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Original article

Effect of virgin coconut oil cake on physical, textural, microbial and sensory attributes of muffins

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Summary A study was carried out to develop muffins by substituting refined wheat flour (RWF) with virgin coconut oil (VCO) cake (0–50 g/100 g flour blend). Progressive replacement of RWF with VCO cake resulted in significant ($P < 0.05$) decrease in peak viscosity of flour blends (from 2527.75 cP in the control to 389.5 cP in 50 g VCO cake/100 g flour blend) and the muffins height (from 34.26 mm in the control to 26.88 mm in 50 g VCO cake/100 g flour blend). Significant colour change was observed in the crust and crumb regions. Free fatty acid and microbial analysis revealed that the quality of muffin samples was unaffected by the addition of VCO cake during 16-day storage at both refrigerated (4 ± 2 °C) and ambient temperature (35 ± 2 °C). Incorporation of 40 g VCO cake/100 g flour blend significantly ($P < 0.05$) increased the overall acceptability of the muffins (with a maximum score of 8.5). Muffins with 40 g VCO cake/100 g flour blend were enriched with protein (8.49 g/100 g), fat (18.46 g/100 g), crude fibre (1.14 g/100 g) and minerals (1.15 g/100 g).

Keywords Muffins, refined wheat flour, virgin coconut oil cake, virgin coconut oil.

Introduction

Changing lifestyle and eating habits of today's generation has opened a vast market for processed food products. Among them, an important category is baked foods. The popularity of bakery products such as bread, biscuits, cakes, muffins and pastries is increasing tremendously. Among them, muffins are sweet baked product appreciated among the consumers of all age groups, especially children due to its good taste and soft texture. The principal ingredients of muffins such as refined wheat flour (RWF), sugar, shortening and egg play an important role in the structure, appearance and eating quality of the final product (Karaoglu & Kotancilar, 2009). As far as coconut is concerned, coconut-based cookies and biscuits are available in the market. But so far, no report has been found on its utilisation in the form of other baked foods like muffins. Coconut and its by-products can be explored for the use as partial substitute for RWF as it is rich in carbohydrate, fat, protein, fibre, etc., which would enrich the nutrient content of the final product.

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Virgin coconut oil (VCO) cake is a co-product obtained during the production of the VCO. Virgin coconut oil is an important value-added product of coconut which is the oil obtained from the fresh and matured kernel of the coconut through manual or mechanical means, with or without the use of heat and without subjecting it to any chemical refining, bleaching and deodorizing process (Marina *et al*., 2009). VCO cake obtained during VCO production is rich in protein (20.12 g/100 g), fat (35.57 g/100 g), crude fibre (3.8 g/100 g) as well as dietary fibre (12.75 g/100 g) (Manikantan *et al*., 2015). Arivalagan *et al*. (2015) further evaluated its phenolic activity (158.07 mg Gallic Acid Equivalent) and antioxidant potential (446.88 mg Trolox equivalent using Cupric Reducing Antioxidant Capacity method). It also contains 22.08 g/100 g total soluble sugars and 1.57 g/100 g reducing sugars. The lauric acid present in the cake will help to support the immune system (Trinidad *et al*., 2006). Despite the benefits, its effect on the quality of the value-added products is still unknown to the public. Presently, VCO cake is used as an animal feed or otherwise thrown as waste. Incorporation VCO cake into bakery products like muffins would provide a way for utilisation of this sparingly used co-product and thus, in

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turn, would be advantageous in opening new avenues for VCO industry. The present investigation was therefore undertaken to evaluate the effect of partial replacement of RWF with VCO cake on the quality attributes of muffins.

Materials and methods

Raw materials

Commercial RWF ('Arjun', Ludhiana, Punjab), sugar powder, egg, full fat milk (Mother Dairy, India), butter ('Amul', India), sodium bicarbonate (Bakers, Coimbatore, India) and salt (Tata, India) were purchased from the local market of Ludhiana, Punjab, India. Dried and powdered VCO cake obtained from the West Coast Tall variety was procured from ICAR-Central Plantation Crops Research Institute (ICAR-CPCRI), Kasaragod, Kerala, India.

Chemical analysis

All the reagents used for chemical analysis were of analytical grade and were procured from Merk, New Delhi, India. The proximate analysis such as moisture (method 44–19), protein (method 46–12), fat (method 30–25) and ash (method 8–01) contents of samples was determined using AACC (2000) standard methods. Carbohydrate was calculated by subtracting the sum of moisture, protein, fat and ash from 100. Minerals (calcium and iron) and crude fibre were determined using AOAC method (AOAC 1995).

