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Utilization of Structural Properties of Some Animal Fats to Produce Shortening and Its Use in Biscuit Production

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ABSTRACT

The aim of this study is to leverage the structural properties of camel and cow fats by blending them in different proportions (10, 15, 20, 25, 35, and 50%) with palm oil for use in shortening production. The results showed that all physicochemical properties of the three fat sources and their mixtures were within the recommended limits. The blending of camel or cow fats with palm oil improved the oxidative stability of palm oil, increasing its stability from 17.25 hours to 23.36 hours and 22.18 hours at 120°C for camel fat: palm oil and cow fat: palm oil at a 50:50 ratio, respectively. The solid fat content (SFC) of all camel fat: palm oil blends was higher than that of cow fat: palm oil blends. The fatty acid composition analysis revealed that palmitic acid in palm oil, oleic acid in cow fat, and stearic acid in camel fat were the most abundant fatty acids, with percentages of 46.46%, 31.18%, and 31.51%, respectively. Blending camel or cow fats with palm oil reduced the palmitic acid content while increasing the stearic acid content. The manufactured shortenings were tested in biscuit production. The results indicated that the incorporation of camel or cow fats was acceptable in biscuit formulations up to 25% substitution, based on sensory evaluation. The physical properties, texture, water activity, color, and hardness of the biscuits were comparable to those of the control sample across all formulations, except for the 35% and 50% substitution levels, which showed lower quality scores compared to the other samples.

1. Introduction

Fats are significant ingredients in many food industries, particularly in bakery products. In addition to being a source of energy, fat-soluble vitamins (A, D, E, and K), and essential fatty acids, fats also contribute to improving the rheological, viscosity, textural, structural, and sensory properties of bakery products (Choi et al., 2013; Izhar et al., 2022). The consumption rate of vegetable oils in Egypt was estimated at 1.845 million tons between 2016 and 2021, with palm oil accounting for the largest share at 41% (767.2 thousand tons). During the same period, domestic vegetable oil extraction from local and imported seeds amounted to 310.8 thousand tons. In 2021, the cost of imported palm oil reached 957.790 thousand dollars (Abdil Had, 2023). Shortenings are 100% fat products derived from animal fats or vegetable oils. They tenderize food by interrupting or shortening the fat films that form during heating, thereby preventing the hardening of carbohydrate and protein components (Devi and Khatkar, 2016). Palm oil is a potential raw material for shortening production due to its triacylglycerol composition and higher melting temperature compared to most other plant oils (Lai et al., 2012). Plant-based shortenings, particularly palm oil, are preferred in biscuit formulations due to their functional properties and cost-effectiveness (Yanty et al., 2014).Fat plays a crucial role in developing the properties of biscuits.

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The amount and type of fat incorporated into the dough significantly influence its viscosity (Baltsavias et al., 1997) and rheological properties (Jissy and Leelavathi, 2007; Mamat and Hill, 2014; Mamat and Hill, 2018). Fat is essential for preserving biscuit quality by contributing to tenderness (O'Brien et al., 2003), promoting texture, mouthfeel, and overall lubricity through interactions with other ingredients (Stauffer, 1998). Several studies have explored the possibility of substituting animal fats (cow, camel, lamb, and chicken fat) with palm oil to produce shortenings. These studies aimed to improve nutritional quality, compatibility, plasticity, microstructure homogeneity, viscoelastic response, textural properties, reduced cooking loss, brighter baking color, and crystal structure (Osman and Noraini, 1999; Wei et al., 2017; El-Anany and Ali, 2018; Subroto et al., 2020). Notably, animal fats are gaining attention due to their low cholesterol and high unsaturated fatty acid content (Mashaly et al., 2020). Camels and cows hold significant importance in Africa, the Middle East, and Asia as they provide milk, meat, and fat for human consumption. Edible camel and cow fats are used for cooking, though they are sometimes discarded as waste (Meng et al., 2010; Ahmad et al., 2010; Faye et al., 2014; Jorge et al., 2016). Fat constitutes 12-18% of a camel carcass and is stored in the hump, renal, and mesentery (Kurtu, 2004). The fatty acid composition of camel fat varies with the animal's age. The highest percentage of unsaturated fatty acids and the lowest percentage of saturated fatty acids are found in camels under one year old, while the opposite trend is observed in camels aged 1-3 years. Cholesterol levels in camel hump fat (139 mg/100g fresh weight) are lower than those in lamb and beef adipose tissues (196 and 206mg/100g fresh weight, respectively) (Kadim et al., 2013). Although the camel hump is considered offal, some studies highlight its importance as a cooking ingredient. It is regarded as a healthy fat due to its high vitamin E (alpha-tocopherol) content and the presence of saturated fatty acids, along with notable proportions of omega-3, -6, and -9 fatty acids. The combination of these fatty acids and vitamin E may offer protective effects against UVA radiation and exhibit anti-tumor activity (Jassim et al., 2018).

Dry, shelf-stable bakery products such as biscuits, crackers, and breadsticks are widely popular and consumed globally (Calligaris et al., 2008). Biscuits, in particular, are highly appreciated for their affordability, variety of tastes, and long shelf life (Romani et al., 2012). Traditional dry biscuits are made with flour, sugar, eggs, fat, and salt. Fats serve various functions in biscuit formulations, primarily influencing taste and structural properties (Pauly et al., 2013; Sudha et al., 2007).

The objective of this study was to evaluate shortening samples made from blends of palm oil with camel fat and palm oil with cow fat to assess their potential value in industrial applications. The shortening was used in biscuit production, and its effects on the physical properties of the biscuits were compared. The findings suggest that shortening manufacturers can use palm oil-camel fat and palm oil-cow fat blends in bakery formulations to meet consumer demands.

2. Materials and methods

Materials

Fresh fatty tissues (camel renal fat and cow fat) were obtained immediately after slaughtering from the Osim slaughterhouse in Giza Governorate, Egypt. All fatty tissues were stored under freezing conditions until further use. Refined, bleached, and deodorized (RBD) palm oil without antioxidants was obtained from Arma Company, located in the 10th of Ramadan City, Sharkia Governorate, Egypt. All reagents used were of analytical or HPLC grade and were sourced from Merck Millipore (Darmstadt, Germany) and AL Nasr Company, Egypt. All solvents used throughout the study were of analytical grade and were distilled before use.

Methods

Fat Extraction

All fats were extracted from fatty tissues using the wet rendering method. The rendering process was conducted at 90°C for 1 hour. The extracted fats were filtered through Whatman No. 1 filter paper and stored at 5°C (Sugihartono et al., 2019).

