Effect of microencapsulated fat powders on rheological characteristics of biscuit dough and quality of biscuits

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Abstract The effect of microencapsulated fat powders on the rheological characteristics and quality of biscuits were studied and compared with the control native fat normally used in the biscuit industry. Commercial bakery fat was encapsulated using sodium caseinate or skimmed milk powder (SMP) and the fat content in the powders was in the range of 73–78 % for sodium caseinate, whereas it ranged between 57.5 and 61 % with SMP and the sugar content was in the range of 9.8–17.5 %. The rheological characteristics indicated that with high sodium caseinate and SMP, the doughs were more elastic. The TPA analysis showed that with increasing the casein content in the fat powder, the dough hardness increased, and the doughs were less cohesive. The quality of biscuits was comparable with lower amount of encapsulating agents. Powders with lower amount of agents had comparable benefits on the rheological characteristics of the dough and biscuit quality.

Keywords Microencapsulated fat powders · Biscuit dough · Rheological characteristics and biscuit quality

Practical applications Microencapsulated fat powders are getting popular because of convenience, easy to handle. Fat powders were prepared using sodium caseinate and skimmed milk powder as encapsulating agents and studied for its rheological characteristics and biscuit making quality. Biscuits having comparable quality attributes could be prepared using fat powders with low encapsulating agent and high fat content.

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Introduction

Flour, fat and sugar are the three major ingredients for the short dough biscuits. Biscuit dough is a complex system containing lower amount of water. Lot of changes occurs in biscuit dough during baking (Donovan and Mapes 1980; Evans and Haisman 1982; Burt and Ruel 1983). Quality characteristics of biscuits mainly depend on the texture of the biscuits which results from the interactions between ingredients (Chevallier et al. 2000). Fat plays an important role by imparting shortness, richness and tenderness, thereby improving the eating quality of the product. Type of fat used in the preparation of biscuits determines the quality of end product (Jissy and Leelavathi 2007). Type of fat and amount of fat added showed a strong effect in the viscoelastic properties of the dough (Baltsavias et al. 1997). Fat is also considered as a crucial structure component and stiffness of the dough gets reduced on reduction of fat content. At the same time increasing the level of fat content in the formulation showed a softening effect on the consistency of the dough (Miller 1985). Biscuits prepared by replacing the hydrogenated fat by peanut butter had better fatty acid composition with balanced oil quality and were highly acceptable by the sensory panel (Gajera et al. 2010).

Biscuit production on commercial scales is a highly automated process (Faridi 1994; Manley 1996). All ingredients used are bulk and dry ingredients except fat, which is the block fat, added manually to the automated process. Wehrle et al. (1999) developed microencapsulated high fat powders so that fat can be added in dry powder in biscuit formulation. Micro encapsulation process converts block fat into free flowing powder where fat is dispersed in homogenized emulsion under high pressure to form globules. These globules, which are usually lesser than 1 μm , are then spray dried (Keogh and Kennedy 1999). Utilisation of dairy protein was found to be more suitable as encapsulating

agents (Young et al. 1993). Protein levels in the fat powders have affected the dough hardness (O'Brien et al. 2003). Examination of effects of added fat on the rheological properties have not received wide spread attention in the literature, despite the addition of regular fat in bread making (Bloskma and Buhnuk 1998). The main objective of this work was to prepare microencapsulated fat powders using different encapsulating agents used during the preparation of fat powders and study the influence of microencapsulated high fat powders on the rheological characteristics of biscuit dough and biscuit quality in comparison with one prepared using hydrogenated vegetable fat.

Materials and methods

Materials

Commercial wheat flour having 11.5 % moisture, 0.5 % ash, 9.7 % protein and 20 ml Zeleny Sedimentation value was used as the basic raw material. Commercially available bakery fat (Marvo- Hindustan Lever Limited, India) was used in the production of microencapsulated fat powders. Other ingredients used in the biscuit formulation are sugar powder, dextrose, sodium chloride, sodium bicarbonate and ammonium bicarbonate (Qualigens Glaxco India Ltd., Mumbai, India). Glycerol mono stearate (food grade) and Lecithin were the emulsifiers used as emulsifying agents. The encapsulating agents used were sodium caseinate from Hi Media Laboratories Pvt. Ltd. Mumbai, India and skimmed milk powder (SMP) from Amul, Gujarat Co-operative Milk Marketing Federation Ltd. Anand, India.

