Studies on effect of oat and cheese incorporation on sensory and textural quality of short-dough type biscuit

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Abstract In view of their growing importance in human nutrition, incorporation of oats and cheese during the manufacture of short-dough type biscuits was studied. Rolled oats were incorporated at 25, 35 and 45 % of refined wheat flour in short-dough type biscuit formulation. Cheddar and processed cheese were used for flavouring purpose at three levels each, viz. 30, 40 and 50 % on flour basis. The dough exhibited less firmness on oats incorporation as indicated by lower firmness value (21.73 N) as against 25.05 N for control dough measured by Texture Analyser. Addition of cheese to the 25 % oat incorporated dough further reduced its firmness and altered its viscoelastic characteristics. Baking conditions for the oats and cheese incorporated biscuits were optimized as 165 °C for 25–27 min. Sensory evaluation results revealed that the biscuit made from 25 % oat incorporated dough scored highest in most of the sensory attributes including overall acceptability. Cheddar cheese and processed cheese levels were optimized at 30 and 40 % in oats-incorporated dough based on the sensory analysis of biscuits prepared from the dough samples. The moisture and β -glucan contents were 3.93 % and 0.62 %; 4.32 % and 0.60 % for cheddar cheese and processed cheese added biscuits, respectively. The spread ratios were higher in cheese incorporated biscuits than in oat incorporated biscuits. It was concluded that good quality cheese flavoured biscuits can be prepared by incorporating

rolled oats in biscuit formulation along with cheddar or processed cheese.

Keywords Biscuit · Oat · Cheddar cheese · Processed cheese · Hardness · Sensory quality

Introduction

Bakery products – part and parcel of today's foods - are used as carriers of different nutritionally rich ingredients for their diversification. Several health products in bakery section made in such manner are being made available for consumers. Among all the bakery products, biscuits are a popular food-stuff, consumed by a wide range of populations due to their varied taste, ready to eat nature, good nutritional quality, long shelf life and relatively low cost. The biscuit industry in India witnessed annual growth rate of 16 % during the 2008–09 which declined to 11 % during 2009–12. According to the data available, the organized biscuit production increased from 11.00 lakh tonnes in 2003–04 to 20.50 lakh tonnes in 2011–12 (IBMA 2013). The per capita consumption of biscuits in the country is 1.8 kg, as compared to 2.5 kg to 5.5 kg in South East Asian and European countries and 7.5 kg in the USA (IBMA 2013). Because of competition in the market and increased demand for healthy, natural and functional foods, attempts are being made to improve biscuits' nutritive value and functionality. Such value addition is being achieved by increasing the ratios of whole grain raw materials other than wheat or different types of dietary fibre in basic recipes with an attempt to enhance biscuit's protein content and quality, mineral and fibre contents. Of all cereals, oats are being projected as nutritionally much beneficial, but received little attention up till now. Owing to the health benefits of oats, they

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are being incorporated into variety of products like oatcakes, oatmeal cookies, oat muffins and oat bread (McMullen 2000).

Cheese and cheese products are versatile foods that can be incorporated as ingredients or as flavouring substances in the bakery and snacks industries. Cheese confers several nutritional benefits. In particular, it is a good source of fat and protein in easily digestible form and rich source of calcium and vitamins A, B₂ and B₁₂ and minerals. It is also a useful source of highly bioavailable zinc (Buttriss 2003; Hemantbhai 2010). Cheese is used in baked products such as biscuits, pizza, pasta, cheesecake, filled in crackers, bread, sandwich etc. but published literature pertaining to this is very less. From the foregoing description, it may be understood that biscuits containing cheese and oats will be healthier than plain biscuits and they would appeal to all age groups of people. Therefore, this work was taken to develop cheese and oat incorporated / flavoured biscuits.

Materials and methods

Materials

Refined wheat flour, icing sugar and salt (procured from local market), shortening (BESS Brand aerated bakery shortening, KOG-KVT Food Products (India) Pvt. Ltd., Tuticornin, India), oats (Quaker oats), soy lecithin liquid [Trump Crown (India) Pvt. Ltd.], Cheddar (about 4 month ripened) and processed cheese (cheddar cheese of different ripening periods including green cheese prepared at Institute Experimental Dairy), milk powder (Nandini Brand spray dried skim milk powder), glycerol monostearate (Victory Essence Mart, Bangalore, India), and metalized polystyrene packaging material- 61.5 micron thickness (Innoflex Laminators Pvt. Ltd. Bangalore, India) were used in the study.