The Preparation of Shortening

The different fats, palm oil (P), camel fat (CA), and cow tallow (CO)—were melted and mixed according to the ratios specified in Table 1. The mixed fat was heated and stirred at 50°C for 30 minutes. It was then pre-cooled for 20 minutes at room temperature, followed by crystallization at a sharp quenching temperature of 20°C. The mixture was further cooled to 18°C, stirred, and kneaded for 5 minutes at room temperature. Finally, the mixed fat was stored at 25°C for 3 days. The samples were kept at 5°C until analysis (Wei et al., 2017).

Table 1. fatty materials and their blended samples

Name sample	Fat mixing ratio (%)
P	100 Palm oil
CA	100 Camel fat
CO	100 Cow fat
CA1	10 camel fat + 90 Palm oil
CA2	15 camel fat + 85 Palm oil
CA3	20 camel fat + 80 Palm oil
CA4	25 camel fat + 75 Palm oil
CA5	35 camel fat + 65 Palm oil
CA6	50 camel fat + 50 Palm oil
CO1	10 cow fat + 90 Palm oil
CO2	15 cow fat + 85 Palm oil
CO3	20 cow fat + 80 Palm oil
CO4	25 cow l fat + 75 Palm oil
CO5	35 cow fat + 65 Palm oil
CO6	50 cow fat + 50 Palm oil

Physicochemical Analysis

The refractive index (RI) at 25°C, melting point (MP), free fatty acids (FFA) % (expressed as oleic acid), and peroxide value (PV) (meq O_2/kg oil) were determined according to the methods described by AOAC (2019). The color index was measured at 420 nm using the method outlined by A.O.A.C. (2000).

Solid Fat Content (SFC)

The solid fat content (SFC) was determined using the AOCS Official Method (2019). SFC measurements were conducted using nuclear magnetic resonance (NMR) (Minispec mqone). Samples and standards were placed in NMR tubes, melted by heating to 80°C for 30 minutes, and then cooled to 60°C for 15 minutes. They were subsequently maintained at the desired temperatures (20°C, 30°C, and 40°C) for 60 minutes each before measurement.

Oxidative Stability Index (OSI)

The oxidative stability index (OSI) of palm oil (P), camel fat (CA), cow tallow (CO), and their mixtures was determined using the Rancimat method, an accelerated oxidation test (Mendez et al., 1996).

Fatty Acid Analysis

Fatty acid analysis was performed by preparing methyl esters, which were then identified using an Agilent 6890 series gas chromatograph equipped with a DB-23 column (60m × 0.32mm) (ISO, 2017).

Preparation of Biscuit Samples

Biscuits were prepared using the following formulation: 100 g of wheat flour (72% extraction), 33 g of shortening, 36 g of sugar, 3 g of baking powder, 0.25g of vanilla, and 25 ml of water. The preparation method followed the procedure described by Wade (1988).

Sensory Evaluation of biscuit samples

The samples were evaluated by 10 trained panelists randomly selected from the Bread and Pastries

Department at the Food Technology Research Institute, Agricultural Research Center, Giza, Egypt. Quality attributes such as aroma, taste, color, and overall acceptability were scored on a 9-point Hedonic scale. Panelists were instructed to rinse their mouths with water between samples and to avoid making comments during the evaluation to prevent influencing others. The raw scores were compiled and statistically analyzed according to the methods described by Meilgaard et al. (2016). The sensory evaluation results were statistically analyzed using CoStat statistical software (CoHort Software, Monterey, CA, USA). A one-way analysis of variance (ANOVA) was performed using a completely randomized design. Differences were considered statistically significant at $P < 0.05$, and means were compared using Duncan's test. All data were expressed as mean values ± Standard Deviation (SD), as described by Snedecor and Cochran (SAS, 1999).

Determination of Biscuit Color

The color of the biscuit samples was measured in duplicate using the L*a*b* color system, where L* represents lightness, a* represents redness, and b* represents yellowness. Measurements were taken using an X-Rite colorimeter (USA) (Yalcin, 2017).

Physical Properties of Biscuits

The weight of the biscuits was measured using a weighing balance. Thickness and diameter were measured using a caliper. The spread ratio was calculated by dividing the diameter by the thickness. All measurements were performed in triplicate (Yalcin, 2017).

Determination of Water Activity

Water activity (aw) was measured using an electronic device (ER-84, Novasina, Switzerland) equipped with an RTD-42 sensor block (Libor et al., 2006). The water activity of the biscuit samples was determined during storage over a period of 3 months.

Texture Profile Analysis of Biscuit Samples

Hardness (g) was determined according to the method described by A.A.C.C. (2000) using a Brookfield Texture Pro CT V1.6 Build texture analyzer. The hardness of the biscuit samples was measured at zero, 1, 2, and 3 months of storage.

3. Results and Discussion

Free Fatty Acids (FFAs)

Free fatty acids (FFAs) percentage is an important quality parameter for oils and fats. FFAs result from lipid hydrolysis, which is triggered by chemical or enzymatic actions (Abd El-Khair et al., 2019). The results presented in Table 2 show that the FFAs content of the fatty materials and prepared shortening samples ranged between 0.050% and 0.065%. These values are within the recommended limits set by the Codex Alimentarius Commission (2009) and the Egyptian Organization for Standardization and Quality (EOS, 2022), which specify a maximum FFA content of 0.3% for refined oils. This indicates that all samples are of good quality from an FFA perspective.

Peroxide Value (PV)

Peroxide value (PV) is a widely accepted parameter for monitoring the initial stage of lipid oxidation. It reflects the concentration of peroxides and hydroperoxides in fats and oils. Table 2 presents the PV of palm oil, camel fat, cow fat, and their prepared shortenings. Palm oil had the lowest PV (0.96 meq O_2/kg), which can be attributed to the refining process that removes peroxides and hydroperoxides. The PVs of camel and cow fats were 3.98 and 4.61 meq O_2/kg, respectively. The PV for shortenings prepared by blending camel and cow fats with palm oil at ratios of 10%, 15%, 20%, 25%, 35%, and 50% ranged between 1.45 and 2.88 meq O_2/kg. These results indicate that the PV of all samples is below the limit specified by the Codex Alimentarius Codex Stan 1.66/21027 (Codex, 2009) and EOS (2022), which state that the acceptable PV for shortening should be less than 10 meq O_2/kg.

Melting Point (MP)

The melting point (MP) is an important parameter used to describe the melting and hardening properties of oils and fats. It is also useful in determining the industrial applications of fats. The MP is related to the degree of unsaturation in oils and fats; the higher the level of unsaturation, the lower the

MP (Abd El-Khair et al., 2019). Table 2. shows the MP of palm oil, camel fat, and cow fat as 40°C, 48° C, and 46°C, respectively. The MP of all prepared shortening samples ranged from 40°C to 45°C, which is lower than the maximum limit of 46°C specified by Egyptian standards (EOS, 2022). The data also revealed a gradual increase in the MP of the prepared shortening samples as the substitution levels of camel or cow fats in palm oil increased. This increase in MP can be attributed to the higher saturated fatty acid content and lower unsaturated fatty acid content in the blended fatty materials, as shown in Table 4. These results align with findings by Perez-Santana et al. (2022).