Pasting properties of flour blend

Six batches of flour blends were prepared by progressively replacing RWF with VCO cake from 0 to 50 g/100 g flour blend. The pasting properties of the same were determined using a Rapid Visco Analyser (RVA-TecMaster, Model 3-D; Newport Scientific Pty. Ltd., Warriewood, NSW, Australia) with thermocline software (version 3.0, Newport Scientific Inc., Warriewood, Australia) (Lee *et al*., 2002). A suspension of 3.5 g flour (14% moisture) in 25 mL distilled water in an aluminium canister underwent controlled heating and cooling cycle at constant shear. Programmed heating and cooling cycle of short temperature profile (13 min) was carried at 960 rpm for 10 s and thereafter at 160 rpm for the remainder of the test. The sample was equilibrated at 50 °C for 1 min, heated to 95 °C at a rate of 12.2 °C/min, held at 95 °C for 2.5 min, cooled to 50 °C at the rate of 12.2 °C/min and then held at this temperature for 2.1 min. RVA plot of viscosity (cP) vs. time (s) was used to determine peak viscosity (AACC, 2000). The readings were made in triplicate for each flour blend. The test was run for 13 min. with initial temperature and speed being 50 °C and 960 rpm, respectively. The highest temperature used during the test profile was 95 °C, and the lowest speed was 160 rpm.

Preparation of muffin

Muffins preparation was conducted as per the method followed by Goswami *et al*. (2015) with a slight modification. Six muffin batter formulations were made by progressively replacing RWF with VCO cake flour ranging from 0, 10, 20, 30, 40 and 50 g/100 g flour blend. The control formulation consisted of RWF/flour blends (26 g/100 g), sugar (26 g/100 g), egg (21 g/100 g), full fat milk (13 g/100 g), shortening (butter was used) (12 g/100 g), sodium bicarbonate (1.1 g/100 g) and salt (0.1 g/100 g). Unlike the reference followed, the step containing the addition of citric acid (0.8 g/100 g) was avoided because of the sourness perceived in the baked muffins during the prestandardisation experiment.

Initially, the egg (white and yolk) was whipped in a dough mixer (Spar Quart Mini Mixer; SP-800, Taiwan, China) for 2 min at high speed (421 rpm). Sugar was then added and mixed in for 30 s at high speed (421 rpm) followed by addition of milk and shortening and mixed at medium speed (234 rpm) for about 1 min. RWF and VCO cake flour blend and sodium bicarbonate and salt were added and mixed at medium speed (234 rpm) for 1 min. In a silicone mould (12 grooves, three rows of four), paper muffin cups of about 50 mm diameter were arranged, and with the aid of a scoop and weighing balance, each paper muffin cup was filled with 30 g of batter. The silicone mould containing muffin batter was placed on a baking tray. The muffins were then baked in a preheated conventional oven at 200 °C for a maximum of 20 min. VCO cake-based muffin took 15–17 min for baking (end time for baking was prestandardised). Muffins were kept to cool at room temperature (35 ± 2 °C) for 60 min on a rack in order to avoid moisture condensing on their under surface and packed in low density poly ethylene (LDPE) tray. Each muffin batch was prepared in triplicate. Quality attributes of the muffins were analysed as per the standard methods.

Height of muffins (mm)

The height of the muffins was determined using vernier calliper (Model No. CD-800CSX; Mitutoyo Corp., Kawasaki, Japan, least count of 0.01 mm) according to the method followed by Cervera *et al*. (2012). Height was recorded from the highest point of the muffin to the muffin paper cup bottom with four replications.

Weight loss (g/100 g)

Muffin samples were weighed two times, that is before baking and after baking and cooling. The difference in weight was calculated as weight loss.

Colour

The colour of muffin samples was determined in terms of '*L*', '*a*' and '*b*' values using Hunter Lab mini Scan XE Plus colorimeter (Model 45/0-L, HAL, Reston, VA, USA) having 25 mm port size. Colorimeter was calibrated using colour standard (white and black) ceramic tiles supplied by the manufacturer, and the observations were then made using D-65 illuminant and 10° viewing angle. Measurement was taken according to the procedure followed by Goswami *et al*. (2015).

From the '*L*', '*a*' and '*b*' values, hue angle ($h°$), chroma (C) and colour change (ΔE) were computed as follows:

$$h^\circ = \tan^{-1}(b/a) \tag{1}$$

$$C = [a^2 + b^2]^{0.5} \tag{2}$$

$$\Delta E = ((\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2)^{0.5} \tag{3}$$

The indication of ΔE was described according to the procedure followed by Francis & Clydesdale (1975) which is as follows:

$\Delta E < 1$ colour difference are not obvious for human eye,

$\Delta E > 1 < 3$ minor colour difference that could be appreciated by the human eye depending on the hue,

$\Delta E > 3$ colour difference is obvious for the human eye.

Texture

Textural profile analysis was carried out using Texture analyzer (Stable Micro System Ltd, Model TA-XT2i, Godalming, UK). Muffins were cut horizontally at the height of the mould, and the lower half (2.5 cm) was considered for texture measurements while the upper half was discarded according to the method followed by Martinez-Cervera *et al*. (2011). A double compression test was performed using 75-mm-diameter flat-ended cylindrical probe (P/75), to a height of 1.25 cm (50% compression), at a speed of 1 mm s^{-1} with a 5 s waiting time between the two cycles. The peak force required during the first compression cycle is noted and expressed as hardness (*N*). Other parameters such as resilience, cohesiveness, springiness and chewiness (*N*) were calculated as per the reference (Goswami *et al*., 2015).