Method of biscuits preparation

The ingredients and their proportions were (gm): refined wheat flour 100, salt 1.5, milk powder 4, icing sugar 20, fat 50, lecithin 0.25, glyceryl monostearate (GMS) 0.5 and water 15 mL. Rolled oats were ground into a fine powder and used in biscuit formulation at 25, 35 and 45 % levels. Short dough method was followed for biscuit preparation (Manley 2000).

Creaming/ dough preparation Dry ingredients such as refined wheat flour, oats flour, salt and milk powder were sieved before use. Cheese was made into a paste in a dry mixer. Creaming of shortening was done for 5 min, lecithin and GMS were added and mixed well. The icing sugar was added and the cream mixed for 3 min, then the sieved dry ingredients were added and mixed well for further 3 min. This was followed by addition of cheese paste and mixing for additional

3 min. Then using required amount of potable water, dough was made and kneaded to get desired consistency in 6–7 min.

Sheeting The dough was sheeted to a thickness of about 4 mm with a roller.

Cutting The dough sheet was cut into circular shapes with the biscuit mould of 40 mm diameter and the shaped dough pieces were transferred into an aluminium tray for baking.

Baking Baking was done at 165 °C for 25 min in a baking oven (M/s Dolar Equipment Pvt Ltd., Bangalore). The biscuits after baking were slowly cooled to room temperature. For optimization of baking temperature, various temperature – time combinations were tried as shown in Table 2.

Packing The cooled biscuits were packed in metalized polyester pouches and stored until further analysis.

Effect of incorporation of oat on dough texture and biscuit quality

The rolled oat powder was used to replace refined wheat flour in the formulation at three levels as follows: Refined wheat flour : oat=75:25; 65:35 and 55:45 parts. The textural properties of dough and sensory quality of biscuits prepared were evaluated, based on which oat level was optimized for further study.

Effect of incorporation of cheese on dough texture and biscuit quality

Cheddar cheese and processed cheese was separately incorporated in dough formulation containing optimized level of oat. The cheese levels used were: 0, 30, 40 and 50 g per 100 g flour (Flour=Refined wheat flour+optimized oat). The textural properties of dough and sensory quality of biscuits prepared were evaluated, based on which optimum levels of cheddar cheese and processed cheese were recommended.

Optimisation of baking conditions

Commercial baking temperatures vary from 165 to 280 °C for biscuit making (Manley 2000), but for cheese incorporated biscuit these conditions may slightly alter. Therefore baking time-temperature combination for oat and cheese incorporated biscuits has been optimized by studying four different temperatures with different time intervals (Table 1). At each time interval, six biscuits from the baking oven were drawn and surface reflectance (%) was measured by reflectancemeter. The lower the per cent reflectance value, the darker is the biscuit surface and vice versa. Since colour of the biscuits

Table 1 Time-temperature combinations studied for optimization

Temperature (°C)	Time (min)
135	34, 36, 38, 40, 42, 44, 46
145	30, 35, 37, 39, 40, 41, 42
155	25, 27, 29, 30, 31, 33, 35, 37
165	20, 23, 25, 26, 27, 29, 30

may vary significantly at the end stages, even by one minute interval, samples were drawn at appropriate time intervals.

Storage study

The biscuits made from the dough containing optimized levels of oat and cheddar / processed cheese were packed in metalized polyester and stored at 30 °C to study the effect of the storage on the quality of the biscuits. Various changes taking place in biscuits were assessed by the following parameters: sensory attributes, surface colour and instrumental hardness.

Analyses

Textural properties of dough

Dough tempered to 30 °C was shaped into 2×2×2 cm cubes and its texture profile characteristics (hardness and gumminess) were determined by Texture Analyser (A TA.XT plus - Stable Micro System, England) employing two bite test and 50 % compression of sample as per the method of Bourme (1978). Viscoelastic properties namely stress relaxation time and modulus of elasticity at a constant compression by 25 % of sample height were determined by the method described by Rao and Steffe (1992) and Dwarakanath et al. (2013). In both the analyses, p/75 probe was used.

Subjective analysis of biscuits (sensory evaluation)

Biscuits at ambient temperature were served to a panel of ten judges who were asked to evaluate the biscuits for the sensory parameters, namely, colour and appearance, flavour, body and texture and overall acceptance, on a 9- point hedonic scale based on their liking. A score of 9 on the scale indicated 'like extremely' and a score of 1 indicated 'dislike extremely' (Amerine et al. 1965). The sensory evaluation trials were conducted in the sensory evaluation room of the Institute.