Table 2. Physicochemical characteristics of palm oil, camel fat, cow fat and their produced shortening

**Parameter / *Sample	FFAs % as oleic acid	PV meq O_2/kg oil	MP	Color at 420 nm	RI at 40°C	OS (hr) at 120°C
P	0.050	0.96	40.0	0.27	1.4430	17.25
CA	0.060	3.98	48.0	0.53	1.4912	24.80
CO	0.060	4.61	46.0	0.61	1.4915	23.89
CA1	0.050	1.45	40.5	0.29	1.4479	17.90
CA2	0.060	1.58	41.5	0.30	1.4504	18.90
CA3	0.060	1.76	42.0	0.31	1.4528	19.98
CA4	0.060	1.90	42.3	0.32	1.4552	20.70
CA5	0.060	2.11	44.0	0.35	1.4601	22.74
CA6	0.065	2.55	45.0	0.40	1.4673	23.36
CO1	0.050	1.30	40.0	0.29	1.4479	16.78
CO2	0.060	1.57	40.5	0.31	1.4504	17.85
CO3	0.065	1.73	41.0	0.32	1.4528	18.71
CO4	0.060	1.82	42.0	0.34	1.4552	19.55
CO5	0.060	2.32	42.0	0.38	1.4601	20.90
CO6	0.060	2.88	43.0	0.43	1.4674	22.18

*P: palm, CA: camel fat, CO: cow fat, CA1: (10% camel fat+ 90% palm), CA2: (15% camel fat+ 85% palm),CA3: (22% camel fat+ 80% palm),CA4: (25% camel fat+ 75% palm), CA5: (35% camel fat+ 65% palm), CA6: (50% camel fat+ 50% palm), CO1: (10% cow fat+ 90% palm), CO2: (15% cow fat+ 85% palm),CO3: (20% cow fat+ 80% palm), CO4: (25% cow fat+ 75% palm), CO5: (35% cow fat+ 65% palm), CO6: (50% cow fat+ 50% palm).

**FFAs: free fatty acids, PV: peroxide value, MP: Melting Point, R1: refractive index, OS: oxidative stability

Color

Color is a key factor in determining the quality of oils and fats. The color index was measured using a spectrophotometer at 420 nm. As shown in Table 2, palm oil had the lowest color index (0.27 at 420 nm), compared to camel and cow fats, which had color indices of 0.53 and 0.61 at 420nm, respectively. Blending camel or cow fats with palm oil at different levels resulted in slight increases in color values. The darker color of camel and cow fats can be attributed to the exposure of phospholipids to heat during the extraction of fat from animal tissues (Johnson, 2008). Additionally, vegetable oils generally have a lower color index than animal fats due to refining processes such as deodorization and bleaching, which are applied to palm oil (Elgammal, 2006; Askae, 2017).

Refractive Index (RI)

The refractive index (RI) is a useful parameter for estimating the degree of unsaturation in oils and fats. The RI depends on the chemical composition and temperature of the oil or fat (Brahmi et al., 2020). As shown in Table 2, clear differences were observed in the RI values of the tested materials. Palm oil had an RI of 1.4430 at 40°C, while camel and cow fats had higher RI values of 1.4912 and 1.4915 at 40°C, respectively. The RI of shortening samples prepared by blending camel fat or cow fat with palm oil at ratios of 10%, 15%, 20%, 25%, 35%, and 50% showed a gradual increase. These differences in RI are primarily due to variations in fatty acid composition (Wei et al., 2017).

Oxidative Stability Index at 120°C

Understanding the oxidative stability of edible oils and fats provides insight into their expected shelf life, susceptibility to oxidative rancidity during storage and processing, and potential uses for edible or industrial purposes. Oxidative stability is highly correlated with purity, fatty acid composition, and quality criteria of oils and fats (Anwar et al., 2003).

Results in Table 2 indicate that the oxidative stability (hours) at 120°C of camel fat, cow fat, and palm oil was 24.80, 23.89, and 17.25 hours, respectively.

Table 2 also reveals that the oxidative stability (hours) at 120°C of shortening (100% palm oil) increased from 17.25 to 17.90, 18.90, 19.98, 20.70, 22.74, and 23.36 hours when camel fat was added at 10%, 15%, 20%, 25%, 35%, and 50%, respectively. Similarly, oxidative stability increased to 16.78, 17.85, 18.71, 19.55, 20.90, and 22.18 hours when cow fat was added at the same ratios. This increase is attributed to the higher percentage of saturated fatty acids in the blends (Wei et al., 2017). These results clearly demonstrate that blending palm oil with camel fat or cow fat during shortening preparation improves oxidative stability, making the shortenings suitable for baking applications.

Table 3. SFC of palm oil, camel fat, cow fat and their produced shortening

Temperatures / *Sample	20 °C	30 °C	40 °C
P	28.80	12.30	3.47
CA	48.30	33.56	15.48
CO	46.60	32.20	13.48
CA1	29.85	12.94	4.11
CA2	32.25	15.14	5.98
CA3	33.80	15.65	6.60
CA4	34.15	16.20	7.14
CA5	38.35	20.45	9.70
CA6	44.30	30.56	12.23
CO1	29.32	12.85	3.95
CO2	30.87	13.83	4.56
CO3	31.60	14.45	5.64
CO4	33.85	15.77	6.74
CO5	34.15	16.20	7.14
CO6	36.23	18.20	8.56

P: palm, CA: camel fat, CO: cow fat, CA1: (10% camel fat+ 90% palm), CA2: (15% camel fat+ 85% palm),CA2: (15% camel fat+ 85% palm), CA3: (20% camel fat+ 80% palm), CA5: (35% camel fat+ 65% palm), CA6: (50% camel fat+ 50% palm), CO1: (10% cow fat+ 90% palm), CO2: (15% cow fat+ 85% palm),CO3: (20% cow fat+ 80% palm), CO4: (25% cow fat+ 75% palm), CO5: (35% cow fat+ 65% palm), CO6: (50% cow fat+ 50% palm).

