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Instrumental color and texture profile analysis of semidry sausages as influenced by different levels of canola, safflower and olive oils

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Abstract

The experiments were carried out to investigate the effect of partial substitution of buffalo back fat with different levels of virgin canola oil on the color, textural, and sensory properties of semidry fermented sausage of buffalo meat. The samples of semidry sausage were prepared by substituting 15%, 20%, and 25% of buffalo back fat with canola oil. Total four samples were prepared viz., T1, T2, T3 and T4 with different formulations based on different ratios of buffalo back fat and canola oil i.e. T1 (20% buffalo back fat), T2 (17% buffalo back fat + 3% canola oil), T3 (16% buffalo back fat + 4% canola oil), T4 (15% buffalo back fat + 5% canola oil). The instrumental color was measured by Hunter Color Lab under standard conditions. The results showed that treatment of canola oil was significantly ($p<0.05$) found to decrease the lightness (L*) value, but significantly ($p<0.05$) increased the redness (a*) value and yellowness (b*) values of sausage samples. The texture profile was measured by the TAHD texture analyzer under suitable environmental conditions. The texture of sausage samples was determined for five important textural properties, viz., hardness, cohesiveness, springiness, gumminess, and chewiness. The sausage samples incorporated with 5% canola oil were found to have improved hardness, cohesiveness, springiness, gumminess, and chewiness values. The hardness value of the control sample (T1) was found to be 590 g. The treatment of canola oil brought a considerable improvement in the hardness value of treated samples. The hardness values of the treated samples T2, T3 & T4 with 3%, 4%, and 5% substitution of animal fat were found as 632, 696 & 744 g, respectively. From the hardness values, it is clear that the treatments T2, T3 & T4 significantly ($p<0.05$) increased the hardness value of sausage samples. The sensory properties of sausage samples, viz., color, taste, texture, juiciness, tenderness, and palatability, were found under the consumption limit. This study addresses the dual challenge of improving the nutritional profile of buffalo meat sausages while maintaining acceptable technological and sensory quality. Findings from this work provide a scientific basis for the meat processing industry to develop healthier fermented sausage products by incorporating plant-based oils without compromising consumer acceptability. The results are particularly relevant for buffalo-rearing regions where healthier value-added meat products are increasingly in demand.

Keywords

Instrumental color, TPA, sensory, alternate fat, sausage, semidry

1. Introduction

Meat is a healthy and nutritious food, carrying a number of essential elements, including amino acids, fatty acids, minerals, vitamins, etc. Instead of having nutritious elements, the meat has certain limitations, viz., deficiency of dietary fibers, saturated fat, cholesterol, etc. The food devoid of dietary fibers along with cholesterol may cause problems of obesity and overweight [1] (WHO, 2013), which further may affect the immune response of human beings against a variety of infections [2] (Khan and Saghir, 2017). The researchers are putting their efforts into finding sustainable solutions by incorporating and substituting dietary fibers & saturated fat, respectively, to make healthier and functional meat products [3-7] (Monteiro et al., 2017; Oliveira et al., 2013; Yunes et al., 2013; Youssef and Barbut, 2009; Khan & Saghir, 2015). The partial substitution of buffalo fat with canola oil in semidry sausage is a novel idea that has not been given attention anywhere, but some researchers have performed experiments on the substitution of pork fat with canola oil in other meat systems, such as turkey, pork, chicken, etc. The importance of canola oil on the quality of meat products has been claimed by many researchers [8, 9] (Khan and Saghir, 2018; Yunes et al., 2013; Backes et al., 2013) as an example of an excellent fat replacer in a variety of meat products, such as mortadella, Italian salami, etc. Along with the acceptable sensory quality, canola oil is a good source of unsaturated fatty acids and a healthy ratio of ω6/ω3 among the variety of vegetable oils [10, 11] (Biljana et al., 2015; FEDIOL statistics, 2011). The concept of the replacement of saturated fat has already been established for decades. Simultaneously, the focus on salt reduction is also in demand. Total daily fat intake is recommended as 20 – 35% of total calorie intake. However, only six percent of saturated fat is required by the human body, which is approximately thirteen grams of saturated fat on a 2000-calorie diet [12] (AHA, 1992). Today, people have become conscious of their health. Nowadays, noncommunicable diseases are prevalent in society, and they are the major cause of millions of deaths globally [13] (WHO, 2013). Approximately 2.8 million people die every year due to problems related to overweight and obesity [14] (WHO report, 2014). The animal or saturated fat is one of the leading causes of these problems. The researchers are continuously working to reduce the saturated fat and formulate a better fatty acid profile with lower cholesterol in meat products [15, 16] (Ozvural and Vural, 2008; Teye et al., 2006). The vegetable oils are significantly different than animal fat in properties like fatty acid profile, flavor, and color [17] (Swem, 1964). The researchers are facing a number of technical problems while substituting animal fat with sources that carry a larger fraction of unsaturated fatty acids in meat products. These are the concerning issues for food technologists to sustain the organoleptic properties in low or reduced-fat meat products. The palatability or mouth coating is the most influential sensory property of meat products, which is exclusively due to animal or saturated fat. The present study was carried out to assess the effects of partial substitution of buffalo back fat with canola oil on the color, texture, and sensory properties of semidry fermented sausage of buffalo meat.