Reflectance

Reflectance, expressed in percentage, is a measure of the intensity of light reflected from a sample surface when a light of known intensity was incident on it. A value of 100 % indicates white surface which reflects entire light falling on it. Any

value less than 100 indicates a darker sample surface. So, the lower the reflectance value, the darker is the product irrespective of the colour of the sample. The reflectance of the biscuit surface was measured by Reflectancemeter (Elico Co., Hyderabad). The reading on the scale of the Reflectancemeter was adjusted to zero value using a standard black plate under white mode. Then 100 % reflectance reading on the scale was adjusted using a standard white plate. The biscuit sample was directly placed under the lamp of the reflectancemeter and the percent reflectance as shown by the pointer was recorded. Readings were taken at 4–5 places on the surface of biscuit and expressed as average per cent reflectance.

Surface colour

The colour of samples was measured by the method described by Vyawahare and Rao (2011). The sample of biscuits was placed on the bed of the scanner (HP, Scanjet 5370C) and was covered by scanner top. Scanning of the sample was performed under the following scanner parameters: resolution: 75 dpi, sharpness: medium; image quality: medium; background of the sample: white. The image was saved as JPEG file. Colour analysis software namely Adobe Photoshop Version 7.0 compliant with the Microsoft Windows XP environment was used to extract and analyze colour parameters from the scanned image. The scanned image in JPEG format was opened with Adobe Photoshop with elliptical marquee tool (m); style- fixed size; width-3.5 cm; height- 3.5 cm and the following parameters were measured in RGB mode: Lightness (L), red (R), green (G) and blue (B).

Instrumental hardness of biscuits

Hardness of biscuits was measured using Texture Analyser employing Warner Bratzler blade and Slotted Insert (HDP/BS) module with the following settings: test speed: 2 mm/s, distance: 5 mm, and data acquisition rate : 400pps. The biscuit sample was approximately 40±3 mm in width and 6±0.3 mm in thickness. The sample was positioned centrally over the Slotted Insert and the computer was allowed to execute the program by activating 'Run a test' option. The knife penetrated into the biscuit through the slot till the biscuit fractured into two major pieces generating a force-time graph on the monitor. The maximum force reading (i.e. highest peak) on the graph was recorded as hardness of biscuit.

Chemical composition

The biscuits were ground in a mixer into a fine powder, which was used for estimating various chemical parameters: Moisture (AOAC 2012, 925.10 by air oven method), Crude fat (Soxhlet method) (AOAC 2012, No. 2003.06), total protein [standard Micro Kjeldahl method, BIS 1981 using Kjel

plus digestion & distillation assembly (Di SWI-M, KPS-006R, Pelican Instruments, Chennai)] and total ash and acid insoluble ash (AOAC 2012, 923.03 by Direct method). Total carbohydrates were determined by the difference method, free fatty acid (Deeth et al. 1975), Beta- glucan of biscuits was estimated by using McCLEARY method using beta-glucan estimation kit (Megazyme International Ireland Ltd., Marketed by: Pro Lab Marketing Pvt. Ltd. New Delhi, India).

Physical characteristics

Thickness (T) and diameter (D) of moulded dough and biscuits were measured using a mm-scale. Weight (W) of biscuits was measured using a digital weighing balance (0.1 g accuracy) (Spark Brand, Bangalore). Spread ratio of biscuits was measured by the ratio of weight to thickness (W/T) of the biscuits (Sudha et al. 2007).

Water activity was determined using water activity meter (Rotronic Hygroskop, BT-RS1 Ag Switzerland) as follows: The instrument was allowed 15 min warm up time before starting the measurements. The powdered biscuit sample was filled in the plastic dish provided by the instrument manufacturer up to half mark and placed in the dish holder. The sensor probe assembly was kept over the dish holder and the fan button was put on to hasten the equilibration process. Water activity, which is the function of change in capacitance of the sensor to change in equilibrium humidity surrounding biscuit sample, was directly read on the monitor.

Statistical analysis of results

Data obtained during the present project work were subjected to one way ANOVA by SPSS package (15.0 Windows Evaluation Version).