Solid Fat Content (SFC)

Solid fat content (SFC) is an analytical parameter used to determine the proportion of solid fat in fats and oils. SFC is temperature-dependent and serves as a good indicator of the plastic range of a shortening formulation. It reflects the balance between solid and liquid fat and correlates with functional properties such as consistency, spreadability, and sensory acceptance (Augusto et al., 2012). The SFC of palm oil, camel fat, cow fat, and their produced shortenings are presented in Table 3 and Figures 1, 2, 3, and 4. At 20°C, the SFC of the three fatty materials and prepared shortening samples ranged from 28.8% to 48.3%. Camel fat had the highest SFC at 20°C (48.3%), followed by cow fat (46.6%), while palm oil had the lowest SFC (28.8%). As shown in Figure 1, the SFC of all fatty materials decreased at 30°C to 33.56%, 32.20%, and 12.13% for camel fat, cow fat, and palm oil, respectively. At 40°C, the SFC further decreased to 15.48%, 13.48%, and 3.47%, respectively. The suitability of fats for bakery products is primarily assessed by determining SFC at various temperatures. Figures 2, 3, and 4 compare the SFC of prepared shortenings at different ratios of camel fat and cow fat blended with palm oil.

The results show an increase in SFC at 20°C, 30°C, and 40°C as the percentage of camel or cow fat in the blends increased. Additionally, the SFC of camel fat-palm oil blends was higher than that of cow fat-palm oil blends at ratios of 10:90, 15:85, 20:80, 25:75, 35:65, and 50:50.

These results indicate that both camel-based and cow-based shortenings exhibit a wide range of SFC, providing a broad plasticity range suitable for various functional requirements in baking applications.