2. Materials and Methods

2.1 Preparation of starter culture for fermentation

The lyophilized Bacterial strains of Lactobacillus brevis MTCC1750 and Lactobacillus plantarum MTCC1407 were procured from Imtech Chandigarh, Punjab (India). Each bacterial strain was grown in its respective broth media under optimum temperature (37°C) and humidity conditions for 24 to 48 hours inside the B.O.D incubator. After optimum growth, the starter cultures were then stored at 4°C.

2.2 Formulation of semidry fermented sausage

The fermented sausage samples were prepared by mixing with different components viz., Lean meat (2 kg), buffalo back fat (15-20%), canola oil (0-5%), mix spice (15 gm), salt (50 gm), sugar (20 g), dextrose (10 g), condiments (40 gm), ice (150 gm), sodium nitrate (0.30 gm) and sodium ascorbate (1.0 g), sodium hexa-meta phosphate (0.5%), MSG (2 g) along with starter culture of Lactobacillus brevis MTCC1750 and Lactobacillus plantarum MTCC 1407.

2.3 Preparation of semidry fermented sausage

The semidry fermented buffalo sausages were prepared from a comminuted mixture of meat, buffalo back fat, canola oil, salt, spices, and sugar using bacterial culture. The Spices, condiments, and monosodium glutamate (MSG) were added to contribute flavor to semi-dry sausages. Well-mixed mass was further added with different cultures of lactobacillus bacteria, viz., Lactobacillus plantarum MTCC 1407 and Lactobacillus brevis MTCC 1750. The final meat mix of different samples was transferred to the porcelain bowls and incubated at 22°C temperature for 48 hrs with 85% relative humidity to complete fermentation. The completion of fermentation was indicated by a drop in pH of the mixture. After the completion of fermentation, the mixture was stuffed into the casing using the sausage filler machine. Stuffing into fibrous casing was done firmly and carefully to exclude the air inside the casing, which might discolor the meat mix and reduce the shelf life of the sausages. The semi-dry fermented sausages were then subjected to hot smoking at a temperature of 70 °C and 80 to 90% humidity for 4 hours to improve flavor and to inhibit bacterial development. The smoked sausages were dried at 20° C temperature and 70% relative humidity. The drying was done at 18° C temperature and 85% relative humidity with optimum air velocity for about 4 days. Precautions were taken to ensure that sausages neither dried too fast nor retained surface moisture, and did not shrink. At the end, sausage samples were packed in combination film under atmosphere packaging and stored at a refrigerated temperature of 0° C for further study.

2.4 Smoking of fermented sausage solutions

The sausage samples were smoked, followed by fermentation inside the smoke house under controlled temperature of 70°C and 80-90% humidity conditions. The smoke was produced with the burning of hardwood that carries a variety of organic compounds, viz., phenols, carbonyl compounds, aldehydes, and inorganic gases like CO2, etc.

2.5 Drying of smoked sausage samples

Drying is an important processing step that enhances the shelf life of fermented sausage. The smoked fermented sausage samples were dehydrated inside the drying chamber for 3 to 5 days to prepare semidry fermented sausage with a moisture-protein ratio in the range of MPR greater than 2.3:1 but less than 3.7:1 [18] (Caplice and Fitzgerald, 1999). The moisture loss and water activity vary in the range of 8 to 15% and 0.90-0.94, respectively (Caplice and Fitzgerald, 1999).

2.6 Instrumental color analysis

The instrumental color analysis was done with the help of MiniScan XE Plus. The instrument was first calibrated with black and white tiles and then the lightness (L*), Redness (a*) and Yellowness (b*) values of the sausage samples were analysed by taking triplicate readings.

2.7 Texture profile analysis

The texture profile of semidry fermented sausage samples was done with the help of a texture analyzer (TAhd, England). The textural properties, viz., hardness, cohesiveness, gumminess, springiness, and chewiness, were measured to find the effect of partial substitution of buffalo fat with different levels of canola oil.

