Effect of virgin coconut meal (VCM) on the rheological, micro-structure and baking properties of cake and batter

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Abstract Virgin coconut meal (VCM) cakes were prepared by replacing refined wheat flour (maida) (5 to 20 % level) to check its effect on chemical, textural and rheological attributes of cake. The addition of VCM significantly ($p \leq 0.05$) increased redness (a^*), yellowness (b^*) while reduced lightness (L^*) of cakes. The incorporation of VCM affects the hardness, adhesiveness gumminess and chewiness of cake. The effect of flour replacement with VCM increased the viscosity of batter which leads to increase in consistency index and lower the shear thinning behavior. The viscoelastic behavior of cake batter in which elastic modulus (G') and viscous modulus (G'') both were decreased with the increase in percentage of VCM. The differential scanning calorimetry (DSC) analysis revealed that the onset (T_o), end set (T_c) and enthalpy of gelatinization (ΔH) increased with the increased level of VCM.

Keywords Virgin coconut meal (VCM) · Cake · Batter · Texture profile · Differential scanning calorimetry (DSC)

Introduction

The bakery industry is one of the largest organized food industries all over the world because of their ready to eat form and long shelf life (Singh et al. 1993). The annual production

of bread, buns and cakes in the country is estimated around 15.2 lakh tones. Cakes are very popularly occupy a special place in Indian bakeries. Asians are accustomed to eat cake prepared from wheat flour and they are familiar with the taste, texture and flavor of wheat flour cakes. It is widely recognized that beneficial effect of healthy diet not only on quality of life but also on cost effectiveness of healthy care. Most of the bakeries products are develop with incorporation of difference nutritionally rich ingredients (Zoulikha et al. 1998).

Virgin coconut oil (VCO) is the recently emerging highly demanded product in the world and various types of cold and hot presses are used for the extraction of VCO from the fresh coconut kernel at low temperature. The whitish residue remained after extracting coconut oil can be milled to flour named as virgin coconut meal (VCM) (Bawalan 2002). As a source of dietary fiber coconut meal provides a number of health benefits in relation to coronary heart diseases, colon cancer and diabetes (Gunathilake and Abeyrathne 2008; Trinidad et al. 2007). Meal obtained after the extraction of oil generally utilized as cattle feed like poultry, fish and swine industry. However, meal obtained after oil extraction still possess good nutritional properties which could be utilized for value addition of various processed foods. Many in vitro studies have been performed on the animal to check the physiological effect like egg production performance in single comb white leghorn layers (Moorthy 2006), average daily weight gain, average daily feed intake and feed conversion ratio on pigs (Siebra et al. 2008), nutrient digestibility in hens (Lima et al. 2007), egg component and yolk fatty acid composition (Barreto et al. 2006), growth rate of broiler chick (Panigrahi 1992) after supplementation of coconut oil cakes. Dairo and Fasuyi (2008) has reported the protein quality indices of sun dried, oven dried and fermented coconut oil meal on rats. However, data on the use of VCM in the development of various processed foods are scanty.

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Hence, the objective of present investigation were to develop nutritious virgin coconut meal (VCM) cake and study the changes in the physico-chemical, textural and thermal characteristics. Therefore, there is an interesting opportunity prevails to incorporate a combination of wheat flour-VCM into cakes recipes to improve their nutritional properties.

Material and methods

Raw material

All the raw materials for the making of VCM cake includes grounded sugar, egg, baking powder, refined wheat flour (maida) and hydrogenated fat were procured from local market of Mysore while VCM has been obtained from Central Plantation Crops Research Institute (CPCRI), Kasaragod, Kerala, India. The VCM was powdered in an ultra centrifugal mill (Retsch RI, Germany) using 500 μm sieve.