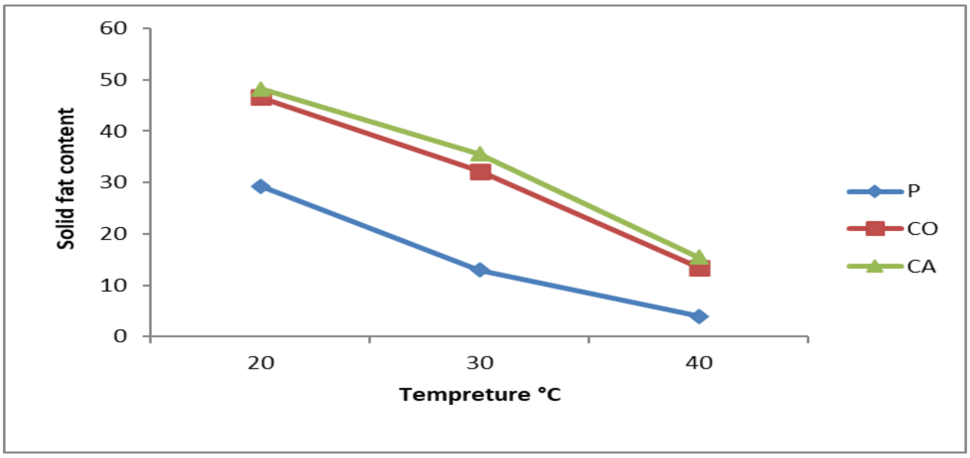

Figure 1. Solid fat content (SFC) of palm oil, cow fat and camel fat

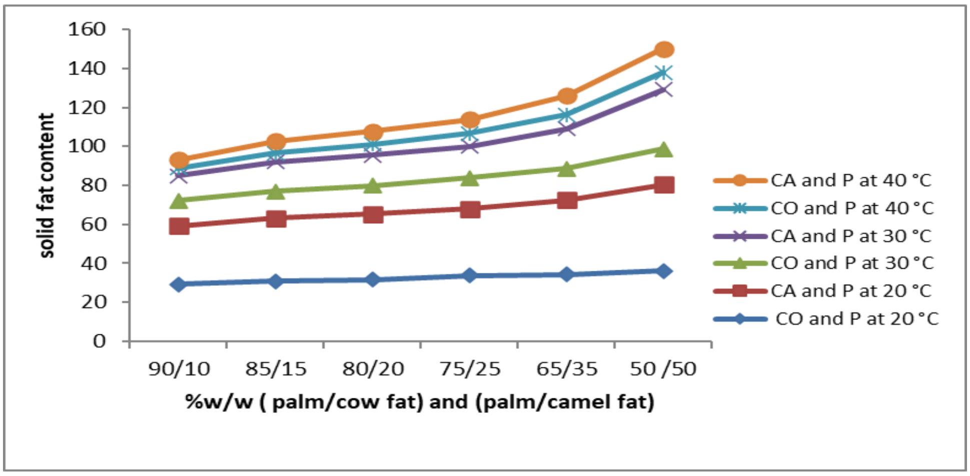

Figure 2. Solid fat content at 20 °C, 30°C, 40 °C of prepared shortening samples

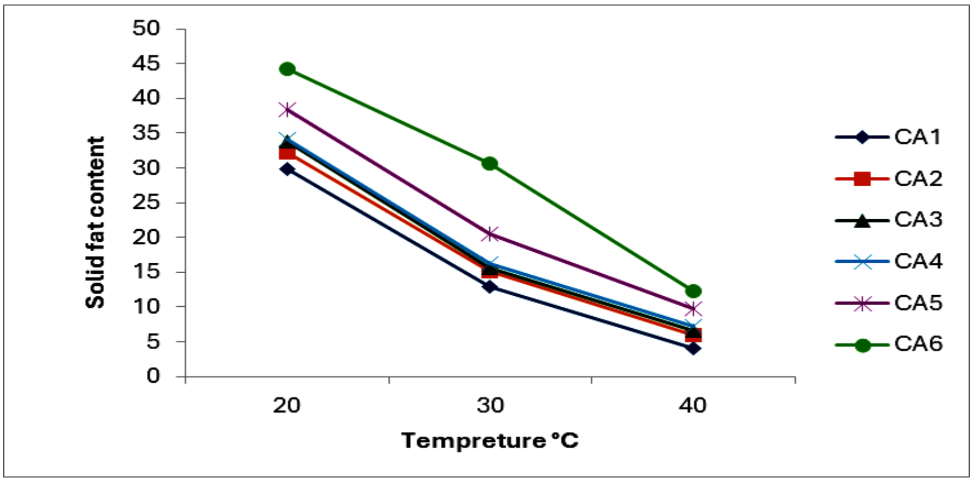

Figure 3. Solid fat content of shortening based on camel fat and palm oil

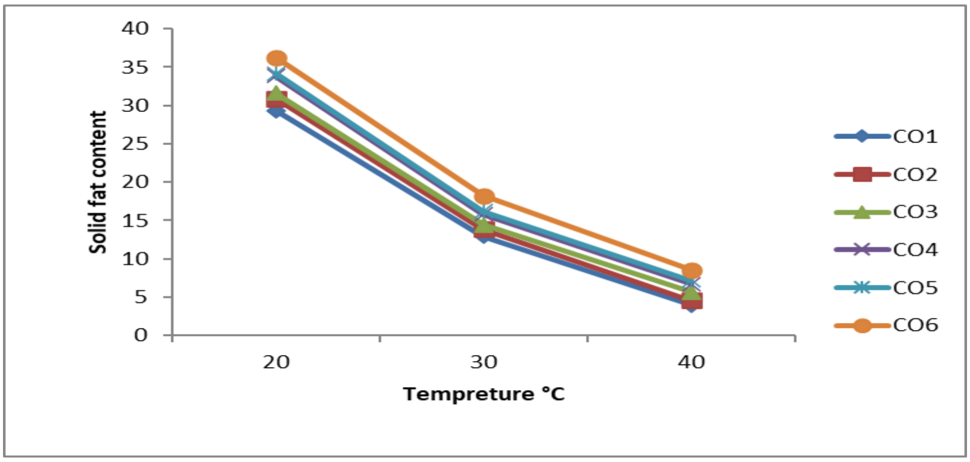

Figure 4. Solid fat content of shortening based on cow fat and palm oil

*P: palm, CA: camel fat, CO: cow fat, CA1: (10% camel fat+ 90% palm), CA2: (15% camel fat+ 85% palm),CA3: (20% camel fat+ 80% palm), CA4: (25% camel fat+ 75% palm), CA5: (35% camel fat+ 65% palm), CA6: (50% camel fat+ 50% palm), CO1: (10% cow fat+ 90% palm), CO2: (15% cow fat+ 85% palm),CO3: (20% cow fat+ 80% palm), CO4: (25% cow fat+ 75% palm), CO5: (35% cow fat+ 65% palm), CO6: (50% cow fat+ 50% palm).
SFA: saturated fatty acids * USFA: unsaturated fatty acids

Fatty Acid Composition

As shown in Table 4, the total saturated fatty acids (SFA) in palm oil, camel fat, and cow fat were 50.81%, 63.02%, and 58.66%, respectively, while the total unsaturated fatty acids (USFA) were 49.19%, 35.33%, and 38.26%, respectively. These results align with findings by Perez-Santana et al. (2022), El-Anany and Ali (2018), Mashaly et al. (2020), and Wei et al. (2017). Palmitic acid (C16:0) was the predominant saturated fatty acid in palm oil, accounting for 46.46%. In camel and cow fats, the predominant saturated fatty acids were stearic acid (C18:0) at 31.51% and 24.14%, respectively, and palmitic acid (C16:0) at 24.14% and 27.51%, respectively. For the prepared shortenings from palm oil blended with camel fat and cow fat at ratios of 100:0, 90:10, 85:15, 80:20, 75:25, 65:35, and 50:50, the results showed a gradual increase in saturated fatty acids across all samples. Specifically, palmitic acid in palm oil (46.46%) gradually decreased to 35.30% and 36.99% in shortenings prepared with 50% camel fat and 50% cow fat, respectively. Similarly, stearic acid, which was 3.17% in palm oil, increased to 17.37% and 13.18% in shortenings with 50% camel fat and 50% cow fat, respectively. The World Health Organization (WHO, 2003) reported convincing evidence that palmitic acid increases the risk of cardiovascular diseases. Fattore and Fanelli (2013) reviewed scientific literature on the association between palm oil and adverse health effects, particularly cardiovascular diseases and cancer. They concluded that the negative health effects of palm oil are primarily linked to its high saturated fatty acid (SFA) content, which has been associated with an increased risk of coronary heart disease and certain cancers in ecological and animal studies. Contrary to the general belief that all saturated fatty acids are harmful, stearic acid appears to have some beneficial effects on human health (Chayes, 1999). Numerous studies have shown that while palmitic acid increases cardiovascular and cancer risks, stearic acid is associated with reducing blood pressure, improving heart function, and lowering cancer risk (Chayes, 1999; Kris-Etherton et al., 2005; Senyilmaz-Tiebe et al., 2018). Additionally, palmitic acid ingestion leads to greater fat accumulation in the body compared to stearic acid (Mondul et al., 2015; Senyilmaz-Tiebe et al., 2018; Vanrooijen et al., 2021). Vanrooijen et al. (2020) and Siri-Tarino et al. (2010) also found that stearic acid decreases the LDL-to-HDL cholesterol ratio compared to palmitic acid. In conclusion, blending camel fat or cow fat with palm oil to prepare shortening samples for biscuit manufacturing generally improved the stearic acid content while reducing palmitic acid levels in all prepared shortening samples under investigation.

Table 4. Fatty acid composition of palm oil, camel fat, cow fat, and their produced shortening

Item	P	CA	CO	CA1	CA2	CA3	CA4	CA5	CA6	CO1	CO2	CO3	CO4	CO5	CO6
C10:0	0	0	0.07	0	0	0	0	0	0	0.01	0.01	0.01	0.02	0.02	0.03
C12:0	0.13	0.17	0.18	0.14	0.14	0.14	0.14	0.15	0.15	0.13	0.13	0.14	0.14	0.15	0.16
C14:0	0.87	4.64	4.62	1.22	1.43	1.63	2.19	2.18	2.76	1.25	1.44	1.62	1.81	2.18	2.75
C14:1	0	0.15	0.5	0.01	0.03	0.03	0.06	0.05	0.07	0.05	0.07	0.10	0.12	0.18	0.25
C15:0	0	0.63	1	0.06	0.09	0.13	0.22	0.22	0.32	0.1	0.15	0.20	0.25	0.35	0.5
C15:1	0	0.2	0.3	0.02	0.03	0.04	0.07	0.07	0.1	0.03	0.05	0.06	0.08	0.11	0.15
C16:0	46.46	24.14	27.51	44.23	43.11	41.99	38.65	38.65	35.3	44.57	43.62	42.67	41.72	39.82	36.99
C16:1	0	1.77	2.25	0.18	0.26	0.35	0.62	0.61	0.89	0.22	0.34	0.45	0.56	0.78	1.12
C17:0	0	1.46	1.67	0.17	0.22	0.29	0.51	0.51	0.73	0.17	0.25	0.34	0.42	0.59	0.83
C17:1	0	0.43	0.58	0.04	0.07	0.09	0.15	0.15	0.22	0.05	0.08	0.12	0.15	0.23	0.29
C18:0	3.17	31.51	23.20	6.01	7.42	8.84	13.09	13.09	17.34	5.17	6.17	7.17	8.18	10.18	13.18
C18:1	41.5	27.85	31.18	40.13	39.45	38.76	36.74	36.73	34.68	40.47	39.93	39.43	38.92	37.88	36.36
C18:2	7.69	2.83	2.4	7.21	6.96	6.72	5.99	5.99	5.26	7.16	6.93	6.63	6.37	5.83	5.04
C18:3	0	1.31	0.46	0.13	0.2	0.26	0.46	0.46	0.64	0.05	0.06	0.09	0.11	0.16	0.23
C18:4	0	0.45	0.36	0.05	0.07	0.09	0.15	0.16	0.23	0.04	0.06	0.07	0.09	0.13	0.18
C20:0	0.18	0.42	0.31	0.2	0.21	0.23	0.26	0.26	0.3	0.19	0.20	0.21	0.21	0.22	0.24
C20:1	0	0.34	0.23	0.03	0.05	0.07	0.12	0.12	0.17	0.02	0.03	0.05	0.06	0.08	0.11
C22:0	0	0.05	0.1	0.01	0.01	0.01	0.02	0.02	0.03	0.01	0.01	0.02	0.02	0.03	0.05
Un known	0	1.65	3.08	0.16	0.25	0.33	0.56	0.58	0.81	0.31	0.47	0.62	0.77	1.08	1.54
Total	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
**SFA	50.81	63.02	58.66	52.04	52.63	53.26	55.08	55.08	56.93	51.6	51.98	52.38	52.77	53.54	54.73
**USFA	49.19	35.33	38.26	47.8	47.12	46.41	44.36	44.34	42.26	CO1	47.55	47.00	46.46	45.38	43.73