2.7 Sensory analysis

The sensory characteristics of cooked buffalo meat sausages were evaluated as per 9-point Hedonic rating tests [19] (Ranganna 1994) for color, taste, texture, juiciness, tenderness, and palatability using 5–10 judges of different age groups having different eating habits.

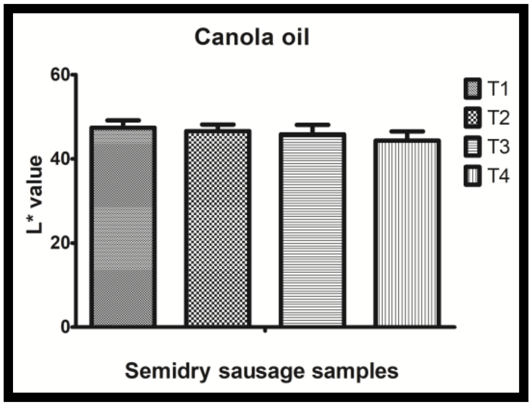
2.8 Sensory analysis

3. Results and Discussion

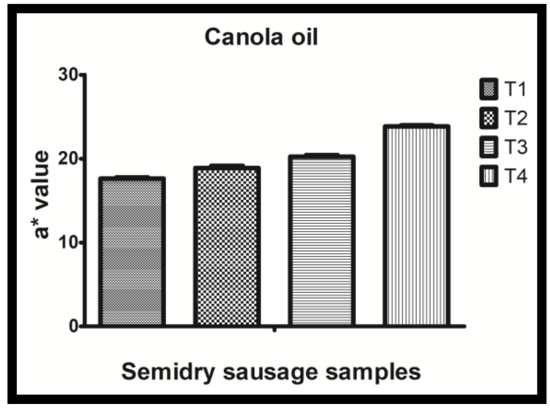
3.1 Instrumental colour analysis (CIE L*a*b*)

3.1.1 With canola oil

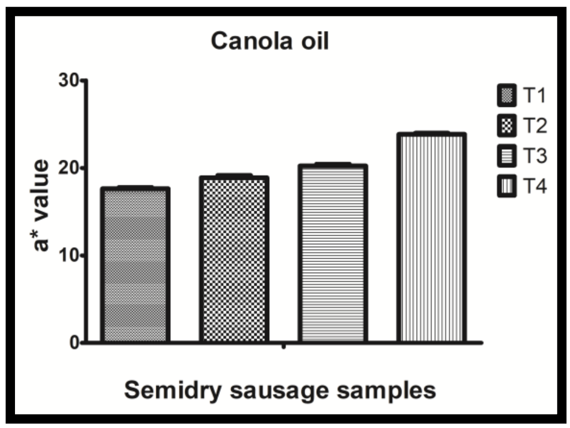
The instrumental color analysis of the sausage samples partially substituted with different levels of canola oil in place of buffalo fat was carried out with the help of the Hunter color lab. The effect of canola oil on Lightness (L*), redness (a*), and yellowness (b*) values were evaluated in different treated samples of semidry sausages. From Figure 1A, it is clear that the lightness value of the control sample (T1) was found as 47.38, and the treatment of canola oil brought a significant ($p<0.05$) decrease in the lightness values of treated samples T2, T3 & T4. The lightness values of samples T2, T3 & T4 with 3%, 4% & 5% canola oil substitution were found as 46.58, 45.83, and 44.32, respectively, while the control sample had 47.38. From Figure 1B, it is clear that the redness value of the control sample (T1) was found as 17.63, and the treatment of canola oil brought a significant ($p<0.05$) increase in the redness values of treated samples T2, T3 & T4. The redness values of samples T2, T3 & T4 with 3%, 4% & 5% canola oil substitution were found as 18.88, 20.23, and 23.84, respectively. The redness values of samples T2. T3 & T4 were found significantly ($p<0.05$) different. This significant ($p<0.05$) increase in redness values of treated samples might be due to the substitution of buffalo fat with different levels of canola oil. From Figure 1C, it is clear that the yellowness value of the control sample (T1) was found as 9.13, and the treatment of canola oil brought a considerable change in the yellowness values of the treated samples T2, T3 & T4. But sample T2 was found with a slight increase in the yellowness value as compared to the control. The yellowness values of samples T2, T3 & T4 with 3%, 4% & 5% canola oil substitution were found as 9.53, 10.12, and 11.53, respectively. The canola oil treatment significantly ($p<0.05$) increased the yellowness value of sausage samples. The results showed that treatment of canola oil was significantly ($p<0.05$) found to decrease the lightness (L*) value, but significantly ($p<0.05$) increased the redness (a*) value and yellowness (b*) values of sausage samples. Similar findings were reported by Kilic and Ozer (2017 [20] who worked with Turkish dry fermented sausage by replacing beef fat with interesterified palm kernel oil. In contrast to this study, various other studies have been done by [21-24]Ospina-E et al. (2012); Fernandez et al. (2005); Muguerza et al. (2003), and Bloukas et al. (1997), who showed that substitution of animal fat with vegetable oils did not create any significant difference in the color attributes of fermented sausages. Furthermore, many other studies were also carried out on non-fermented meat products viz., Youssef and Barbut (2009) [25] where they replaced animal fat with canola oil and found improved lightness (L*) values, reduced redness (a*) values in canola oil treated samples as compared to beef fat treated sausage samples. IT also claimed higher lightness (L*) values and comparatively lower redness (a*) values in vegetable oil treated meat products than the sausage samples prepared with animal fat only.