Preparation of microencapsulated powders

Microencapsulated fat powders (R1 – R6) were prepared using either sodium caseinate or SMP as encapsulating agents (Table 1) as described by Shivakumar et al. 2011.

Table 1 Composition of fat powders

	Encapsulating agent (%)	Fat content (%)	Sugar content (%)
R1	Sodium caseinate — 6.5	78.0	13
R2	Sodium caseinate — 8.8	70.0	17.5
R3	Sodium caseinate — 9.8	78.4	9.8
R4	Sodium caseinate — 12.2	73.0	12.2
R5	Skimmed milk powder — 24.4	61.0	12.2
R6	Skimmed milk powder — 28.7	57.5	11.5

Moisture content; 0.6 – 2 %, free fat content; 20 – 25 %

Flowability of fat powders (angle of repose) = 45 – 50°

Values are means ($n=3$)

The process consists of preparing aqueous phase with encapsulating agents mainly sodium caseinate (13 – 14 %) or using SMP (26 %) instead of casein, sugar 6 %, emulsifier 2 – 3 %, along with water to obtain solids content of about 18 – 20°B. The fat phase was prepared by melting the fat and mixed with the emulsifier. Both aqueous and fat phases were homogenized using a homogeniser (Ultra Turrax, T - 25) for about 15 – 20 min. The homogenized emulsion so obtained was spray dried (Bowen spray drier) with 90 – 95 °C outlet temperature and 140 °C inlet temperature to obtain a free flowing powder passing through 90 mesh (163 µm).

Characteristics of fat powders

The fat powders were analysed for moisture content by toluene distillation method. The total fat content was estimated using petroleum ether (60 – 80 °C) as solvent as per AOCS (2000) procedure. Free fat in the powder was determined by taking a known weight of the product, stirred for 10 min without destruction of capsules with petroleum ether (60 – 80 °C) solvent, decanted and the residue was dried. The difference in volatile oil content before and after washing with petroleum ether was taken as the content of surface oil (Darviriyakul et al. 2002; Sankarikutty et al. 1998). The flowability of fat powder was measured the as the angle of repose, by allowing the fat powder to fall from funnel and measuring the angle of repose.

Preparation of biscuits

Test baking of biscuits was carried out using either saturated fat or encapsulated fat powders by following the method described by Sudha et al. (2007). For the preparation of biscuits using micro encapsulated fat powders, fat powder corresponding to 20 g fat was used so that the amount of fat used in the formulation remained constant. After baking, biscuits were cooled to room temperature, packed in polypropylene pouches and sealed till further use.

Biscuit dough characteristics

Studies on biscuit dough consistency was carried out as described by Sai Manohar and Haridas Rao (1999) using a Henry Simon Research water Absorption Meter (RWAM) with additional 2 kg weight. Biscuit dough (45 g) was cut into small pieces and packed into the dough holder and fixed to RWAM. The time taken to move a distance of 1 cm by RWAM was recorded in seconds.

Farinograph studies

Consistency of the biscuit dough was measured using a farinograph (CW, Brabender Instruments, Duisburg,

Germany) according to Sai Manohar and Haridas Rao (1999). Three hundred grams of biscuit dough mixed in Hobart Mixer was transferred into the 300 g farinograph bowl and the instrument was run for 10 min. Biscuit dough consistency (peak height) and farinograph bandwidth was measured at 0 and 10 min. The average of two measurements was taken in each case.

Texture profile analysis of biscuit dough

Texture profile of the biscuit dough was measured using Lloyd Universal Testing Machine (Model LR-5k, Harrpshire, England) using an 8.5 cm stainless steel plunger as described in Sangeetha et al. (2011). Parameters measured were hardness (maximum resistance to first compression peak; N), cohesiveness (ratio of the positive force area during the second compression to that of the first compression), springiness (the height of the sample which it recovers between the end of the first bite and the start of the second bite) and adhesiveness (negative force area of the first bite). Experiments were carried in triplicates and average values are reported.

Biscuit evaluation

Evaluation of biscuits was carried out for spread (W), thickness (T) and spread ratio (W/T). Objective evaluation of texture of biscuits was measured by using a Texture Analyser (TA-Hdi, Stable Micro System, UK) by following the triple beam technique described by Gains (1991). A cross-head speed of 10 mm/min with a load cell of 50 kg was used in studies and the force required to break ten biscuits were recorded and reported as average value. Experiments were carried in triplicates and average values are reported.