Preparation of VCM cake

Cake were formulated and prepared according to the method by Gupta et al. (2009) in triplicates Hydrogenated fat (16 g) and sugar (26 g) was whipped for 5 mins in laboratory mixer (Hobart N 50, Ontario, Canada) at speed 3 separately. Fresh eggs including albumen and yolk (26 g) were whipped for 2 min at speed 3 with vanilla essence (1 ml). Refined wheat flour (30 g) and baking powder (1 g) were sifted together and kept separately. Add the whipped egg, VCM and sifted wheat flour-baking powder in whipped cream (hydrogenated fat and sugar) and mixed for 30s. The cake batter was transferred into baking trays measuring 18x18x4 cm and baked at 170 °C for 30mins in a laboratory oven (National Manufacturing Company, Lincoln, NE). The cake slices cut in dimension of 5x5x3cm size for the various analyses (Fig. 1).

Proximate analysis and physical properties of cake

Moisture, protein, fat, ash and crude fiber were determined as per Association of Official Analytical Chemists (1980) method. The physical properties of VCM cakes were carried out in triplicates. The cake was cooled for 1 h and then cut from the centre to measure physical properties like volume index, symmetry index and uniformity index using cake measuring template as described in 10–91 AACC (1995). Specific gravity of batter was determined by dividing the weight of a constant volume of batter by the weight of a constant volume of water.

Color evaluation of VCM cakes

Color measurements of VCM cake and batter samples were packed in transparent polypropylene pouches for color

measurement in triplicate by using a Hunter colorimeter Model D-25 optical Sensor (Hunter Associates Laboratory Inc., Reston, VA., USA), on the basis of L^* , a^* and b^* values. A polypropylene (pp) pouch containing samples were placed above the light source, covered with a white plate and L^* , a^* and b^* colour values were recorded. The instrument (45°/0° geometry, 10° observer) was calibrated against a standard red-coloured reference tile ($L_s = 25.54$, $a_s = 28.89$, $b_s = 12.03$). The L^* value indicates the lightness, 0–100 representing dark to light. The a^* value gives the degree of the red–green colour, with a higher positive a^* value indicating more red. The b^* value indicates the degree of the yellow–blue colour, with a higher positive b^* value indicating more yellow Brewer et al. (1992).

VCM cake batter microscopy evaluation

The freshly prepared cake batters of the control and with different levels of VCM batter (5–20 %) were examined by placing the batter 20 μm thick on a slide and squashing with a thin cover slip. The samples were then observed under image analyzer (Olympus Micro Image Analyzer, Lite Version 4.0; USA) with a magnification of 10 $\times$ (Hoseney and Delcour 2010).

Instrumental textural profile analysis of cake crumb

Texture profile analysis was performed using the texture analyzer (TAHDI, Stable Microsystems, London, UK) loaded with Texture Expert software (Version 1.22; Stable Microsystems, London, UK). Cake crumb samples in the form of 3 cm thick cubes were cut from the center of the cake. Sample was placed on the platform of a Texture Analyzer and compressed to 50 % of its initial height twice in two cycles with a flat circular 75 mm probe with penetration distance 5 mm and trigger force 40 g taking 50 kg load cell. The pretest, test, post test speed were 2 mm/s, 1 mm/s and 2 mm/s respectively. Texture profile curve obtained which give textural parameters like hardness, adhesiveness, springiness, chewiness and cohesiveness (Gupta et al. 2009).

Differential scanning calorimetry of VCM containing samples

The thermal properties of VCM cake and batter were determined by using DSC-821 (Mettler Toledo, Switzerland) equipped with a thermal analysis data station. The samples were weighed into a 40 μl capacity aluminum pan (Mettler, ME 27331) and distilled water was added in cake crumb only with the help of Hamilton micro-syringe. The samples were hermetically sealed and allowed to stand for 30 min at room temperature before heating in DSC. The DSC analyzer was calibrated using indium and empty aluminum pan was used as

Fig. 1 Flowchart for the preparation of cake

reference sample pans. Both were heated at the rate of 10 °C/min from 20 °C to 200 °C for the estimation of endothermal changes as the temperature increased (Yasunga et al. 1968).