(A)



(B)



(C)

Figure 1 (A) L* values of semidry sausages incorporated with different levels of canola oils (B) a* values of semidry sausages incorporated with different levels of canola oils (C) b* values of semidry sausages incorporated with different levels of canola oils. Means ± SD; T1= 20% buffalo fat (control), T2= 17% buffalo fat + 3% canola oil, T3= 16% buffalo fat + 4% canola oil, T4= 15% buffalo fat + 5% canola oil.

3.1.2 With Safflower oil

From Figure 2A, it is clear that the lightness value of the control sample (T1) was found as 47.38, and the treatment of safflower oil brought no significant ($p<0.05$) change in the lightness values of treated samples T5, while samples T6 and T7 were found to have significantly ($p<0.05$) lower lightness values as compared to the control. The lightness values of treated samples T5, T6 & T7 with 3%, 4% & 5% safflower oil substitution were found as 47.30, 45.70, and 45.48, respectively. The lightness (L*) value of safflower oil was measured as 45.24 [26] (Katkade et al., 2018). The lightness value of sample T5 was slightly lower than the control sample but not found significantly ($p<0.05$) different. The lightness value of treated samples T6 and T7 was found to be significantly ($p<0.05$) lower. Hence, the safflower oil significantly ($p<0.05$) decreased the lightness value of samples T6 and T7. This decrease in the lightness value may be due to the substitution of buffalo fat with safflower oil, which had a slightly pale-yellow color. From Figure 2B, it is clear that the redness value of the control sample (T1) was 17.63, and the treatments of safflower oil brought an increment in the redness value of sausages. Hence, treated samples T5, T6 & T7 had greater redness values as compared to the control. The redness values of samples T5, T6 & T7 were 20.25, 21.03, and 22.18, respectively. The safflower oil significantly ($p<0.05$) increased the redness values of samples T5, T6 & T7. The treatments T5 & T6 did not make any significant ($p<0.05$) difference in redness value between each other. From Figure 2C, it is clear that the yellowness value of the control sample (T1) was found as 9.13, and the treatment of safflower oil brought no significant ($p<0.05$) change in the yellowness values of treated samples T5, T6 & T7. The yellowness values of samples T5, T6 & T7 with 3%, 4% & 5% safflower oil substitution were found as 9.44, 9.55, and 10.04, respectively. The results show that safflower oil did not make a significant ($p<0.05$) effect on the yellowness values of sausage samples.