Results and discussion

Effect of incorporation of oats on dough quality

Rolled oats ground into a fine powder were incorporated at 25, 35 and 45 % levels. On incorporation of oats in the dough at 25 %, firmness of the dough decreased from 25.05 to 21.73 N indicating that the dough became softer, but higher levels of oats did not much change the firmness (Fig. 1a). The dough also became less adhesive as shown by the trend of gumminess figures (Fig. 1a). When refined wheat flour is mixed with water and kneaded, the starch in it absorbs water and swells becoming sticky and very cohesive. The dough formation takes place by water absorption aided by gluten development (Manley 2000). The decrease in firmness by oats incorporation may be attributed to the interaction between polysaccharides and proteins from wheat flour as reported by Jones and

Erlander (1967). Use of Farinograph might give better picture of influence of oats on dough quality, however in the present study Texture Analyser was used which also yielded satisfactory results. Sudha et al. (2007) observed that dough strength decreased significantly from 8.5 to 4 and 7.0 to 3.5 min in the case of dough incorporated with oat and barley. Their results showed weakening of the dough with the increasing level of bran. The resistance to extension values also gradually decreased for blends with increasing levels of oat and barley. The development time, i.e. the time required to reach 500 FU in farinograph, increased considerably for doughs containing oat bran, which needed three times longer time to develop than the control. Oat bran gave the most stable dough, followed by wheat bran and thereafter fine durum and rye bran (Purhagen et al. 2012). The decrease in dough resistance and dough extensibility was attributed to the effects of gluten dilution, water retention and higher levels of fat (Salehifar and Shahedi 2007). Similar observations were made in the present study.

Stress relaxation time (t_r) for the 0 % oats was 0.402 s. As shown in the Fig. 1b, as oats level increased stress relaxation time and modulus of elasticity of dough also increased. Stress relaxation time is defined as the time required for the stress to be relaxed to a value equal to 36.7 % of the stress applied on sample, in a stress relaxation test. Modulus of elasticity is the value equal to the value of stress/strain. Since modulus of elasticity represents that elastic character (Patel and Rao 2012), it can be inferred that solid character of the dough also increased. This was corroborated by longer stress relaxation times.

Effect of incorporation of oats level on biscuits quality

The upper limit of oats incorporation was determined by preliminary trials in which it was observed that beyond 45 % level of incorporation it was difficult to prepare optimum quality dough because of very less cohesive nature of the dough. Hence, the oats incorporation was restricted to 25–45 % level for study of effect on biscuits. The colour and appearance score for control biscuits was 8.05, and with 25 % and 35 % oats it was 8.02 and 7.70 respectively, while the score for biscuits with 45 % oats decreased to 7.44, which was statistically less than that of control but same as 35 % oat biscuits (Table 2). The biscuits with incorporated oats were slightly darker, similar observation being made by Sudha et al. (2007) in case of biscuits made by incorporation of oat bran, but use of barley bran resulted in marginal variation. They reported whiteness values of 17.12, 20.26, 14.16, 13.85 and 11.99 % for oats incorporation levels of 0, 10, 20, 30 and 40 % in biscuits.

A similar trend was observed in flavour scores. The control biscuits possessed mild, normal biscuit flavor with a flavor score of 7.43. The score improved to 7.82 with 25 % oats incorporation because of pleasantness of the oats flavor. However, this score reduced to 7.70 and 7.34 with 35 and

Fig. 1 Effect of oats incorporation on the rheological characteristics of biscuit-dough (a) hardness and gumminess (b) Modulus of elasticity (primary vertical axis) and stress relaxation time (secondary vertical axis)

45 % oats attributable to increased cooked flavor and dry mouthfeel. These changes are ascribed to oats incorporation. Salehifar and Shahedi (2007) reported that heat induced reactions of precursors in oat groats are responsible for the development of oat flavour during its processing into commercial food products.

The body and texture score for biscuits with 0 % oats was 7.90 which almost remained the same with 25 % oats incorporation. However further increase in oats content reduced the scores because the biscuit became harder. The scores were 7.28 and 7.08 for the biscuits prepared with 35 and 45 % oats incorporation, respectively. In a similar study, Sudha et al. (2007) recorded that 30 % oats bran incorporation was acceptable in biscuits. Peymanpour et al. (2012) suggested use of up to 10–30 % of oat flour in the bread production. Overall acceptance scores of control, 25, 35 and 45 % oats level biscuits in the present study were 8.00, 7.90, 7.32 and 7.27, respectively (Table 2). Increasing oats level decreased the overall acceptance score but the decrease in score was significant only at higher than 25 % oats incorporation. The effect of oats was found to be statistically significant ($P < 0.05$).