Free fatty acid content (g/100 g)

All the six muffin batches were packed in LDPE tray and kept for storage at ambient (35 ± 2 °C) and refrigerated condition (4 ± 2 °C) for 16 days. The samples were estimated for per cent free fatty acid (FFA) content at 4-day interval as per the method described by Thapar *et al*. (1988).

Microbial evaluation (cfu/g)

Dilution plating technique was followed for the estimation of microbial population in the muffin samples. The samples were analysed for total plate count, yeast and mould and total coliforms using standard plate count agar, Martin rose bengal agar and eosin methylene blue agar, respectively, at 0-, 4-, 8-, 12-, and 16-day interval. The results were expressed in terms of colony-forming unit (cfu) per g of muffin sample.

Sensory evaluation

The consumer acceptance test was conducted using semi-trained panellists (n = 25) consisted of scientists, technical staff under different age categories (<30, 30–40, 40–50 and >50) and children (age 13–15 and 16–18). Samples presented before the panel were coded with random three digit numbers. Before the evaluation, test and parameters were briefed. The panel was provided with two pieces of muffins for every experimental sample and asked to score them for different sensory attributes. Water was also provided to panellist as taste neutraliser. Sensory attributes like appearance, texture, flavour, taste and overall acceptability for the muffin samples were assessed using 9-point hedonic scale. (BIS, 1971).

Statistical analysis

Results were analysed for statistical significance by factorial analysis of variance (ANOVA), and means were compared using Tukey's studentised range test in SAS-9.2 Software (Cary, NC, USA).

Results and Discussion

Virgin coconut oil cake was analysed for moisture, protein, fat, ash and carbohydrate, and the corresponding values were 4.9 ± 1.0 g/100 g, 15.4 ± 0.3 g/100 g, 39.2 ± 4.2 g/100 g, 5.2 ± 0.7 g/100 g and 35.4 ± 5.4 g/100 g, respectively.

Pasting properties of flour blend

Pasting properties indicate the changes happened in the starch during heating and cooling in excess water.

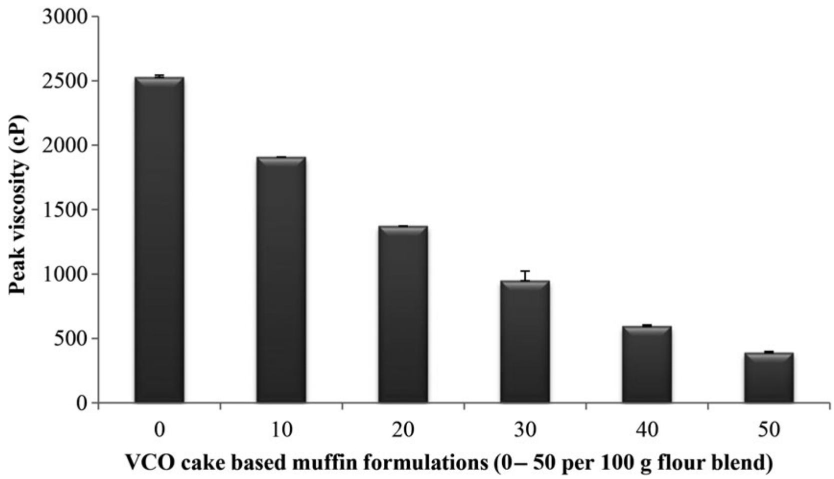

Figure 1 Effect of virgin coconut oil cake-based muffin formulations on peak viscosity of flour blend.

Progressive replacement of RWF with VCO cake had a significant effect on the peak viscosity. The changing trend in the peak viscosity with varying levels of VCO cake is shown in Fig. 1. The effect of VCO cake on batter viscosity was clearly visible. Peak viscosity decreased from 2527.8 cP of the RWF to 389.5 cP of the VCO cake (50 g/100 g flour blend). This is might be due to the increase in lipid, fibre and mineral content of the batter with increasing level of VCO cake flour that compete with starch granules for water absorption and hence obstructed the swelling of starch granules. Goswami *et al.* (2015) and Nimsung *et al.* (2007) also reported that the addition of lipid, fibre and mineral content to the batter would lead to decrease in the peak viscosity. This decrease is beneficial, as the excessive increase in viscosity could lead to problems in batter handling, mould filling and cleaning the machinery.