Rheological properties measurement

Dynamic rheological studies of cake batter were performed on Modular Compact Rheometer (Physica, Model MCR 100, USA). The data were recorded using US 200/32 V₂; 3,021, 001,472–33,024 software (USA) using the probe parallel plate 50 mm diameter. Samples were loaded and covered with flap to prevent dehydration and the gap was adjusted to 2 mm ± 0.5. The viscosities of samples were analyzed as a function of shear rate (0–500 s⁻¹) under steady shear conditions. At each shear rate, the sample was sheared for 15 s to reach steady state. The dynamic oscillatory shear flow measurements of the storage modulus (G'), the loss modulus (G'') and the loss tangent $\tan \delta = G''/G'$ were analyzed at frequency dependence (0.1–100 Hz) and 0.1 % strain. The temperature was controlled at 25 °C by circulating water bath (Handleman et al. 1961).

Statistical analysis

The data analysis, for Duncan multiple comparisons and response optimization were done using STATISTICA stat software release 8.0 package (Srivastava et al. 2011).

Sensory evaluation

Sensory evaluation of VCM based products and oil were carried out on the basis of 9-point Hedonic scale (ranging from 9 = like extremely to 1 = dislike extremely) by a panel of 25 semi trained panelists. All panelists were between the ages of 25 to 50 years. The order of the presentation of samples was randomized and different 2 digit number codes were used for

the sample sets. The coded samples were served at room temperature (25 °C) on a white disposable plastic plates and taste neutral water was provided for rinsing. The sensory evaluation was carried out for color, flavor, taste, texture and overall acceptability (OAA) of the product. The order of presentation between the coded samples was varied from one storage time to another. The results were presented as mean of 10 evaluations from 25 panelists (Larmond 1997).

Result and discussion

Effect of VCM on physical properties of cakes and batter microscopy

Batter specific gravity is related to the ability of the batter to incorporate air during mixing and it is also related to air cell size distribution in batter. During mixing the air incorporation in batter leads to the decrease in specific gravity. In the present study due to incorporation of VCM weight of the batter increased while volume decreased which results in higher value of specific gravity (Arunepanlop et al. 1996). The effects of percentage of VCM on physical properties of batter are shown in Table 1. In the present study VCM batter containing 0 % VCM has low specific gravity i.e. 1.01 (due to air incorporation volume increase for the same weight of batter) which was further increased with the VCM percentage (5 to 20 %). This could be due to the presence of coarser size of VCM (containing 55 % IDF and 4 % SDF) which hinder the incorporation of air as VCM has no surface active agents and emulsifying properties (i.e. not able to form a membrane around oil droplet) to retain the air in batter like other flour and soluble fiber. This can be justifying by the micrographs of batter containing VCM at different percentage (0 to 20 %). In the control batter sample (0%VCM) leads to formation of large, small and very

Table 1 Physical properties of cakes containing different concentration of VCM ($n = 3$)

VCM (%)	Volume index	Symmetry index	Uniformity index	Specific gravity	Weight loss (%)
0	11.71 ± 0.01^c	1.00 ± 0.01^a	0.21 ± 0.01^a	1.01 ± 0.01^a	19.85 ± 0.14^a
5	11.33 ± 0.01^c	0.91 ± 0.01^{ab}	0.32 ± 0.02^a	1.04 ± 0.02^a	21.92 ± 0.06^a
10	10.50 ± 0.11^b	0.82 ± 0.02^b	0.54 ± 0.01^b	1.12 ± 0.01^b	25.78 ± 0.03^b
15	10.31 ± 0.02^{ab}	0.63 ± 0.01^c	0.60 ± 0.02^{bc}	1.21 ± 0.01^c	37.84 ± 0.11^c
20	9.72 ± 0.12^a	0.41 ± 0.01^d	0.71 ± 0.02^c	1.25 ± 0.02^c	39.55 ± 0.03^c