*P: palm, CA: camel fat, CO: cow fat, CA1: (10% camel fat+ 90% palm), CA2: (15% camel fat+ 85% palm),CA3: (20% camel fat+ 80% palm), CA4: (25% camel fat+ 75% palm), CA5: (35% camel fat+ 65% palm), CA6: (50% camel fat+ 50% palm), CO1: (10% cow fat+ 90% palm), CO2: (15% cow fat+ 85% palm),CO3: (20% cow fat+ 80% palm), CO4: (25% cow fat+ 75% palm), CO5: (35% cow fat+ 65% palm), CO6: (50% cow fat+ 50% palm).
SFA: saturated fatty acids * USFA: unsaturated fatty acids

Sensory Evaluation of Biscuits

The sensory attributes of the biscuit samples appearance, texture, taste, odor, and overall acceptability—are presented in Table 5. Biscuits prepared using palm oil shortening served as the reference (control) samples. Biscuits produced from wheat flour and shortening prepared by blending palm oil with camel fat or cow fat at ratios of 90:10, 85:15, and 80:20 were found to be acceptable and did not differ significantly from the control in terms of sensory properties. However, biscuit samples made with shortening containing a 50:50 ratio of palm oil to camel fat or cow fat received the lowest scores for taste, odor, and overall acceptability. These results indicate that palm oil can be replaced with camel fat or cow fat to produce shortenings for biscuit preparation at substitution levels of up to 25% without negatively affecting the sensory properties of the final product.

Physical Properties of Biscuits

The physical properties of the biscuit samples are presented in Table (6). The results for thickness (mm), diameter (mm), volume (cm^3), weight (g), and specific volume (cm^3/g) ranged between 3.2–5.0, 5.0–5.5, 48–54, 42.25–59.80, and 0.86–1.18, respectively. The results indicate that replacing palm oil with camel fat or cow fat did not negatively affect the physical properties of the biscuits. On the contrary, some biscuit samples produced from shortenings prepared with a mixture of palm oil and camel or cow fat showed improvements compared to the control. These findings are consistent with studies by Osman and Noraini (1999) and Zhang et al. (2018), who reported that blending cow fat with palm oil improved the physical characteristics of bakery products.

Table 5. Sensory evaluation of biscuit samples

Parameter / Samples	Appearance	Texture	Taste	Odor	General acceptability
P	7.3[a]	7.3[a]	8[a]	8.5[a]	8[a]
CA1	7.0[a]	7.0[a]	8[a]	8.5[a]	7.7[a]
CA2	7.0[a]	7.3[a]	7.7[ab]	8.0[a]	7.62[a]
CA3	7.0a	7.0a	7.5ab	8.0a	7.5a
CA4	6.3[ab]	6.3[a]	6.7[ab]	7.4[ab]	6.75[ab]
CA5	6.6[ab]	6.6[a]	6.7[b]	6.3[b]	6.60[ab]
CA6	5.7[b]	6.3[a]	5.7[b]	5.8[ab]	5.60[b]
CO1	7.7[a]	7.8[a]	7.7[ab]	8.7[a]	7.90[a]
CO2	7.3[a]	7.7[a]	7.7[ab]	7.5[ab]	7.50[a]
CO3	7.0a	7.4a	7.2ab	7.5ab	7.20a
CO4	6.7[ab]	7.3[a]	6.7[ab]	7.4[ab]	7.00[a]
CO5	6.0[b]	7.0[a]	6.7[ab]	6.7[ab]	6.5[ab]
CO6	6.5[b]	6.7[a]	5.7[b]	5.8[b]	6.00[ab]

Values with the same letters have no significant difference ($p>0.05$)
*P: palm, CA: camel fat, CO: cow fat, CA1: (10% camel fat+ 90% palm), CA2: (15% camel fat+ 85% palm),CA3: (20% camel fat+ 80% palm), CA4: (25% camel fat+ 75% palm), CA5: (35% camel fat+ 65% palm), CA6: (50% camel fat+ 50% palm), CO1: (10% cow fat+ 90% palm), CO2: (15% cow fat+ 85% palm),CO3: (20% cow fat+ 80% palm), CO4: (25% cow fat+ 75% palm), CO5: (35% cow fat+ 65% palm), CO6: (50% cow fat+ 50% palm).

Color of Biscuits

Color is a key characteristic of food products that significantly influences consumer perception and serves as an indicator of acceptability (Rosna et al., 2021). Data in Table 7 show the color parameters (L*, a*, b*) of the biscuit samples. The results indicate no significant differences in L*, a*, and b* values between samples containing camel fat or cow fat and the control sample.

Table 6. Physical properties of biscuit samples

Parameter / *Samples	Thickness (mm)	Diameter (mm)	Volume (cm^3)	Weight (g)	Specific volume (cm^3/g)
P	3.4	5.0	54.00	54.37	0.99
CA1	3.4	5.0	55.20	51.10	1.08
CA2	3.2	5.2	54.00	50.69	1.06
CA3	3.3	5.2	54.00	51.00	1.05
CA4	3.4	5.2	54.00	54.60	0.99
CA5	3.2	5.4	48.00	50.85	0.96
CA6	3.5	5.4	52.00	59.86	0.86
CO1	3.0	5.3	48.00	47.96	1.00
CO2	3.0	5.3	50.00	49.14	1.02
CO3	3.2	5.4	50.00	51.30	0.97
CO4	3.2	5.4	48.00	52.05	0.92
CO5	3.4	5.4	50.00	46.00	1.09
CO6	3.6	5.5	50.00	42.25	1.18

*P: palm, CA: camel fat, CO: cow fat, CA1: (10% camel fat+ 90% palm), CA2: (15% camel fat+ 85% palm),CA3: (20% camel fat+ 80% palm), CA4: (25% camel fat+ 75% palm), CA5: (35% camel fat+ 65% palm), CA6: (50% camel fat+ 50% palm), CO1: (10% cow fat+ 90% palm), CO2: (15% cow fat+ 85% palm),CO3: (20% cow fat+ 80% palm), CO4: (25% cow fat+ 75% palm), CO5: (35% cow fat+ 65% palm), CO6: (50% cow fat+ 50% palm).