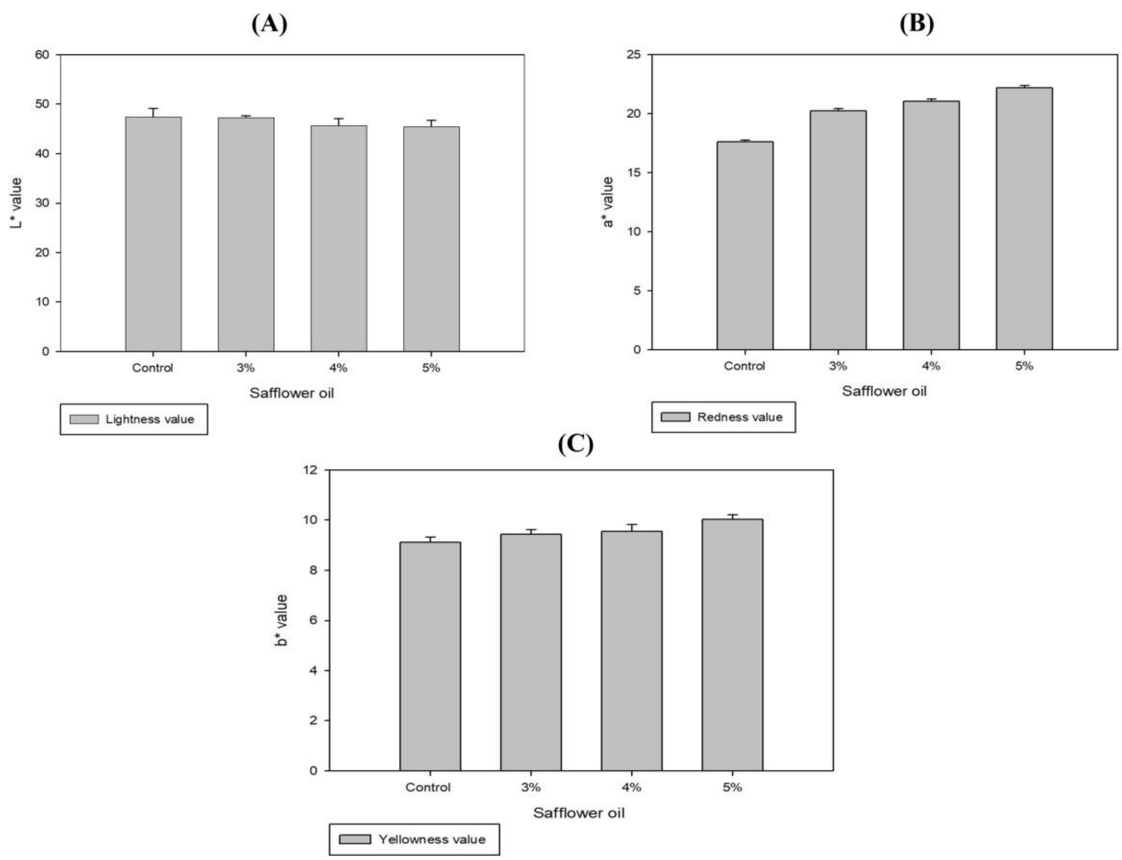


Figure 2 (A) L* values of semidry sausages incorporated with different levels of safflower oils. (B) a* values of semidry sausages incorporated with different levels of safflower oils (C) b* values of semidry sausages incorporated with different levels of safflower oils. Means ± SD; T1= 20% buffalo fat (control), T2= 17% buffalo fat + 3% safflower oil, T3= 16% buffalo fat + 4% safflower, T4= 15% buffalo fat + 5% safflower oil.

3.1.2 With olive oil

The redness value of the control sample (T1) was found to be 17.63. The redness values of treated samples T8, T9 & T10 with 3%, 4% & 5% olive oil were found as 18.14, 18.05, and 17.90, respectively. The results show that olive oil brought no significant ($p<0.05$) difference in the redness values of treated samples. The reason for the insignificant ($p>0.05$) difference in the redness values of sausages may be due to the lack of effect of olive oil treatment on the blooming of sausage color during smoking. The yellowness value of the control sample (T1) was found as 9.13, and the treatment of olive oil brought a significant ($p<0.05$) improvement in the yellowness values of treated samples T8, T9 & T10. The yellowness values of samples T8, T9 & T10 with 3%, 4% & 5% olive oil were found as 10.75, 12.19, and 15.94, respectively. From Table 1, it is clear that olive oil brought a significant ($p<0.05$) improvement in the yellowness values of treated samples. The results showed that olive oil brought a significant ($p<0.05$) increase in the lightness (L*) and yellowness (b*) values, but brought a non-significant ($p<0.05$) effect on the redness (a*) values of treated samples. Similar findings were reported by [27] Kilic and Ozer (2017) who worked with Turkish dry fermented sausage by replacing beef fat with interesterified palm kernel oil. In contrast to this study, various other researchers, such as [28-31]Ospina-E et al. (2012), Fernandez et al. (2005), Muguerza et al. (2003), and Bloukas et al. (1997), did a lot of work on fat substitution, and they claimed that the substitution of animal fat with vegetable oils did not create any significant difference in the color attributes of fermented sausages.

Table 1: Effect of partial substitution of buffalo fat with olive oil on instrumental colour of semidry sausages

Parameters	T1	T8	T9	T10
Lightness (L*) value	47.38±1.76^{d}	48.50±0.54^{c}	49.88±1.10^{b}	50.26±2.26^{a}
Redness (a*) value	17.63±0.14^{a}	18.14±0.23^{a}	18.05±0.30^{a}	17.90±0.27^{a}
Yellowness (b*) value	9.13±0.90^{d}	10.75±0.63^{c}	12.19±0.71^{b}	15.94±0.83^{a}

Means ± SD; Means with different letters differ significantly ($p<0.05$)

T1= 20% buffalo fat (control), T8= 17% buffalo fat + 3% olive oil, T9= 16% buffalo fat + 4% olive oil, T10= 15% buffalo fat + 5% olive oil.