Mean values with the same superscript letters within the same column do not differ significantly ($p \leq 0.05$)

small air bubbles after mixing as clearly visible in Fig. 2a. But as the percentage of VCM has been increased the clear large air bubbles are not visible while in place of that small air bubbles are uniformly distributed in batter. Very less small sized air bubbles are predominantly seen in 20 % VCM sample (Fig. 2b, c, d). This may be due to the presence of fiber in VCM sample which hinder the formation of air bubbles (reduction of foam stability). The air cells were uneven sized and distribution in the batter was of non-uniform nature which affects the symmetry index, uniformity and volume index of cake. In the present study the increase percentage of VCM leads to reduction in volume index, symmetry index above 5 % level while uniformity index and specific gravity increased in the similar pattern. Symmetry index is an indicator of surface contour while uniformity index is a measure of cake symmetry. Symmetry indicates the difference in height between the central zone and the lateral zone. Thus, high symmetry suggest that cakes mainly rise in their central part, while a negative symmetry indicates that cake volume falls down at the end of the baking process. The control sample had a high symmetry index indicating that the cake had more height in

the centre and less at the sides and a convex shape. The lowering of symmetry index indicated that the cakes showed a flatter surface at higher level of VCM (20 %) (Presence of fiber entraps least amount of air during mixing). In the same way the high incorporation of VCM leads to the higher uniformity index values (revealed that the cakes had uneven surface). The similar result can also relate to volume index i.e. high percentage of VCM increase the viscosity (This can be also justified with the particle size of refined wheat flour 150μ which was less than the VCM 500μ that could impede expansion and diminish cake volume (Campbell and Mougeot 1999).

Batter viscosity is the determining factor for the cake quality after as during mixing and baking (formation of CO_2). If the viscosity was too low air bubbles were escape quickly during baking (resulting in low cake volume) and if it is too high it does not allow enough air bubbles to form during batter mixing which can impede expansion (Hoseney and Delcour 2010). The datas were justified with the results reported by Gomez et al. (2010). Some authors have reported that upto certain level of incorporation of fiber increase volume index

Fig. 2 Photomicrograph of VCM cake batter

Fig. 3 Storage modulus (G'), loss modulus (G''), loss factor ($\tan \delta$) and viscosity of VCM cake batter

but more addition of fiber leads to reduction in volume index (Table 1).

Effect of VCM on rheology of cake batter

The batter viscosity is the important factor controlling the final volume (volume index) of a cake during baking. It has been reported that upto a certain limit of increase in viscosity aids in incorporating and retaining more air bubbles thus providing more stability to the cake (Handleman et al. 1961) but if viscosity increase beyond the limit it impede the expansion during baking. In the present study the viscosity of cake batter was a function of shear rate as shown in Fig. 3. All the samples containing VCM of different percentage (5 %–20 %) showed high viscosity at ambient temperature (shear thinning behavior over the shear rate) which was agreed with the result reported by Shalke et al. (1988). Earlier some studies reported that increased batter viscosity had tendency to retain air incorporation in the cake batter (leads to increase in volume index) but this phenomenon was not applicable for VCM batter because of the coarser particle size of VCM which impede the expansion of cake during baking (reduction of air cell formation). The dynamic oscillatory shear viscoelastic property