Table 7. Color of biscuit samples

*Samples	*L*	*a*	*b*
P	74.08	1.53	24.41
CA1	75.61	1.69	24.24
CA2	74.87	1.76	24.13
CA3	74.86	1.71	24.23
CA4	74.85	1.66	24.44
CA5	74.80	1.50	24.67
CA6	74.80	1.64	24.98
CO1	75.10	1.47	24.18
CO2	74.87	1.54	24.18
CO3	74,90	1.57	54.31
CO4	74.90	1.52	24.37
CO5	74.84	1.62	24.44
CO6	74.77	1.63	24.23

*P: palm, CA: camel fat, CO: cow fat, CA1: (10% camel fat+ 90% palm), CA2: (15% camel fat+ 85% palm),CA3: (20% camel fat+ 80% palm), CA4: (25% camel fat+ 75% palm), CA5: (35% camel fat+ 65% palm), CA6: (50% camel fat+ 50% palm), CO1: (10% cow fat+ 90% palm), CO2: (15% cow fat+ 85% palm),CO3: (20% cow fat+ 80% palm), CO4: (25% cow fat+ 75% palm), CO5: (35% cow fat+ 65% palm), CO6: (50% cow fat+ 50% palm).

Water Activity and Hardness Values of Biscuit Samples During Storage Period

Water activity (aw) significantly impacts the shelf life of biscuits. Biscuits with lower water activity have a longer shelf life, as they are less susceptible to microbial growth and enzymatic reactions that cause spoilage (Libor et al., 2006). Growth limits indicate that pathogenic bacteria cease growing at water activities below 0.87, while common spoilage yeasts and molds stop growing at 0.70 aw, which is considered the practical limit. Only xerophilic and osmophilic organisms can grow below 0.70 aw, and all microbial growth stops at water activities below 0.60 (Beuchat, 1983; Mamat et al., 2014). The results in Table 8 and Figure 5 show that the water activity of biscuit samples at zero time ranged from 0.240 to 0.247 aw. After 3 months of storage, the highest water activity was recorded for the control sample containing palm oil. These findings align with those reported by Federi-

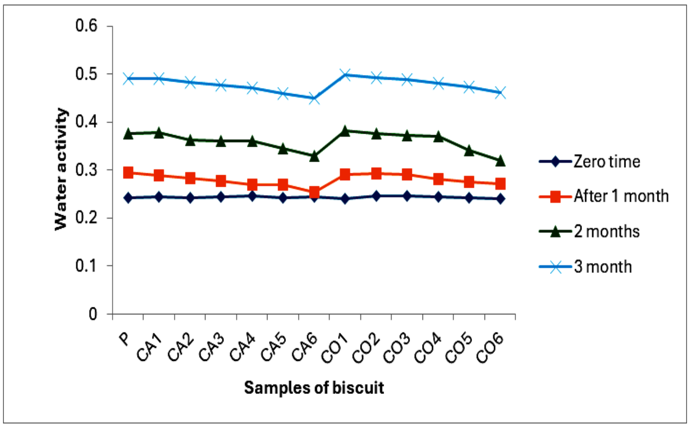

Figure 5. Water activity values of biscuit samples

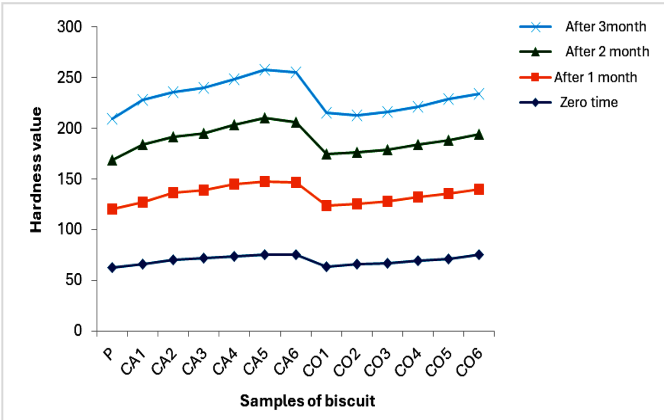

Figure 6. Hardness values of biscuit samples during storage period

*P: palm, CA: camel fat, CO: cow fat, CA1: (10% camel fat+ 90% palm), CA2: (15% camel fat+ 85% palm),CA3: (20% camel fat+ 80% palm), CA4: (25% camel fat+ 75% palm), CA5: (35% camel fat+ 65% palm), CA6: (50% camel fat+ 50% palm), CO1: (10% cow fat+ 90% palm), CO2: (15% cow fat+ 85% palm),CO3: (20% cow fat+ 80% palm), CO4: (25% cow fat+ 75% palm), CO5: (35% cow fat+ 65% palm), CO6: (50% cow fat+ 50% palm).

The hardness values of all biscuit samples showed a decreasing trend over time, with no significant differences observed among them. During the first 30 days of storage, a decrease in hardness (Figure 6) coincided with an increase in water activity and moisture content. Hardness refers to the resistance of the biscuit to breaking force in a three-point bending test. At the beginning of the test (zero time), the 13 samples exhibited high hardness values ranging between 62.17g and 75.62g. The control sample (P) had the lowest hardness (62.17g), followed by CO1 (63.31g). In contrast, the CA6 sample recorded the highest hardness value (75.62 g), followed by CO6 (75.26g). These results align with findings by Mamat et al. (2014), who reported that biscuits made with palm mid-fraction and butter had the highest breaking force, significantly differing ($p < 0.05$) from those made with palm oil and palm olein. Biscuits made with palm olein had the lowest breaking force. It was also observed that dough hardness influenced biscuit texture; dough with higher solid fat content was the hardest, while dough containing palm olein was the least hard. A similar effect was noted by O'Brien et al. (2003), who found that biscuits produced with lower free fat (higher solid fat) had higher breaking strength.

During storage, the hardness of the biscuit samples decreased to a certain extent. The decrease in hardness was more pronounced in samples substituted with camel or cow fats compared to the control samples.