Sensory evaluation

Biscuits were evaluated by a panel of six judges for different sensory attributes namely colour and appearance, texture, taste and overall quality on a 9 point hedonic scale, according to Hood and Jood (2005). Experiments were carried in triplicates and average values are reported.

Statistical evaluation

Results obtained were subjected to statistical analysis using Duncan's Multiple Range Test (Steel and Torrie 1980).

Results and discussion

The composition of fat powders prepared using either sodium caseinate or SMP as the two encapsulating agents with varying fat and sugar levels are presented in Table 1. These fat powders had the moisture content and free fat content in the range of 0.6 – 2 %, 20 – 25 % respectively. The flowability of fat powders (angle of repose) ranged between 45 and 50°. The water required to prepare the biscuit dough of desired consistency measured by an extrusion time of 45 ± 3 s using RWAM was slightly higher for biscuit dough prepared using fat powder when compared to biscuit dough prepared using traditional bakery fat (Table 2). The water requirement for the preparation of control biscuit dough was 18 ml, whereas the water needed for the biscuit dough prepared using fat powders with increasing levels of sodium caseinate as encapsulating agent (R1 to R4) increased by 2 – 3 % higher than control as can be seen in Table 2. Increase in sodium caseinate in powders increased the dough water

Table 2 Effect of encapsulating agent on the farinograph consistency and TPA analysis of the biscuit dough

Sample	Water required for dough preparation (%)	Moisture in dough (%)	Farinograph characteristics				Hardness (N)	Cohesiveness	Springiness (mm)	Adesiveness (Nmm)
			Dough consistency (BU)		Band width (BU)					
			0 min	10 min	0 min	10 min				
Control	18	20.4	380 ^c	475 ^b	120 ^d	180 ^d	250.0 ^g	0.16 ^a	1.44 ^b	12.7 ^d
R1	18	20.8	385 ^c	470 ^b	125 ^d	185 ^d	312.0 ^f	0.11 ^a	1.61 ^a	14.9 ^c
R2	20	20.7	430 ^b	470 ^b	140 ^c	180 ^d	335.8 ^e	0.12 ^a	1.08 ^d	24.5 ^b
R3	21	21.7	440 ^{ab}	480 ^{ab}	160 ^b	210 ^b	362.9 ^d	0.17 ^a	1.29 ^c	29.3 ^a
R4	21	19.5	470 ^a	510 ^a	180 ^a	280 ^a	413.9 ^c	0.15 ^a	1.62 ^a	28.2 ^a
R5	16	19.0	440 ^{ab}	460 ^{bc}	145 ^c	180 ^d	424.9 ^b	0.08 ^b	1.61 ^a	6.29 ^e
R6	17	18.4	470 ^a	490 ^a	180 ^a	200 ^c	456.4 ^a	0.07 ^b	0.70 ^e	5.27 ^e
SEM (±)	—	—	5.0	9.1	10.5	9.6	5.11	0.02	0.06	0.11
DF	—	—	14	14	14	14	36	36	36	36

TPA texture profile analysis, BU Brabender units, values are means ($n=3$); values for a particular column followed by different letters ^c differ significantly ($p<0.05$); SEM standard error of mean; DF degrees of freedom, refer to Table 1 for R1 to R6

requirement, which may be due to the presence of milk protein casein having higher water absorption capacity. Use of skimmed milk powder as the encapsulating agent reduced the water absorption required for the dough preparation by about 2 %. Fat helps in coating the flour particle thereby inhibiting the development of gluten protein resulting in softer doughs (Menjivar and Faridi 1994). Fat also helps in the lubricating action in the dough so that little water is sufficient to reach the required consistency (Spies 1990; Manley 1996). In case of the fat powder R2, though the sugar content is higher and fat content is lower, the water requirement was comparable to the dough prepared from R1 (Table 2). In case of sample R3, the water required for the formation of biscuit dough increased by 1 %, even though the fat content was the same as in R1, which is due to higher casein content. When SMP was used the water requirement was comparatively lower than the control.