Effect of incorporation of cheese on dough quality

Cheddar cheese or processed cheese was added to biscuit formulation at 20, 30 and 40 g per 100 g flour (75 g refined wheat

flour +25 g oat) and the effect on dough quality studied. Cheddar cheese is a ripened cheese which being a viscoelastic material displays both solid (elastic) as well as viscous characters (flow) (Gunasekaran and Ak 2003). Hence, its incorporation in dough may have profound impact on the quality of dough and change in viscoelastic characteristics. On cheese incorporation, the firmness of the dough drastically reduced from 21.73 N in control to 9.6 N in 30 % cheese added dough (Fig. 2a). Further increase in cheese level decreased firmness, but only marginally. It showed that addition of ripened cheese softened the dough. However, the gumminess showed decreasing trend with increase in cheese level.

With regard to viscoelastic characteristics, the cheese addition decreased the stress relaxation time from 0.422 to 0.364 s when cheese was incorporated at 30 % level. With increase in the cheese level from 30 to 50 %, stress relaxation time was reduced from 0.364 to 0.360 s which is insignificant. Modulus of elasticity values of the dough decreased with increase in cheese levels indicating that the dough became significantly soft on cheese incorporation.

It was also observed that by addition of processed cheese, the dough became soft as indicated by firmness values. This observation was similar to that in cheddar cheese addition. However, the drop in firmness by 30 % cheese incorporation was more than that in case of cheddar cheese addition. The hardness of the dough reduced with increasing levels of the cheese, the values being 12.05, 4.45 and 3.71 N respectively for 30, 40 and 50 % cheese levels. Gumminess of the dough gradually decreased with increase in the cheese level as shown in Fig. 2a. With regard to viscoelastic characteristics, same trend of cheddar cheese addition was observed that is, modulus of elasticity and viscosity values decreased with increased processed cheese incorporation (Fig. 2b). These changes are as expected because in ripened cheese, the protein matrix is broken down by continued proteolysis and is softened (Gunasekaran and Ak 2003). As a result, when stress is applied, the stress relaxes faster imparting similar characteristic to the dough also. That is the reason why stress relaxation time decreased by incorporation of cheese. The same reason applies to processed cheese incorporation as well. This is the reason that modulus of elasticity decreased by cheese incorporation and the dough tended towards viscous nature.

Table 2 Effect of oats level in dough formulation on sensory quality of biscuits

Oats level in biscuit formulation (%)	CA	FL	BT	OA
0	8.05±0.07 ^b	7.43±0.07 ^{ab}	7.90±0.06 ^b	8.00±0.06 ^b
25	8.02±0.08 ^b	7.82±0.13 ^b	7.88±0.10 ^b	7.90±0.09 ^b
35	7.70±0.10 ^{ab}	7.70±0.09 ^{ab}	7.28±0.08 ^a	7.32±0.09 ^a
45	7.44±0.12 ^a	7.34±0.10 ^a	7.08±0.10 ^a	7.27±0.10 ^a

Values with different superscripts in a column are significantly different from each other ($P < 0.05$)

CA Colour and appearance; FL Flavour; BT Body and texture; OA Overall acceptance

Fig. 2 Effect of incorporation of cheddar and processed cheese on the rheological characteristics of 25 % oat-incorporated biscuit-dough (a) hardness and gumminess (b) ME (Modulus of elasticity) (primary vertical axis) and SRT (stress relaxation time) (secondary vertical axis)

Rezzoug et al. (1998) reported that fat contributes to the reduction of the elastic nature of dough, less shrinking of the dough at cut-out. Adding fat softened the dough, and caused a reduction in viscosity and relaxation time. This is relevant in case of use of ripened cheese in which part of fat exists in free state, which Guinee et al. (2000) probably expressed as ‘expressible fat’.

Effect of incorporation of cheese on biscuit quality

Incorporation of cheese into the formulation, affected the sensory quality of the oat incorporated biscuits. The biscuits prepared with 25 % oats and 0, 30, 40 and 50 % cheese on flour basis were subjected to sensory evaluation and the scores are presented in Fig. 3a. Cheddar cheese incorporation resulted in

slight darkening of biscuits whereas processed cheese incorporation slightly whitened the biscuits. In general as cheese level increased, the biscuit acceptability either remained the same or decreased. Of course this depended on the level of oats incorporation. This may be because of ripened cheddar cheese which yielded a baked flavour combined with oats flavour. Probably such flavour was liked less by the panelists. Use of cheese up to 40 % level, imparted cheese flavor to biscuits, but similar scores as control indicated that the panelists liked the experimental biscuits on par with control and not more. These observations were reflected in overall acceptance scores also. From these results it may be concluded that cheese incorporation did not enhance the sensorial characteristics, but the scores were in well acceptable range. Up to the level of 40 % incorporation, there was no significant reduction in