(storage moduli (G'), loss moduli (G'') and $\tan \delta$) of cake batters were investigated as a function of frequency (Fig. 3). VCM has water absorption capacity (WAC) 4 g/g which leads to lower the amount of free water in system making the batter harder to deform (Dogan 2002). The $\tan \delta$ is a rheological parameter often used in food rheology that shows the relative contributions of elastic and viscous components to the material. The magnitude of G' is affected by a number of factors apparently the frequency dependence is determined by the quantity of protein and moisture content. Low protein flour took less water to reach target consistency and G' were higher at high frequency. In the present investigation though VCM was rich in protein content and with the increase in VCM percentage protein content of batter got increased yet VCM was rich in fiber which hinder the availability of free water results decreased in G' and G'' (less elastic and viscous modulus) (Navickis et al. 1982). All the samples containing VCM had phase shift angle ($\tan \delta$) of less than 1 indicating highly associated batters due to colloidal forces (Fig. 3). The colloidal force ($\tan \delta$) of batters increased with increasing the VCM concentration suggesting a decrease in cohesiveness of batter. This in turn could be due to the fact that fiber in VCM requires longer time to hydrate.

Table 2 Chemical and nutritional components of cake containing VCM ($n = 3$)

VCM (%)	Moisture (%)	Fat (%)	Protein (%)	Fiber (%)	Ash (%)	Carbohydrate (%)
0	10.67 ± 0.11 ^a	18.51 ± 0.11 ^a	5.91 ± 0.02 ^a	0.09 ± 0.01 ^a	0.41 ± 0.01 ^a	64.43 ± 1.01 ^a
5	12.89 ± 0.11 ^a	22.23 ± 0.13 ^b	6.23 ± 0.11 ^a	0.65 ± 0.02 ^a	0.48 ± 0.02 ^b	57.48 ± 1.03 ^b
10	14.68 ± 0.12 ^b	24.99 ± 0.16 ^b	6.51 ± 0.10 ^{ab}	1.29 ± 0.03 ^b	0.55 ± 0.01 ^c	51.99 ± 1.03 ^b
15	16.47 ± 0.17 ^c	28.69 ± 0.13 ^c	6.83 ± 0.12 ^b	1.79 ± 0.02 ^c	0.63 ± 0.02 ^d	45.62 ± 1.04 ^c
20	17.23 ± 0.12 ^c	32.79 ± 0.14 ^d	7.14 ± 0.04 ^c	2.35 ± 0.01 ^d	0.70 ± 0.02 ^e	39.83 ± 1.02 ^d

Mean values with the same superscript letters within the same column do not differ significantly ($p \leq 0.05$)

Table 3 Color values of VCM cake crust, crumb and batter ($n = 3$)

VCM (%)	Crust			Crumb			Batter		
	L*	a*	b*	L*	a*	b*	L*	a*	b*
0	58.28 ± 0.01 ^a	7.21 ± 0.11 ^a	25.03 ± 0.09 ^a	56.47 ± 0.21 ^a	0.92 ± 0.01 ^a	16.80 ± 1.02 ^a	47.76 ± 0.11 ^a	0.26 ± 0.01 ^a	16.31 ± 0.11 ^a
5	57.24 ± 0.21 ^a	8.81 ± 0.11 ^b	26.16 ± 0.07 ^a	56.27 ± 0.15 ^a	1.06 ± 0.03 ^a	18.18 ± 0.11 ^b	47.43 ± 0.11 ^a	0.28 ± 0.02 ^a	17.28 ± 0.03 ^{ab}
10	56.31 ± 0.11 ^b	9.17 ± 0.12 ^{bc}	28.71 ± 0.06 ^b	54.43 ± 0.06 ^b	1.18 ± 0.04 ^b	18.76 ± 0.10 ^b	44.72 ± 0.20 ^b	0.39 ± 0.01 ^a	18.15 ± 0.11 ^b
15	54.08 ± 0.20 ^c	9.21 ± 0.11 ^c	32.51 ± 0.08 ^c	52.31 ± 0.11 ^c	1.32 ± 0.01 ^b	19.27 ± 0.01 ^c	43.86 ± 0.10 ^b	0.46 ± 0.02 ^b	19.54 ± 0.11 ^c
20	51.22 ± 0.12 ^d	10.01 ± 0.05 ^d	34.91 ± 0.12 ^d	52.17 ± 0.11 ^c	1.87 ± 0.03 ^d	20.73 ± 0.11 ^d	43.58 ± 0.11 ^b	0.95 ± 0.01 ^c	20.16 ± 0.10 ^c