Height of muffins

Virgin coconut oil cake substituted flour resulted in a decrease in the height of muffins. It ranged from 26.9 to 34.3 mm. Results were in agreement with the findings of Baixauli *et al.* (2008). This decrease in the height of muffins containing VCO cake might be attributed to the decreased specific gravity (Khalil, 1998), limited gas cell stability due to dilution of gluten with increasing levels of VCO cake and lower peak viscosity of the muffin batter during heating (Shelke *et al.*, 1990). However, there was no significant difference among the control, muffin with 10 and 20 g VCO cake/100 g flour blend (Table 1). It was observed that muffins prepared with 50 g VCO cake had the minimum height (26.9 mm). Loss in both height and volume was also obtained in the muffin formulations with soluble cocoa fibre, peach dietary fibre and resistant starch (Grigelmo-Miguel *et al.*, 2001; Baixauli *et al.*, 2008; Martinez-Cervera *et al.*, 2011). In general, the addition of any type of fibre to the ingredients of a bakery product causes a reduction in both the height and volume of the final product (Peressini & Sensidoni, 2009).

Weight loss

Partial replacement of VCO cake resulted in nonsignificant ($P > 0.05$) weight loss in the muffins after baking (Table 1). However, maximum weight loss was observed in the formulation with 40 and 50 g VCO cake/100 g flour blend (12.3 g/100 g). The weight loss was close to 12 g/100 g for all the formulations. The higher water-binding capacity of RWF allowed little moisture to evaporate during baking, and hence, there was lesser weight loss.

Colour

Variations in muffin formulations affected the colour of final product. The main mass transfer characteristics associated with baking include an evaporation front moving from the surface towards the product core. The evaporation front divides the product into two zones: the crust (outer zone, dehydrated) and the crumb (inner zone, humid) (Ureta *et al.*, 2014). Surface crust colour is an important quality attribute used to characterise the end of the baking process (AitAmeur *et al.*, 2007). Maillard reaction occurring during baking gave brown colour to the crust. The major factors that influence browning are temperature, pH, water activity, reducing sugar, protein and amino acids (Purlis, 2010). As the temperature rises, the water content quickly reduced from the surface. The first Maillard reaction occurs at this stage. These conditions lead to the formation of the typical brown crust. Water loss will be lesser and slower from the crumb

Table 1 Effect of VCO cake on physical properties of muffin formulations

VCO cake formulation (g/100 g)	Muffin height (mm)	Weight loss (g/100 g)	Crust colour				Crumb colour			
			Lightness (*L*)	Hue (*h*°)	Chroma (*C*)	Colour change (Δ*E*)	Lightness (*L*)	Hue (*h*°)	Chroma (*C*)	Colour change (Δ*E*)
0	34.3 ± 1.8^{a}	11.1 ± 1.2^{a}	53.2 ± 2.2^{a}	44.4 ± 2.2^{a}	63.7 ± 3.7^{a}	0.00	76.5 ± 0.3^{a}	86.5 ± 0.3^{a}	31.3 ± 0.6^{a}	0.00
10	33.7 ± 1.7^{a}	11.8 ± 2.5^{a}	51.8 ± 1.6^{a,b}	44.0 ± 0.5^{a}	63.1 ± 1.0^{a,b}	2.0 ± 0.7^{d}	75.7 ± 0.8^{a}	84.9 ± 0.3^{b}	30.3 ± 0.3^{b}	1.6 ± 0.6^{e}
20	32.2 ± 0.8^{a,b}	12.1 ± 1.5^{a}	50.5 ± 0.5^{b,c}	44.1 ± 0.8^{a}	63.1 ± 1.2^{a,b}	2.9 ± 0.6^{c,d}	73.2 ± 0.5^{b}	84.2 ± 0.3^{c}	30.0 ± 0.3^{b,c}	3.8 ± 0.6^{d}
30	29.8 ± 3.2^{b}	12.2 ± 1.5^{a}	49.2 ± 0.5^{c,d}	44.0 ± 0.2^{a}	62.9 ± 0.4^{a,b}	4.0 ± 0.5^{c}	72.1 ± 0.6^{c}	81.8 ± 0.6^{d}	30.0 ± 0.2^{b,c}	5.3 ± 0.6^{c}
40	29.5 ± 1.5^{b,c}	12.3 ± 0.9^{a}	48.2 ± 0.5^{d}	43.6 ± 1.0^{a}	62.4 ± 0.9^{a,b}	5.3 ± 0.2^{b}	71.7 ± 0.9^{c}	80.1 ± 0.3^{e}	29.5 ± 0.1^{c,d}	6.2 ± 0.8^{b}
50	26.9 ± 0.6^{c}	12.3 ± 1.8^{a}	47.5 ± 0.7^{d}	41.1 ± 2.4^{b}	60.4 ± 2.1^{b}	7.2 ± 1.8^{a}	68.1 ± 0.5^{d}	78.4 ± 0.6^{f}	29.1 ± 0.4^{c,d}	9.7 ± 0.5^{a}

VCO, virgin coconut oil.
The results are presented as mean ± standard deviation.
Mean values not sharing the same letter differ significantly ($P < 0.05$).

region and relatively high water activity continues and temperature will not go beyond 105 °C. Here, Maillard reaction very slowly progresses; therefore, the crumb attains a light colour (Gonzalez-Mateo *et al.*, 2009).