Fig. 3 Effect of type of cheese and cheese level on the overall quality of biscuit with (a) 25 % oats (b) 35 % oats and (c) 45 % oats

Fig. 4 Effect of baking time temperature combination on reflectance of oat (25 % oats) and cheese incorporated biscuit (a) cheddar cheese (b) processed cheese

scores. However, between the two types of cheese, cheddar had better flavour acceptance scores and processed cheese better body and texture scores (Fig. 3b and c). Un-ripened cheese like mozzarella may yield a good flavour on baking, but ripened cheeses may not yield acceptable flavour on baking possibly because of liberation of volatile compounds. This is one of the reasons that synthetic cheese flavours are employed for use in baked foodstuffs.

Optimization of baking conditions of biscuits

Four different temperatures with different time intervals were studied for the purpose (Table 1). At each time interval, six biscuits from the baking oven were drawn and analysed. According to the trend of results obtained, the per cent reflectance decreased as the time of baking increased i.e. whiteness decreased (Fig. 4a). It was observed that as the baking temperature increased, the total baking time was less, which could be ascribed to faster Maillard browning occurring at higher temperatures (Fox and McSweeney 2003). The per cent reflectance values at optimized conditions were: 67 % at 135 °C for 42 min, 70 % at 145 °C for 37 min, 69 % at 155 °C for 30 min and 70 % at 165 °C for 27 min. The same trend was recorded for the processed cheese (Fig. 4b) containing biscuits as that of cheddar cheese, but reflectance values were higher than those of cheddar cheese containing biscuits. As compared to the cheddar cheese, processed cheese was baked in less time

Table 3 Optimized baking time temperature combinations

Baking temperature	Cheddar cheese incorporated biscuit	Processed cheese incorporated biscuit
135 °C	42 min	42 min
145 °C	37 min	35 min
155 °C	30 min	29 min
165 °C	27 min	25 min

and brown colour formation in biscuit was also less. The per cent reflectance values for finalized baking time temperature combinations were: 68 % at 135 °C for 42 min, 74 % at 145 °C for 35 min, 74 % at 155 °C for 29 min and 72 % at 165 °C for 25 min. The sensory acceptance scores for these combinations were subjected to statistical analysis and when no significant difference between time intervals was observed, the minimum time was selected. Finalized time temperature combinations are given in Table 3.

Storage study

Changes in sensory quality of cheese incorporated oat biscuit

The biscuits made from the formulation containing finalized level of cheddar cheese (30 % on the flour basis) and oats (25 % replacement of refined wheat flour) were packed in metalized polyester and stored at 30 °C to study the effect of the storage days on the quality of the biscuits. As the storage days increased reduction in the colour and appearance (CA)

Table 4 Effect of storage days on the sensory attributes of cheddar cheese incorporated oat biscuit

Days of storage	CA	FL	BT	OA
0	7.79±0.07 ^d	7.74±0.11	7.72±0.13 ^d	7.70±0.09 ^d
15	7.74±0.09 ^{cd}	7.67±0.13	7.58±0.17 ^{cd}	7.61±0.11 ^{cd}
30	7.65±0.08 ^{cd}	7.66±0.11	7.55±0.09 ^{bcd}	7.53±0.10 ^{bcd}
45	7.43±0.17 ^{bc}	7.59±0.14	7.39±0.10 ^{abcd}	7.41±0.08 ^{bcd}
60	7.22±0.16 ^{ab}	7.51±0.14	7.22±0.09 ^{abc}	7.36±0.09 ^{abc}
75	7.19±0.19 ^{ab}	7.47±0.19	7.10±0.06 ^{ab}	7.21±0.07 ^{ab}
90	7.03±0.07 ^a	7.33±0.12	6.96±0.10 ^a	7.07±0.09 ^a

Values with different superscripts in a column are significantly different from each other ($P<0.05$)

CA Colour and appearance; FL Flavour; BT Body and texture; OA Overall acceptance

Table 5 Effect of storage days on processed cheese incorporated oat biscuit quality

Days of storage	CA	FL	BT	OA
0	7.84±0.09 ^c	7.58±0.15 ^c	7.73±0.08 ^d	7.72±0.10 ^d
15	7.73±0.09 ^c	7.47±0.09 ^{bc}	7.60±0.09 ^{cd}	7.53±0.13 ^{cd}
30	7.71±0.10 ^c	7.40±0.13 ^{bc}	7.55±0.09 ^{cd}	7.49±0.12 ^{bcd}
45	7.64±0.08 ^{bc}	7.36±0.12 ^{bc}	7.41±0.10 ^{bc}	7.39±0.12 ^{bc}
60	7.59±0.09 ^{bc}	7.30±0.16 ^{abc}	7.30±0.08 ^b	7.34±0.11 ^{ab}
75	7.45±0.11 ^b	7.21±0.13 ^{ab}	7.17±0.09 ^{ab}	7.18±0.11 ^{ab}
90	7.16±0.09 ^a	6.98±0.10 ^a	7.00±0.11 ^a	7.05±0.11 ^a