Mean values with the same superscript letters within the same column do not differ significantly ($p \leq 0.05$)

Effect of VCM on the proximate composition of VCM cake

Virgin coconut meal contains 10.81 ± 0.62 % moisture, 54.98 ± 1.05 % fat, 14.92 ± 0.25 % protein, 15.20 ± 0.2 % crude fiber, 2.54 ± 0.05 % ash content and 1.57 ± 0.02 % carbohydrate (by difference). It is a rich source of minerals like calcium (83.78 ± 0.015 mg/100 g), Sodium (98.77 ± 0.03 mg/100 g) and potassium (1700 ± 0.15 mg/100 g). Iron and zinc are present comparatively lower concentration, i.e., 22.76 ± 0.14 and 2.57 ± 0.05 mg/100 g respectively. Its water absorption capacity and solubility index were 4.82 g/g and 0.45 g/g respectively. Major fatty acid present in VCM was lauric acid (54.37 %) followed by myristic acid (20.13 %), palmitic acid (8.61 %), capric acid (5.81 %), oleic acid (5.49 %), stearic acid (3.14 %), linoleic acid (1.55 %) and caprylic acid (0.69 %). Proximate composition of cakes prepared by using VCM (5–20 %) is given in Table 2. It is evident that incorporation of VCM resulting changes in moisture content from 10.67 to 17.23 %, fat 18.51 % to 32.79 %, protein 5.91 % to 7.14 %, ash content 0.41 to 0.70 %, fibre 0.09 to 2.35 % and carbohydrate 64.43 % to 39.83 %. The statistical analysis of proximate composition revealed that there was no significant ($p \leq 0.05$) difference observed in moisture content up to 5 % replacement but addition of VCM above 5 % level, showed significant ($p \leq 0.05$) increase in moisture content. This may be due to high water absorption capacity of meal, i.e., 4.82 g/g which gradually increase with rise in the

concentration of VCM in cake. Similar, results has been reported by Tyagi et al. (2007) in mustard flour biscuit. The incorporation of VCM (5–20 %) resulted in considerable increase in the fat, protein, fibre and ash content of cake as mentioned in Table 2.

Changes in color values of crust and crumb

Baking leads to a common phenomenon i.e. surface browning in all bakery products. Generally, the color of the crust was affected by maillard and caramelization reaction during baking while the crumb color was affected by components used in the formulation. The color of crust, crumb, and batter varied with the quantity of the VCM and there was significant ($p \leq 0.05$) effect on color observed on cake crust, crumb and batter due to the addition of VCM in comparison to control (Table 3). As the percentage of VCM was replaced more with refined wheat flour, the L*value got lowered significantly ($p \leq 0.05$) after addition of VCM more than 5 % in cake which indicates the darkness of crumb and crust of cakes with higher percentage VCM than the control. This may be due to the intrinsic color of whole VCM caused the darkening of cake's crust, crumb and batter. The results were in agreement of color values which reported by Brewer et al. (1992) in soy protein and fiber incorporated cakes. Color measurement is required to estimate the brown pigments are formed in the advanced stages of browning reactions. The a* and b* value (which is the index of yellowness-blueness and redness-greenness)

Table 4 Textural properties of cakes containing different concentration of VCM ($n = 3$)