Crust

The computed lightness ('*L*'), hue (*h*°), chrome (*C*) and colour change (Δ*E*) values of the muffin's crust are given in Table 1. Maximum '*L*' value was obtained for the control (53.2), which was statistically similar with 10 g VCO cake/100 g flour blend. A general trend of decreasing '*L*' value with increasing VCO cake level was observed. This decrease was due to the natural brownish colour and the protein content (15.4 g/100 g) of VCO cake. Similarly, decreased '*L*' value of barnyard millet-based muffins was attributed to the dull cream colour of barnyard millet (Veena *et al.*, 2005) than RWF.

As far as the hue value of crust is concerned, a nonsignificant difference among the muffin formulations except for 50 g VCO cake flour was observed. The lighter the batter colour, the higher the hue value and vice versa (Baixauli *et al.*, 2008).

There was a nonsignificant effect in chroma of VCO cake-based muffin formulations (10–50 g VCO cake/100 g flour blend). The highest value was observed for the control sample (63.7).

The influence of the colour of VCO cake was clearly reflected in the Δ*E* values. It ranged from 2.0 to 7.2. Δ*E* obtained for 50 g VCO cake-based formulation was the highest (7.2) among the six batches. According to the result obtained for Δ*E*, muffins with 30, 40 and 50 g VCO cake/100 g flour blend were appreciable ($\Delta E > 3$).

Crumb

The crumb '*L*' value ranged from 68.1 to 76.5. Similar to the result obtained for crust '*L*' value, the control and 10 g VCO cake-based formulation was statistically similar with each other with the highest value among all the formulations. The lowest '*L*' value was observed in the muffin sample with 50 g VCO cake/100 g flour blend.

Unlike the hue value obtained for crust region, all the muffin formulations significantly influenced the hue of crumb. Addition of VCO cake resulted in significant ($P < 0.05$) decrease in the hue value from 86.5 in the control to 78.4 in 50 g VCO cake-based formulation.

Regarding chroma, control and 50 g VCO cake-based muffin formulation obtained the highest and lowest value, respectively. Increasing level of VCO cake resulted in decreased chroma value. Although fat was increasing in the muffin formulation with the addition of VCO cake (from 0 to 50 g/100 g flour blend), Maillard reaction could not take place in the crumb region.

The ΔE value varied from 1.6 to 9.7. The trend observed in ΔE value of different formulations was similar to that of crust. Muffins with 20, 30, 40 and 50 g VCO cake/100 g flour blend were appreciable ($\Delta E > 3$). Martinez-Cervera *et al.* (2011) reported that low-fat replacement of muffins with cocoa fat resulted in acceptable ΔE.

Texture

Texture is one of the main characteristics of bakery products. Fat contributes to aeration, crumb texture and mouth feel of the muffins. Increased level of VCO cake resulted in increased softness in the prepared muffins. One reason is the richness of fat in VCO cake which led to a significant change in the textural properties of the prepared muffins. Another reason being the richness of sugar exists in the VCO cake decreased gluten development and thus resulted in an increase in softness. These facts were evident from the significant ($P < 0.05$) decrease in hardness, springiness, resilience and chewiness of muffins with increasing levels of VCO cake. The changes in textural parameters are given in Table 2.

Hardness values of the muffin formulations containing VCO cake were significantly lower ($P < 0.05$) than control. It decreased significantly from 80.97 N (control) to 25.49 N (50 g VCO cake/100 g flour blend). It was in the order of control <10 g VCO cake <20 g VCO cake <30 g VCO cake <40 g VCO cake and <50 g VCO cake. Addition of VCO cake in the batter resulted in drastic reduction in hardness indicating a softer and crumbly texture. Reduction in fat content leads to increase in hardness (Jauharah *et al.*, 2014). It is evident that the presence of fat content (39.2 g/100 g) in the VCO cake resulted in decreased hardness in baked muffins. Addition of soluble fat and fibre led to the reduction in hardness to brownies (Swanson *et al.*, 2002).

Table 2 Effect of VCO cake on textural properties of muffin formulations

VCO cake formulation (g/100 g flour blend)	Hardness (*N*)	Springiness	Resilience	Chewiness (*N*)
0	80.97 ± 3.7^{a}	0.88 ± 0.0^{a}	0.22 ± 0.1^{a}	35.37 ± 0.9^{a}
10	67.23 ± 2.2^{b}	0.82 ± 0.0^{b}	0.17 ± 0.0^{a,b}	25.35 ± 0.0^{b}
20	60.06 ± 1.2^{c}	0.77 ± 0.1^{c}	0.16 ± 0.0^{b}	20.05 ± 0.7^{c}
30	38.86 ± 4.2^{d}	0.72 ± 0.7^{d}	0.14 ± 0.0^{b,c}	10.18 ± 0.2^{d}
40	34.66 ± 2.0^{e}	0.59 ± 0.1^{e}	0.09 ± 0.0^{c}	8.66 ± 0.4^{d}
50	25.49 ± 1.6^{f}	0.43 ± 0.0^{f}	0.08 ± 0.0^{c}	4.21 ± 0.4^{e}

VCO, virgin coconut oil.
The results are presented as mean ± standard deviation.
Mean values not sharing the same letter differ significantly ($P < 0.05$).