3.2 Texture analysis of semidry fermented buffalo meat sausages

The texture analysis of semi dry fermented buffalo meat sausage samples was done in fresh condition i.e. on the zero day of the sample preparation. The total ten samples were tested for texture analysis carrying different levels of vegetable oils viz., 15%, 20% and 25% each of canola oil, safflower oil and olive oil.

3.2.1 Hardness

The sausage samples were tested for their hardness values using a texture analyzer. The hardness value of the control sample (T1) was found to be 590 g. The incorporation of canola oil brought a considerable improvement in the hardness value of treated samples. From Figure 3, it is clear that the hardness values of treated samples T2, T3 & T4 with 3%, 4%, and 5% substitution of animal fat were found as 632, 696 & 744 g, respectively. The treatments T2, T3 & T4 significantly ($p<0.05$) increased the hardness value of sausage samples. The incorporation of safflower oil brought a considerable improvement in the hardness value of treated samples. The hardness values of treated samples T5, T6 & T7 with 3%, 4% and 5% substitution of buffalo fat with safflower oil were found as 640, 683 & 722 g, respectively. The treatments T5, T6 & T7 significantly ($p<0.05$) increased the hardness value of sausage samples. The increasing value of hardness could be mainly attributed to the substitution of buffalo fat with safflower oil. The incorporation of olive oil brought a considerable improvement in the hardness value of treated samples. The hardness values of treated samples T8, T9 & T10 with 3%, 4%, and 5% substitution of animal fat were found as 624, 667 & 718 g, respectively. The treatments T8, T9 & T10 significantly ($p<0.05$) increased the hardness value of sausage samples. The increasing value of hardness might be associated with the substitution of buffalo fat with olive oil. The increasing value of hardness could be mainly attributed to the substitution of buffalo fat with canola oil. Similar results of improved hardness value were reported by [27] Kilic and Ozer (2017), who substituted animal fat with vegetable oil in dry sausage. Youssef and Barbut (2009; 2011) [32, 33] suggested similar results of higher hardness value in meat products treated with canola oil as compared to beef fat. Many other researchers also advocated similar findings by replacing the animal fat with vegetable oils to increase the hardness value of meat products [34-41] (Fernandez-Diez et al., 2016 ; Baek et al., 2016 ; Fonseca et al., 2015 ; Choi et al., 2013 ; Ruiz-Capillas et al., 2012 ; Liaros et al., 2009 ; Choi et al., 2009 ; Mendoza et al., 2001).

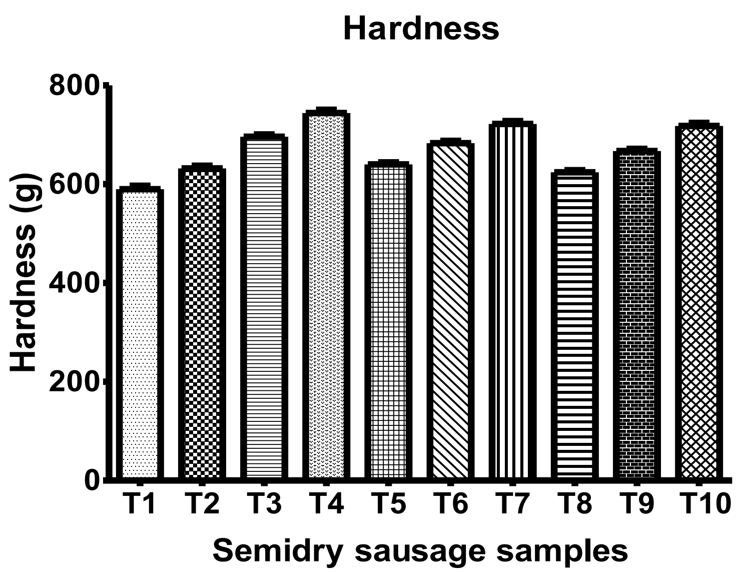


Figure 3: Hardness values of semidry sausages incorporated with different levels of vegetable oils

Means ± SD; T1= 20% buffalo fat (control), T2= 17% buffalo fat + 3% canola oil, T3= 16% buffalo fat + 4% canola oil, T4= 15% buffalo fat + 5% canola oil, T5=17% buffalo fat + 3% safflower oil, T6=16% buffalo fat + 4% safflower oil, T7=15% buffalo fat + 5% safflower oil, T8=17% buffalo fat + 3% olive oil, T9=16% buffalo fat + 4% olive oil, T10=15% buffalo fat + 5% olive oil