VCM (%)	Hardness (N)	Adhesiveness (g.sec)	Springiness	Cohesiveness	Gumminess	Chewiness
0	24.22 ± 0.03 ^c	−4.75 ± 0.11 ^a	0.85 ± 0.01 ^a	0.87 ± 0.01 ^a	25.20 ± 0.12 ^a	20.51 ± 0.01 ^a
5	27.39 ± 0.02 ^b	−4.76 ± 0.10 ^a	0.84 ± 0.01 ^a	0.86 ± 0.02 ^a	24.72 ± 0.13 ^a	20.09 ± 0.12 ^a
10	28.74 ± 0.05 ^b	−6.72 ± 0.13 ^b	0.80 ± 0.01 ^{bc}	0.81 ± 0.03 ^b	21.88 ± 0.11 ^b	18.58 ± 0.02 ^b
15	31.66 ± 0.04 ^a	−7.54 ± 0.04 ^b	0.79 ± 0.01 ^{cd}	0.80 ± 0.01 ^b	19.65 ± 0.14 ^c	16.98 ± 0.05 ^b
20	32.79 ± 0.06 ^a	−9.34 ± 0.02 ^c	0.78 ± 0.01 ^d	0.78 ± 0.01 ^c	17.47 ± 0.03 ^d	13.37 ± 0.15 ^c

Mean values with the same superscript letters within the same column do not differ significantly ($p \leq 0.05$)

were found significantly ($p \leq 0.05$) increased with the higher percentage ($>5\%$) of VCM incorporation in comparison to control. The similar trend has been reported biscuits fortified with corn and potato flour. Some studies on the color changes by replacing VCM have been reported in biscuits (Srivastava et al. 2010).

Effect of VCM on textural profile analysis of samples

The effect of the presence of VCM on texture characteristic of cake tabulated in Table 4. Texture of cakes was significantly ($p \leq 0.05$) affected by replacement of flour with VCM. The percentage of VCM increased more than 5 % the cohesiveness, gumminess and chewiness decreased while adhesiveness and hardness increased significantly ($p \leq 0.05$) in VCM cakes than that of control (Table 4). This may be due to the lower volume index which in turn was due to higher specific gravity of cake batter caused by variation in water absorption of VCM at higher replacement levels leads to reduction in strength of gluten bonds (because of coarser size of VCM 500 μ in comparison to the wheat flour 150 μ). There was significant ($p \leq 0.05$) negative correlation ($r = 99.76\%$) between the cake volume and hardness as during baking fiber reduce the air incorporation and impede expansion.

Effect of VCM on thermal analysis of cake and batter

The extent of gelatinization plays an important role in textural quality of freshly baked products and may influence the shelf life of the products. Differential scanning calorimetry (DSC) results showed there was significant ($p \leq 0.05$) difference between T_o , T_c , T_p and ΔH of batter and cake which indicates that some of starch was already gelatinized in cake baking. The crust portion of cake has not been analyzed for DSC as the type of bakery products (depending on product formulation and process) decided the degree of starch gelatinization (Derby et al. 1975). Generally, in cake crust starch was completely gelatinized while in crumb (centre portion of cake) was not

Fig. 4 Representative graph of Differential Scanning calorimetry showing effect of VCM on Cake (crumb) and batter

gelatinized (Yasunga et al. 1968). From the present data T_o , T_c , T_p and ΔH were higher for batter in comparison to crumb (center portion of cake) this may be due to the uncaramelized sugar present in batter system which has property to increase the gelatinization temperature of starch or it may also be explained by the competition between sugar and fiber for water which limits the availability of water (Abboud and Hosney 1984). High flour replacement by VCM (containing 15 % fiber) modifies the mechanism of water mobility and availability in the food system which gives a general trend that high fiber concentration leads to high T_o , T_p and lower T_c , ΔH value (Table 5). Free moisture present in the system probably is the most important factor which governs starch swelling (Audider 1968). Restricted or delayed swelling of starch granules resulted from the presence of fiber (delay T_o in flour–fiber mixture). During melting fiber absorbs more water and make it unavailable for the remaining ungelatinized granules. In order to this ungelatinized granules will melt at high temperature (high T_p) and will require less energy to disorganize its structure. In cake and batter the lower value of ΔH indicates that reduction in starch available for gelatinization (Fig. 4). This reduction is likely due to water being retained from the starch granules by fiber and from a general reduction in starch content of the pastes because of the replacement of fiber. As ΔH decrease by restricted water availability which leads to the restriction in