Springiness is a vital quality characteristic of muffins which indicates the ability of the sample to recover its height during the time that elapses before the end of the first compression and the start of the second. It measures elasticity by determining the extent of recovery between the first and second compression. It is associated with the number of air bubbles incorporated into the muffins during mixing process (Rahman *et al.*, 2015). Springiness of the muffins was also adversely affected by the addition of VCO cake (from 0.88 to 0.43 in the control and 50 g VCO-based formulation, respectively), which was evident from the lower springiness values obtained for VCO cake-based formulations (0.82, 0.77, 0.72, 0.59 and 0.43 in 10, 20, 30, 40 and 50 g VCO cake-based formulations, respectively) in comparison with the control (0.88). Addition of ingredients rich in carbohydrate and minerals is known to decrease the springiness of muffins, which was noticed by Goswami *et al.* (2015) after the incorporation of barnyard millet in the flour blend.

Resilience depicts the ability of the product to recover after deformation. Decreasing trend in resilience with the addition of VCO cake was observed. However, resilience of the muffins containing 10 g VCO cake/100 g flour blend (0.17) was statistically ($P > 0.05$) similar with the control (0.22), 20 g VCO cake (0.16) and 30 g VCO cake (0.14)/100 g flour blends. The lowest value (0.08) for resilience was obtained for the muffins containing 50 g VCO cake-based formulation. This indicated that due to the crumby and softer texture of muffins, it took more time to regain back after the first compression.

Chewiness is the parameter associated with the ease or difficulty in chewing the food. Chewiness of muffins was significantly influenced ($P < 0.05$) by VCO cake level. The maximum and minimum value for chewiness was obtained for the control (35.37 N) and 50 g VCO cake-based formulation (4.21 N), respectively. There was no significant difference between the chewiness of muffins with 30 and 40 g VCO cake/100 g flour blend. The more crumbly texture of the VCO cake-based muffins might attribute to the dilution of gluten in muffin formulations. Similar result was reported by Bhaduri (2013) in the replacement of wheat flour with gluten-free flour such as rice and quinoa flour in the muffin formulation. The decreased viscosity of muffin batter resulted into a decrease in hardness and chewiness. However, all the textural parameters vary depending on the ingredients used. For example, increase in the chewiness of muffins was found with increased level of wheat grass powder (Rahman *et al.*, 2015). Rajiv *et al.* (2011) and Srivastava *et al.* (2012) reported a decrease in cohesiveness, chewiness and springiness values of the muffins with increasing level of finger millet flour blend and fenugreek seed husk.

Free fatty acid

The changes in FFA content of muffins prepared from RWF and VCO cake during storage (0, 4, 8, 12 and 16th day) at ambient (35 ± 2 °C) and refrigerated condition (4 ± 2 °C) were analysed and depicted in Figs 2 and 3, respectively.

From Fig. 2, it can be observed that the FFA content increased significantly during storage. A gradual increase was observed till the end of storage. A lower FFA was observed in the muffins stored under refrigerated condition (Fig. 3). It ranged from 0.07–0.40 g/100 g and 0.07–0.15 g/100 g in ambient and refrigerated storage condition, respectively. Nevertheless, the content remained under acceptable limit specified under Asian and Pacific Coconut Community (≤0.5%) till 16 days of storage (Dayrit *et al.*, 2007). At the end of storage, FFA of muffins with 50 g VCO cake/100 g flour blend (under ambient condition) reached to 0.40 g/100 g.

Comparison between the increase in FFA content during the initial (0th day) and final (16th day) evaluation was also statistically analysed, and the result (Table 3) revealed that under ambient condition, FFA content of muffins with 50 g VCO cake/100 g flour blend and the control was significantly higher than the rest of the formulations. Muffins prepared with RWF had comparatively higher FFA content during the storage under refrigerated condition. It means that the rate of increase in FFA of VCO cake (as per cent lauric acid) was significantly lesser under refrigerated storage condition. Goswami *et al.* (2015) observed a sharp increase in FFA in the 100 g barnyard millet flour/100 g flour blend up to 3 days of storage (both in ambient and refrigerated condition) followed by a decrease up to 6 days in which the control muffin sample showed higher FFA.