Farinograph characteristics

The farinograph consistency and the bandwidth recorded at 0 and 10 min are presented in Table 2. The farinograph consistency for the control biscuit dough was 380 BU and increased to 475 BU at 10 min. Doughs prepared using fat powders R1 to R6 had much higher dough consistency (430–470 BU) indicating it to be stiffer dough, which further increased to 470–510 BU at 10 min showing it to be more cohesive than the control dough. The bandwidths, which denote the elastic properties of the dough, were smooth and narrow for control dough and were wider for doughs prepared with fat powders R1–R6 (Table 2). This refers to the absence of sufficient free fat resulting in increase in the consistency. This may again be due to the presence of sodium caseinate, which might have not allowed fat to be free in the dough. Olewink and Kulp (1984) inferred that

distribution of fat and water in the system affects the physical properties of gluten. Increase in water uptake for dough with fat powders might have made the dough more elastic by offering more resistance to mixing and wider band. Pyler (1988) reported that plastic fat helps in aerating the dough and less aerated dough would be rather denser. Biscuit dough containing milk powder as encapsulating agent with high fat content had an initial consistency of 440 BU and 470 BU for low fat content in the powder. Also the consistency did not change much after 10 min of mixing. Dough prepared using either control fat or R1 had comparable band width (Table 2) as the fat and sugar contents in the powder are relatively higher and the percentage of encapsulating agent is low. With increasing amounts of encapsulating agents, the band width also increased. The dough containing lower amount of milk powder had a bandwidth of 145 BU and 180 BU at 0 and 10 min respectively. This shows that it is behaving like plastic shortening, which usually helps in the formation of tenacious dough.

Texture analysis

The TPA analysis of the biscuit dough indicated that the dough hardness was significantly higher for dough containing fat powders irrespective of the encapsulating agent used, when compared to the vegetable native fat (Table 3). The higher water requirement for dough having fat powders might, have contributed to the increase in the dough hardness values (O'Brien et al. 1999). The hardness values were further higher, where milk powder (R5 and R6) was used as the encapsulating agent. Springiness values, which describe the recovery of the dough between the two bites, were similar for doughs using native fat and fat powders with sodium caseinate, where as it was quite low when SMP was

Table 3 Moisture content, physical characteristics and sensory attributes of biscuits

	Moisture content (%)	Physical characteristics					Sensory attributes				
		Weight* (g)	Width* (mm)	Thickness* (mm)	Spread ratio	Texture** (kg force)	Colour and appearance (9)	Crumb colour (9)	Texture (9)	Taste (9)	Overall quality (9)
Control	2.22	6.1±0.01	56.1±0.01	5.9±0.01	9.5	1.22±0.11	8.32a	8.45a	8.58a	8.49a	8.57a
R1	2.26	6.2±0.02	54.8±0.11	5.6±0.01	9.8	1.57±0.18	7.42b	7.34b	7.25a	7.89ab	7.2c
R2	2.65	6.7±0.01	55.3±0.05	5.7±0.02	9.7	1.67±0.14	7.05c	7.28bc	7.09b	7.05c	7.15c
R3	2.22	6.5±0.02	55.8±0.02	5.7±0.02	9.8	1.45±0.11	6.92c	7.25bc	7.45a	7.92ab	7.87ab
R4	1.25	6.6±0.01	53.5±0.01	5.6±0.03	9.6	2.10±0.15	6.45d	7.05c	6.12c	6.25d	6.7d
R5	1.15	7.1±0.02	56.1±0.03	5.8±0.04	9.7	1.84±0.12	7.51ab	7.42b	7.12b	7.25b	7.27b
R6	0.84	6.9±0.02	55.7±0.02	5.8±0.01	9.6	2.15±0.13	7.62a	7.35b	7.24a	7.32b	7.38b
SEM (±)	—	—	—	—	—	—	0.11	0.12	0.11	0.21	0.19

Values are means ± standard deviations (**n*=3; ***n*=6)

Values for a particular column differ significantly when followed by different letters (*p*<0.05); SEM standard error of mean at 36 degrees of freedom, refer to Table 1 for R1 to R6

Table 4 Correlation matrix for the rheological characteristics of dough and biscuit parameters

	Farinograph consistency ^a (BU)	Band width ^a (min)	Dough hardness (N)	Cohesiveness	Springiness (mm)	Width (mm)	Thickness (mm)	Texture (kg force)
Band width	0.77							
Dough hardness	0.857	0.605						
Cohesiveness	-0.657	-0.235	-0.003					
Springiness	-0.292	0.500	-0.596	0.552				
Width	0.611	0.087	0.804	-0.683	-0.786			
Thickness	-0.553	0.467	-0.210	0.330	-0.514	-0.013		
Texture	0.878	0.689	0.905	-0.837	-0.419	0.638	-0.416	
Overall quality	-0.867	-0.470	-0.620	0.724	0.047	-0.528	0.832	-0.767

