 0.3$ ) <sup>l</sup>

Standard deviation is reported in brackets.

Different letters indicate statistically significant differences ( $P \leq 0.05$ ) among recipes for each *CIE L\*a\*b\** parameters.