Values with different superscripts in a column are significantly different from each other ($P<0.05$)

CA Colour and appearance; FL Flavour; BT Body and texture; OA Overall acceptance

score was observed from 7.79 to 7.03 from 0 to 90 days of storage. The reduction in the score may be because of continued browning discolouration in biscuits as indicated by reducing reflectance values (Table 4). There was decrease in flavor score which on 90th day was 7.33 indicating it was still acceptable. Body and texture score of the biscuit decreased from 7.72 to 6.96 from 0 to 90 days however, this was not statistically significant. Overall acceptability showed that all the scores were in acceptable range during the entire period of storage study. The changes in the scores were not significant ($P>0.05$) (Table 4).

In processed cheese incorporated biscuits, storage resulted in decrease in CA scores from 7.84 to 7.16 from 0 to 90 days, but the scores were in the acceptable range (Table 5). The same trend appeared for the flavor attribute also. The body and texture score decreased from 7.73 to 7.00 at the end of 90 days. Overall acceptability score showed decreasing trend from 0 to 90 days with 7.72 to 7.05 scores, which were all in acceptable range. The decrease in sensory scores of the biscuit samples was statistically significant ($P<0.05$). Chowdhury et al. (2012) also

Table 6 Effect of storage days on chemical quality of product

Particulars	Type of biscuit	Storage, days						
		0	15	30	45	60	75	90
FFA (% OA)	Cheddar	0.104	0.123	0.158	0.164	0.173	0.183	0.190
	Processed	0.082	0.092	0.126	0.136	0.141	0.151	0.169
Moisture (%)	Cheddar	3.52	3.62	3.64	3.47	3.53	3.67	3.94
	Processed	4.41	4.54	4.64	4.81	5.24	5.30	5.32

reported shelf life of more than 90 days at ambient temperatures for biscuits sold in Bangladesh.

Changes in instrumental colour parameters of cheese incorporated oat biscuit

Colour is an important characteristic for baked products because it, together with texture and aroma, contributes to consumer preference. During the storage study, colour changes in biscuit samples were observed. As mentioned in the Fig. 5a and b, values for the Luminosity, Red (R), Green (G) and Blue (B) colour were estimated because luminosity measures the whiteness of the biscuits and RGB values represent the basic colours. The colours were measured on the scale having a maximum value of 250. The study showed that colour decreased from 0 to 15 days, then there was no much change up to 60 days, but at 75 days showed an increase which then decreased up to 90 days. Overall, it may be observed that the colour of biscuit composed of three basic colours red, green and blue in certain proportions. While red and green components are present in greater intensities, the blue component was present in lower intensity. It may also be seen from Fig. 5a and b that the ratio between red and green almost remained the same throughout the storage, but their intensities varied. Increase in the colour values from 60 to 75 days could be due to the fat blooming caused by the oozing out of fat from biscuit and its crystallization on the surface forming a white

Fig. 5 Changes in colour parameters during storage of biscuit prepared by incorporation of oats (25 % level in formulation) and (a) cheddar cheese & (b) processed cheese

Fig. 6 Changes in textural quality of oats and cheese incorporated biscuits* during storage (* contain optimised levels of 25 % oat+40 % processed cheese on flour basis; 25 % oat+30 % Cheddar cheese on flour basis)

layer resulting in the increased colour values. Same trend was observed in both cheddar and processed cheese added biscuits (Fig. 5a and b).

Comparison of luminosity values showed that processed cheese added biscuits showed more ‘whiteness’ than cheddar cheese added biscuits (Fig. 5b). This may be because ripened cheddar cheese might have developed brown colour faster than processed cheese due to availability of several reducing compounds and amino groups formed by breakdown of compounds during ripening (Fox et al. 2004).