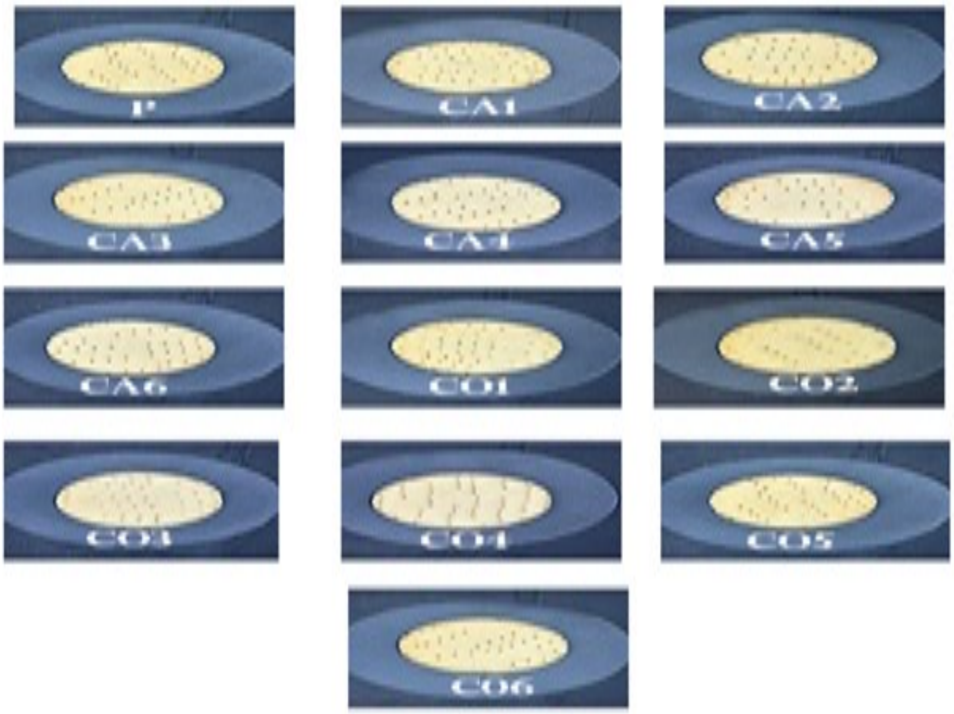

Figure 7. Biscuit samples made from fatty materials and their blended

Effect of storage periods on the peroxide value and free fatty acids of biscuit samples

Biscuits are sensitive to moisture and can undergo oxidative rancidity and hydrolytic rancidity even at low moisture levels due to their high fat content. The level of auto-oxidation in fat extracted from biscuits was evaluated using free fatty acids (FFA) and peroxide value (PV). Key biscuit ingredients such as flour, sugar, and fat are susceptible to oxygen reactions. The large surface area of biscuits accelerates oxidation due to exposure to oxygen and light (Kumar et al., 2014). The results in Table 8 show a gradual increase in PV during the 3-month storage period at room temperature for all biscuit samples. However, the PV for all samples remained below 10 meq O_2/kg, which is the permissible limit set by the World Food Program (FAO, 2021).

Free fatty acids (FFA) are used to measure hydrolytic rancidity, which indicates the breakdown of glycerides by lipase enzymes (Onwuka, 2018). The FFA content of fat extracted from all biscuit samples increased slightly during the storage period (Table 8). Nevertheless, the FFA levels remained within the limit specified by the FAO Codex standard (less than 1%) (FAO, 1999).

Table 8. FFA and PV of biscuit samples during storage period

Storage period / *samples	Before baking		After baking		after 1 month		after 2 month		after 3 month	
	PV	FFA	PV	FFA	PV	FFA	PV	FFA	PV	FFA
P	0.96	0.05	1.41	0.07	1.74	0.08	2.10	0.11	2.68	0.15
CA1	1.45	0.05	1.75	0.10	2.15	0.11	2.45	0.14	2.89	0.19
CA2	1.58	0.06	1.89	0.10	2.19	0.12	2.59	0.13	2.76	0.16
CA3	1.68	0.05	1.95	0.10	2.22	0.12	2.67	0.14	2.84	0.18
CA4	1.90	0.05	2.30	0.09	2.54	0.12	2.88	0.16	2.95	0.20
CA5	2.11	0.07	2.48	0.08	2.87	0.08	2.98	0.13	3.19	0.17
CA6	2.55	0.065	2.85	0.10	3.08	0.12	3.21	0.15	3.39	0.20
CO1	1.30	0.05	1.67	0.07	1.97	0.09	2.31	0.11	2.47	0.19
CO2	1.57	0.06	2.03	0.07	2.33	0.08	2.63	0.12	2.82	0.14
CO3	1.63	0.06	2.10	0.07	2.27	0.09	2.70	0.13	2.89	0.16
CO4	1.82	0.07	2.25	0.09	2.51	0.10	2.81	0.15	2.99	0.18
CO5	2.32	0.05	2.80	0.08	3.01	0.11	3.11	0.15	3.30	0.19
CO6	2.88	0.05	3.20	0.10	3.39	0.13	3.47	0.16	3.52	0.21

*P: palm, CA: camel fat, CO: cow fat, CA1: (10% camel fat+ 90% palm), CA2: (15% camel fat+ 85% palm),CA3: (20% camel fat+ 80% palm), CA4: (25% camel fat+ 75% palm), CA5: (35% camel fat+ 65% palm), CA6: (50% camel fat+ 50% palm), CO1: (10% cow fat+ 90% palm), CO2: (15% cow fat+ 85% palm),CO3: (20% cow fat+ 80% palm), CO4: (25% cow fat+ 75% palm), CO5: (35% cow fat+ 65% palm), CO6: (50% cow fat+ 50% palm).

4. Conclusions

This study successfully substituted a portion of imported palm oil, the primary raw material used in shortening preparation, with locally sourced animal fats (camel and cow). The physical and chemical properties of all prepared shortening samples were within the recommended limits. Additionally, the addition of camel or cow fat to palm oil at up to 50% of the prepared blends increased the solid fat content (SFC), making the shortenings suitable for bakery processing. The oxidative stability of the shortening samples also improved gradually as the proportion of camel or cow fat in the blends increased. In terms of fatty acid composition, blending camel or cow fat with palm oil resulted in a gradual decrease in palmitic acid and a gradual increase in stearic acid in all prepared shortening samples. This improvement aligns with scientific literature highlighting the health benefits of modifying the saturated fatty acid profile. From a technological perspective, the results demonstrate that palm oil can be replaced with camel or cow fat to produce shortenings for biscuit preparation at substitution levels of up to 25% without negatively affecting the sensory properties of the final product.

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