BU/Brabender units

^a 0 min

used in fat powder. Similarly, cohesiveness values did not significantly vary for doughs containing vegetable native fat and powders with sodium caseinate and it was significantly lower for dough with SMP as the encapsulating agent, though the water required was lower than the control dough. Wehrle et al. (1999) reported increased hardness and decreased cohesiveness for doughs containing either whey protein concentrate or sodium caseinate, when compared to control dough containing either margarine or butter. Cohesiveness in dough is mainly due to the plasticity of the shortening used (Hoseney 1986). Higher the casein contents in fat powder, higher the dough hardness, lesser cohesiveness and higher springiness values.

Physical characteristics of biscuits

Even though the processing conditions were same, the spread (width) and thickness of the biscuits varied for biscuits prepared using native fat or encapsulated fat. Biscuits prepared with fat powder containing sodium caseinate had relatively lower spread values and were slightly thinner. The spread and thickness values for biscuits with fat powder having SMP as encapsulating agent were comparable to those of control (Table 3). The force required to break a biscuit describes the hardness or brittleness of the biscuit. Snap test values of the biscuits as indicated in Table 3 show that the control biscuit required the lowest force at breaking point. The breaking strength values of biscuits increased when fat powder was used irrespective of the agent. Biscuits with fat powders R3 and R4, R5 and R6 had relatively higher snap values and were not easy to break. Higher snap test values have been reported by several authors, irrespective of the encapsulating agent and encapsulation process conditions (O'Brien et al. 2003). During mixing of the dough, fat component and aqueous phases compete for the surface of the flour particle to coat. If fat

coats before hydration, then biscuits would be less harder (Glicksman 1991; Manley 1996; Menjivar and Faridi 1994).

Sensory quality of biscuits

The biscuits prepared using fat powders R1 – R6 had relatively lower scores than the control biscuits (Table 3). The colour and appearance of the biscuits prepared using fat powders R1, R5 and R6 were lower than those of control, whereas the biscuits from fat powders R2 – R4 were slightly darker. The surface of biscuit with fat powder had less sheen and rough surface. The crumb colour scores of the biscuits were comparable for all the fat powders. Biscuits with R4 had the lowest score, which may be due to high sodium caseinate content and low fat content in the fat powder. Taste of the biscuits from fat powders R1 and R3 was comparable to control, whereas all other biscuits were significantly different. Among the fat powders used, the overall quality score for R3 was the highest and lowest for R4, which may be due to variation in sodium caseinate in the fat powders.

Fig 1 Relation between dough hardness and biscuit texture

Relation between dough characteristics and biscuit parameters

The relation between dough characteristics and biscuit parameters is presented in Table 4 in the form of correlation matrix. It can be observed that some of the dough characteristics have affected the biscuit quality. Bandwidth of the farinogram positively correlated to the consistency ($r=0.77$). Similarly the dough hardness positively correlated to the consistency ($r=0.857$) and bandwidth ($r=0.605$), whereas the adhesiveness and springiness negatively correlated to farinograph consistency, band width and dough hardness. The width of the biscuit, which is an important quality parameter, positively correlated to farinograph parameters and dough hardness and negatively correlated to cohesiveness and springiness. The thickness of the biscuit was found to be negatively correlated to most of the parameters. The texture of the biscuit negatively correlated to springiness and thickness. Relation between biscuit dough hardness and biscuit texture is presented in Fig. 1 as a result of regression analysis. It clearly indicates that with increase in dough hardness, the biscuit texture values increased. Thus the type and percentage of encapsulating agent used and the quantity of fat and sugar content in the fat powders have a great influence on the biscuit quality. This study infers that there is some relation between dough characteristics and biscuits quality as observed by Schober et al. (2003).

Conclusion

The study indicates that there is significant difference in the rheological characteristics of the biscuit dough prepared from native fat and encapsulated fat powders. The amount of encapsulating agent, type of the agent and other ingredients used in the encapsulation process affect the properties of the dough and biscuit quality. The water required for the dough was more when the percentage of encapsulating agent i.e. sodium caseinate was more, whereas when smp was used, the percentage of fat content was low and water required was also low. The dough hardness values were higher for doughs containing higher amount of caseinate and also when smp was used. Biscuits having fairly acceptable quality attributes could be prepared using fat powders with low encapsulating agent and high fat content.

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