3.2.1 Cohesiveness

The cohesiveness value for the control sample (T1) was 0.52. The incorporation of canola oil resulted in a considerable improvement in the cohesiveness value of the treated samples. From Figure 4, it is clear that the cohesiveness values of the treated samples T2, T3 & T4 with 3%, 4%, and 5% substitution of animal fat, respectively, were 0.58, 0.63, and 0.67. The treatments T2, T3 & T4 significantly ($p < 0.05$) increased the cohesiveness of sausage samples. The increasing value of cohesiveness could mainly be attributed to the substitution of buffalo fat with canola oil. Similar results were claimed by Baek et al. (2016), who replaced pork back fat with canola oil in emulsion sausages and spent layer meat. The incorporation of safflower oil resulted in a considerable reduction in the cohesiveness values of the treated samples. The cohesiveness values of treated samples T5, T6 & T7 with 3%, 4% and 5% substitution of animal fat with safflower oil, were found as 0.48, 0.43 & 0.39, respectively. The treatments T5, T6 & T7 significantly ($p < 0.05$) decreased the cohesiveness of sausage samples. The decrease in cohesiveness is presumably due to the substitution of buffalo fat with safflower oil. Similar results were reported by Fernandez-Diez et al. (2016) [34], who partially replaced fat with boiled quinoa in dry-cured sausage. The reduction in cohesiveness value resulting from substituting fat with vegetable oils was also demonstrated by Ruiz-Capillas et al. (2012), Yoo et al. (2007), and Mendoza et al. (2001) [41-43]. The incorporation of olive oil resulted in a considerable improvement in the cohesiveness value of the treated samples. The cohesiveness values of treated samples T8, T9 & T10 with 3%, 4%, and 5% substitution of animal fat were found as 0.55, 0.61 & 0.65, respectively. The olive oil treatment resulted in a significant ($p < 0.05$) improvement in the cohesiveness of sausage samples. The increasing value of cohesiveness might be associated with the substitution of buffalo fat with olive oil. Similar findings were reported by Baek et al. (2016) [35]], who replaced pork back fat with vegetable oils in emulsion sausages made from spent layer meat.

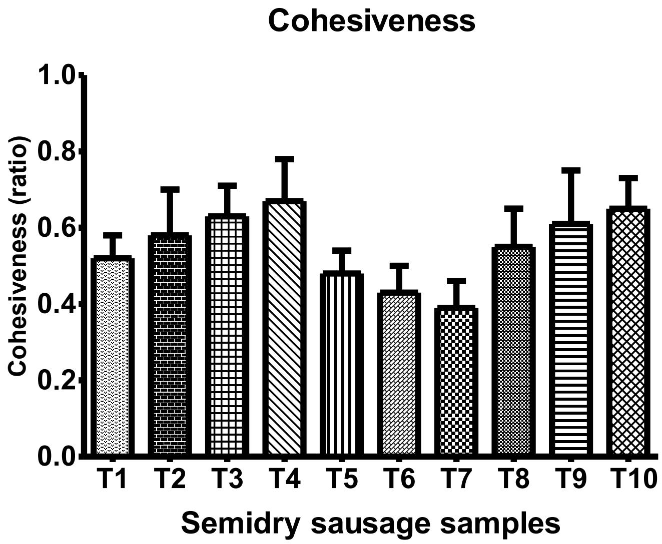


Figure 4: Cohesiveness values of semidry sausages incorporated with different levels of vegetable oils

Means ± SD; T1= 20% buffalo fat (control), T2= 17% buffalo fat + 3% canola oil, T3= 16% buffalo fat + 4% canola oil, T4= 15% buffalo fat + 5% canola oil, T5=17% buffalo fat + 3% safflower oil, buffalo fat + 3% olive oil, T9=16% buffalo fat + 4% olive oil, T10=15% buffalo fat + 5% olive oil