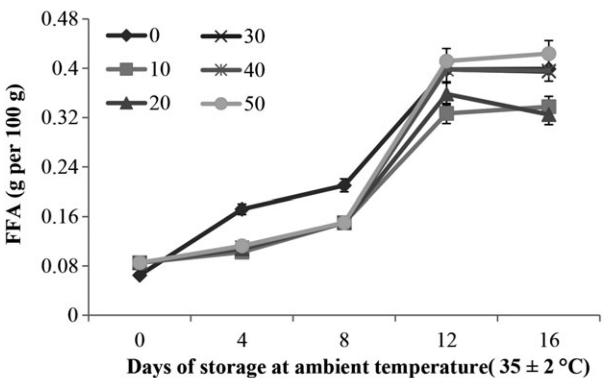

Figure 2 Changes in free fatty acid content of muffin samples prepared from refined wheat flour and virgin coconut oil cake during storage at ambient (35 ± 2 °C) condition.

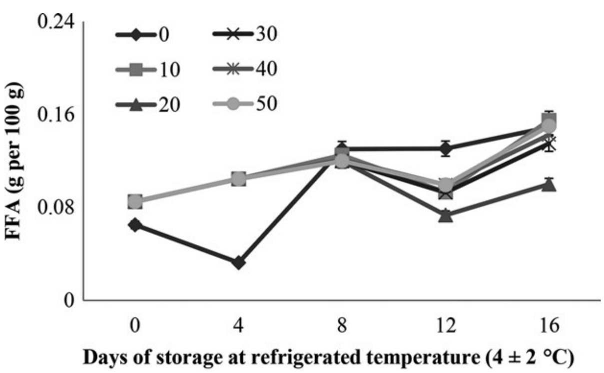

Figure 3 Changes in free fatty acid content of muffin samples prepared from refined wheat flour and virgin coconut oil cake during storage at refrigerated (4 ± 2 °C) condition.

Microbial evaluation

Muffins were evaluated for total aerobic bacteria, yeast and moulds and total coliforms at 0-, 4-, 8-, 12- and 16-day interval. It was observed that till 16 days, the products were safe under both refrigerated (4 ± 2 °C) and ambient (35 ± 2 °C) conditions. On 16th day, bacterial count of 1.3×10^5 cfu/g was obtained from the control sample. Plating of VCO cake-based muffin formulations resulted in a count lesser than 30 which is identical to nondetectable count. However, after 16 days of storage, visible mould growth was observed in the samples kept under ambient condition. The presence of oil in the VCO cake might act as antimicrobial agent (Satheesh, 2015). Chauhan *et al.* (2001) reported *Bacillus* species as the predominant bacterial isolates and *Penicillium* and *Aspergillus* as the

Table 3 Increase in FFA content (between 0th and 16th day) of muffin formulations during storage

VCO cake formulation (g/100 g flour blend)	Increase in FFA during ambient storage (35 ± 2 °C)	Increase in FFA during refrigerated storage (4 ± 2 °C)
0	$0.33 \pm 0.01^{a,b}$	0.08 ± 0.01^{a}
10	0.25 ± 0.02^{c}	$0.07 \pm 0.01^{a,b}$
20	0.24 ± 0.00^{c}	0.02 ± 0.00^{d}
30	0.31 ± 0.01^{b}	0.05 ± 0.02^{c}
40	0.31 ± 0.00^{b}	$0.06 \pm 0.02^{b,c}$
50	0.34 ± 0.03^{a}	$0.07 \pm 0.00^{b,c}$

VCO, virgin coconut oil; FFA, free fatty acid.
Mean values not sharing the same letter differ significantly ($P < 0.05$).
The results are presented as mean ± standard deviation.

predominant moulds in muffins. During microbial evaluation of barnyard millet-based muffins, Goswami *et al*. (2015) observed that microbial count of muffin samples prepared with 100 g barnyard millet flour remained under acceptable limit for more than 15 days under both the storage conditions.

Sensory evaluation

The mean sensory scores of the parameters such as appearance and colour, odour, texture, flavour and taste and the overall acceptability of the muffin formulations as affected by the level of VCO cake are given in Table 4. The sensory panel found statistical similarity among the appearance and colour of all the muffin formulations. Muffins containing 40 g VCO cake/100 g flour blend obtained the maximum score for odour (7.85). The lowest score for odour was obtained for the control (7.25) and the muffins with 50 g VCO cake-based formulation (7.25). Regarding texture, as the VCO concentration increased, the product became softer because of the enriched fat presents in the VCO cake (39.2 g/100 g). Texture of 40 and 50 g VCO cake-based formulations was significantly different from other formulations including control with a mean score of 8.55 and 8.83, respectively. The control sample obtained the lowest score for flavour and taste. The order of preference of muffins with VCO cake (in terms of flavour & taste) was 40 > 50 > 30 > 20 > 10 g > 0 g/100 g flour blend with mean score of 8.46, 7.95, 7.65, 7.50, 7.20 and 7.15, respectively. However, there was no statistical difference between 40 and 50 g VCO cake-based formulations. The mean overall acceptability scores of the VCO cake-based formulations ranged from 7.31 to 8.50. At 5% significance, muffins prepared with 40 and 50 g VCO cake/100 g flour blend scored 8.50, 8.10, reflecting the criteria ‘like very much’. All the muffin formulations with VCO cake had higher acceptability score over the control. However, while considering the lower odour scores and the predominant oily taste perceived (which was mentioned in the remark sheet of the sensory score card) in the muffin sample with 50 g VCO cake/100 g flour blend, the 40 g VCO cake-based sample was selected as the best among the different formulations.