Changes in chemical quality of cheese incorporated oat biscuit

During the storage, the physico-chemical changes undergoing in the biscuit samples were measured in terms of moisture, free fatty acid (FFA) and water activity. The FFA content varied from 0.104 to 0.190 % oleic acid for cheddar cheese and from 0.082 to 0.169 % oleic acid for the processed cheese incorporated biscuits during the entire period of storage (Table 6). It may be assumed from the increase in FFA that during storage some hydrolysis of fat might have taken place releasing FFA. However, this was not so significant as to adversely affect the flavour score. Manley (2000) reported that hydrolytic rancidity caused by FFA release is rare in biscuits. Since biscuits have low water activity, little change in FFA content may be expected. The moisture content in cheddar cheese incorporated biscuits varied from 3.52 to 3.94 % and for processed cheese incorporated biscuits it varied from 4.41 to 5.32 %. The increase in the moisture content during the storage period may be due to the absorption of moisture from the head space of the packaging material because there are no possibilities for the absorption of moisture through packaging material (film thickness 61.5 μm) which is a good barrier to moisture. The water activity values remained almost the same throughout the storage

i.e. 0.205 to 0.312 and 0.294 to 0.411 for cheddar and processed cheese added biscuits, respectively.

Changes in textural quality of cheese incorporated oat biscuit

There were some changes in textural characteristics of the biscuits during storage (Fig. 6), but there was no specific trend. In general in cheddar cheese biscuit there was decreasing trend in hardness from 63 to 42 N though there were some variations in between and for processed cheese incorporated biscuits hardness decreased from 63 to 41 N. As mentioned earlier, the moisture content varied from 3.52 to 5.32 %; The textural changes are expected to take place in biscuits during storage because of conformational changes that continue even during static storage of processed foods as reported by Brennan (2006).

Table 7 Physico-chemical characteristics of the oat and cheese incorporated biscuits

Parameters	Oat incorporated biscuits	Cheddar cheese incorporated biscuit	Processed cheese incorporated biscuit
Moisture, %	2.94	3.93	4.32
Crude fat, %	24.23	26.91	28.35
Protein, %	8.52	12.52	12.89
Carbohydrate, %	62.28	53.94	51.69
Ash, %	2.03	2.70	2.75
Acid insoluble ash, %	0.18	0.13	0.12
β -glucan, %	0.70	0.62	0.60
Water activity	0.206	0.279	0.353
Hardness (N)	76.18 $\pm$ 11.83	47.36 $\pm$ 6.23	52.29 $\pm$ 5.16
Diameter (mm)	38.30 $\pm$ 0.3	41.00 $\pm$ 0.6	41.30 $\pm$ 0.3
Thickness (mm)	6.00 $\pm$ 0.58	5.67 $\pm$ 0.33	5.32 $\pm$ 0.1
Weight (gm)	8.59 $\pm$ 0.01	9.32 $\pm$ 0.08	8.48 $\pm$ 0.24
Spread ratio	6.52 $\pm$ 0.7	7.30 $\pm$ 0.55	7.76 $\pm$ 0.06

Proximate chemical composition of cheese incorporated oat biscuit

There was not much change in chemical composition of the biscuits with and without cheese except in fat and protein contents which were higher in the former samples of biscuits (Table 7). The β -glucan content was 0.70 in oat incorporated biscuit, 0.62 and 0.60 % in oat and cheddar cheese and processed cheese incorporated biscuits, respectively.

Physical properties

Hardness of biscuit decreased by cheese incorporation (Table 7). It was also noticed that the spread ratio was higher in cheese incorporated biscuit (7.30–7.76) than oat incorporated biscuits (6.52). Higher spread ratio means that during baking the dough spreading was more. As a result, the diameter and thickness of biscuit also decreased as can be seen from the values given in Table 7. Sudha et al. (2007) also reported that oat bran incorporation showed an increase in spread (55.3–56.0 mm). In their study, the spread ratios for 10, 20, 30 and 40 % oat bran incorporations were 7.6, 8.3, 8.18 and 8.24, respectively. Rezzoug et al. (1998) reported that fat contributes to spreading characteristics of the dough.

Conclusion

It can be concluded that 25 % of oats replacement of refined wheat flour, along with addition of 30 % cheddar cheese or 40 % processed cheese on flour basis are recommended for preparation of good quality cheese flavoured biscuits. The optimum baking conditions for oat and cheese incorporated biscuit were 165 °C for 25–27 min. The biscuits could be stored for more than 90 days at 30 °C without adverse changes in sensory quality. Oats and cheese incorporated biscuits were shown to be highly nutritive with 12.53 % and 12.89 % protein, 26.91 and 28.35 % fat, 2.70 % and 2.75 % minerals and 0.62 % and 0.60 % beta-glucan for cheddar and processed cheese incorporated biscuits respectively.

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