Table 5 Effect of VCM on the thermal properties of batter and cake

VCM (%)	Crumb				Batter			
	T_o	T_p	T_c	ΔH (J/g)	T_o	T_p	T_c	ΔH (J/g)
0	63.41 $\pm$ 0.11 ^a	68.16 $\pm$ 0.13 ^a	72.29 $\pm$ 0.13 ^a	14.16 $\pm$ 0.08 ^a	72.79 $\pm$ 0.01 ^a	77.39 $\pm$ 0.07 ^a	81.69 $\pm$ 0.01 ^a	23.39 $\pm$ 0.13 ^a
5	63.64 $\pm$ 0.12 ^a	68.32 $\pm$ 0.17 ^a	72.82 $\pm$ 0.14 ^a	15.73 $\pm$ 0.01 ^a	73.81 $\pm$ 0.02 ^a	78.11 $\pm$ 0.03 ^a	82.38 $\pm$ 0.02 ^a	24.34 $\pm$ 0.08 ^a
10	65.15 $\pm$ 0.13 ^a	70.35 $\pm$ 0.14 ^a	75.69 $\pm$ 0.15 ^b	20.35 $\pm$ 0.05 ^b	76.39 $\pm$ 0.05 ^b	80.28 $\pm$ 0.02 ^a	84.26 $\pm$ 0.03 ^a	28.87 $\pm$ 0.09 ^b
15	72.34 $\pm$ 0.16 ^b	75.36 $\pm$ 0.13 ^b	78.39 $\pm$ 0.18 ^d	25.11 $\pm$ 0.02 ^c	80.24 $\pm$ 0.07 ^c	84.13 $\pm$ 0.01 ^b	88.38 $\pm$ 0.02 ^b	32.56 $\pm$ 0.06 ^c
20	76.86 $\pm$ 0.17 ^c	80.24 $\pm$ 0.12 ^c	82.33 $\pm$ 0.15 ^c	29.39 $\pm$ 0.03 ^d	87.31 $\pm$ 0.05 ^d	89.27 $\pm$ 0.04 ^c	90.26 $\pm$ 0.06 ^c	39.97 $\pm$ 0.02 ^d

Mean values with the same superscript letters within the same column do not differ significantly ($p \leq 0.05$): T_o (On set temperature), T_p (Peak temperature), T_c (End set temperature)

starch–water system the T_c increased progressively (Khanna and Tester 2006). In fiber enriched batter fiber replacement of flour encompass a diluting gluten and starch effect (Pomeranz et al. 1977), a disruption of starch gluten matrix that forces gas cells to expand in a particular dimension and an increased in fiber content leads to dough weaking (Collar et al. 2005, 2006). The diluting effect of gelatinized starch by the presence of fiber would decrease the starch availability for crystallization.

Sensory evaluation of VCM cake

The texture, color, aroma and overall acceptability scores of VCM incorporated cake were in the acceptable range (6–9). Surface color of the cake was pale yellow upto 10 % level; thereafter it turned dark yellow at 20 % level of substitution which leads to the low score on hedonic scale by panelist. The cake was soft in the case of control sample while increase in the concentration of VCM leads to increase in hardness which was in accordance with the texture measurements. The cake containing 10 % VCM was the most acceptable by 25 panelists and rated highest hedonic score i.e. 9.

Conclusion

From the data shown in this study it is apparent that cake mixture with up to 15 % VCM replacement can be used without causing any deterioration in food quality with the replacement of refined wheat flour cake volume and symmetry index which leads to the increase hardness and decrease in gumminess and chewiness. Color characteristics of cakes such as L^* , a^* , b^* values varied significantly with addition of VCM than the control. The data obtained from thermal property showed that onset (T_o), endset (T_c) temperatures and enthalpy of gelatinization (ΔH) got affected by VCM.

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