Proximate analysis of the selected muffin sample

The proximate analysis of the muffins prepared with 40 g VCO cake/100 g flour blend as well the control sample (prepared with RWF) was analysed and shown in Table 5. Muffins prepared with VCO cake had a crumby and softer texture; hence, the moisture content was comparatively lower than the control. The protein- and fat-rich VCO cake leads to enriching the prepared muffins (8.5 g/100 g and 18.5 g/100 g protein and fat, respectively) as compared to the control (7.2 g/100 g and 16.8 g/100 g protein and fat, respectively). The higher mineral content present in the VCO cake-based muffin indirectly resulted in higher ash content (2.2 g/100 g) than the control (1.0 g/100 g). Lower carbohydrate level was observed in VCO cake-based muffins than the control (50.6 g/100 g and 51.2 g/100 g, respectively). This meagre change is because of the higher fat and protein of the VCO

Table 5 Proximate analysis of the RWF-based muffin (control) and VCO cake (40 g/100 g)-based muffins

Composition	RWF-based muffins (control)	VCO cake-based muffins (40 g/100 g)
Moisture (g/100 g)	23.8 ± 0.2	20.3 ± 0.3
Total calories (cal)	385 ± 0.3	403 ± 0.3
Protein (g/100 g)	7.2 ± 0.6	8.5 ± 0.6
Crude fat (g/100 g)	16.8 ± 0.4	18.5 ± 0.7
Ash (g/100 g)	1.0 ± 0.6	2.2 ± 0.7
Carbohydrate (g/100 g)	51.2 ± 0.1	50.6 ± 0.9
Crude fibre (g/100 g)	0.2 ± 0.0	1.1 ± 0.1
Total minerals (g/100 g)	0.6 ± 0.0	1.1 ± 0.0

VCO, virgin coconut oil; RWF, refined wheat flour.
The results are presented as mean ± standard deviation.

Table 4 Effect of VCO cake on sensory attributes of muffin formulations

VCO cake formulation (g/100 g flour blend)	Appearance and colour	Odour	Texture	Flavour and taste	Overall acceptability
0	8.20 ± 0.42[a]	7.25 ± 0.79[b]	7.00 ± 0.53[b]	7.15 ± 0.82[c]	7.29 ± 0.83[c]
10	8.00 ± 0.47[a]	7.55 ± 0.69[a,b]	7.00 ± 0.53[b]	7.20 ± 0.79[c]	7.31 ± 0.74[c]
20	8.06 ± 0.35[a]	7.57 ± 0.66[a,b]	7.05 ± 0.83[b]	7.50 ± 0.85[b,c]	7.51 ± 0.58[b,c]
30	8.01 ± 0.45[a]	7.68 ± 0.69[a,b]	7.50 ± 0.71[b]	7.65 ± 0.47[b,c]	7.69 ± 0.83[b,c]
40	8.10 ± 0.57[a]	7.85 ± 0.63[a]	8.55 ± 0.69[a]	8.46 ± 0.55[a]	8.50 ± 0.44[a]
50	8.20 ± 0.67[a]	7.25 ± 0.79[b]	8.83 ± 0.44[a]	7.95 ± 0.44[a,b]	8.10 ± 0.61[a,b]

VCO, virgin coconut oil.
The results are presented as mean ± standard deviation.
Mean values not sharing the same letter differ significantly ($P < 0.05$).

cake-based muffins. Crude fibre content was found to be higher in the VCO cake-based muffin (1.1 g/100 g) than the control (0.2 g/100 g). Because of the richness of the nutritional content of the VCO cake in terms of protein, crude fat, crude fibre and minerals, Manikantan *et al.* (2015) suggested its application for the preparation of extruded snacks.

Conclusion

The present study indicated that incorporation of VCO cake in muffin formulations resulted in significant effect on physical, textural and sensory attributes of the muffins. There was a decrease in the baked height, hardness, springiness, chewiness and resilience due to the reduction in gluten. The presence of VCO cake gave additional softness and crumby structure in the prepared muffin formulations. Even, all the VCO cake formulations (from 10 to 50 g/100 g flour blend) were liked by the sensory panel. The only problem found with the muffins containing 50 g VCO cake was its oily taste. However, the sensory acceptability of the VCO cake-based muffins was in the acceptable range (>7) with 40 g VCO cake having the maximum score of 8.50 which indicated the possible potential of development of this coconut co-product as raw material for intermediate foods like muffins. The product has a potential market as high nutritious high-calorie snack food among baked products appreciated by the sensory panel. As currently VCO cake is an underutilised co-product, the nutritionally enriched muffins prepared from VCO cake could increase the food uses of muffins as well as support the value chain of VCO-based ventures.

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