3.2.2 Springiness

The springiness of the control sample (T1) was 0.78 mm. The incorporation of canola oil resulted in a significant improvement in the springiness of treated samples. From Figure 5, it is clear that the springiness values of the treated samples T2, T3 & T4 with 3%, 4%, and 5% substitution of animal fat were 0.82, 0.85 & 0.87 mm, respectively. The treatments T2, T3 & T4 significantly ($p < 0.05$) increased the springiness of sausage samples. The increase in springiness could mainly be attributed to substituting buffalo fat with canola oil. Similar results were claimed by [32] Youssef and Barbut (2009), who replaced pork back fat with canola oil in emulsion sausages and spent layer meat. The incorporation of safflower oil did not result in a significant ($p<0.05$) difference in springiness value between treated samples and the control. The springiness values of treated samples T5, T6 & T7 with 3%, 4%, and 5% substitution of animal fat were found as 0.79, 0.82 & 0.84 mm, respectively. The treatments T5, T6 & T7 brought a slight increment in the springiness value of sausage samples which were not found significant ($p<0.5$) as compared to control. Similar results were claimed by Fernandez-Diez et al. (2016) [34], who partially replaced fat with boiled quinoa in dry-cured sausage. The incorporation of olive oil resulted in a considerable improvement in the springiness of treated samples. The springiness values of treated samples T8, T9 & T10 with 3%, 4%, and 5% substitution of animal fat were found as 0.81, 0.84 & 0.86 mm, respectively. The treatments T8, T9 & T10 significantly ($p < 0.05$) increased the springiness of sausage samples. The increasing value of springiness might be attributed to the substitution of buffalo fat with olive oil. Similar results were reported by Youssef and Barbut (2009) [32], who replaced pork back fat with vegetable oil in emulsion sausages made with spent layer meat.

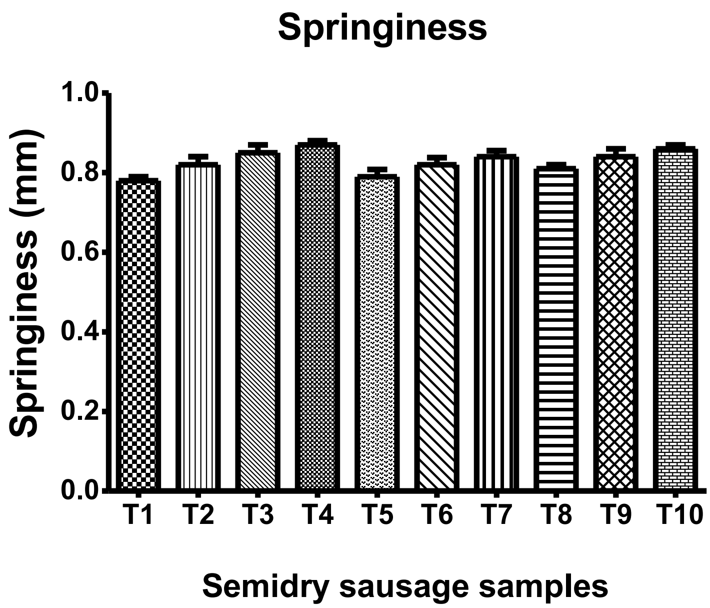


Figure 5: Springiness values of semidry sausages incorporated with different levels of vegetable oils.

Means ± SD; T1= 20% buffalo fat (control), T2= 17% buffalo fat + 3% canola oil, T3= 16% buffalo fat + 4% canola oil T4= 15% buffalo fat + 5% canola oil, T5=17% buffalo fat + 3% safflower oil, T6=16% buffalo fat + 4% safflower oil, T7=15% buffalo fat + 5% safflower oil, T8=17% buffalo fat + 3% olive oil, T9=16% buffalo fat + 4% olive oil, T10=15% buffalo fat + 5% olive oil

3.2.3 Gumminess

The gumminess value of the control sample (T1) was 306.8 g. The incorporation of canola oil resulted in a considerable improvement in the gumminess value of the treated samples. From Figure 6, it is clear that the gumminess values of the treated samples T2, T3 & T4 with 3%, 4%, and 5% substitution of animal fat were 366.56, 438.48 & 498 g, respectively. The treatments T2, T3 & T4 significantly ($p < 0.05$) increased the gumminess of sausage samples. The increasing value of gumminess could mainly be attributed to substituting buffalo fat with canola oil. Similar results were claimed by Baek et al. (2016) [35], who replaced pork back fat with canola oil in emulsion sausages and spent layer meat. Youssef and Barbut (2009) [44] also suggested similar findings by replacing canola oil in meat products. The gumminess values of the treated samples T5, T6 & T7 with 3%, 4%, and 5% substitution of animal fat were found to be 307.2, 293.69 & 281.58 g, respectively. The incorporation of safflower oil did not result in a significant ($p<0.05$) difference in the gumminess value of the treated sample T5 compared to the control. But treatments T6 & T7 resulted in a considerable reduction in the gumminess values of the samples relative to the control. The treatments T6 & T7 significantly ($p < 0.05$) decreased the gumminess of sausage samples. The decrease in inness may be attributed to a reduction in the cohesiveness of treaplethe s. The incorporation of olive oil resulted in an incredible improvement in the gumminess of the treated samples. The gumminess values of the treated samples T8, T9 & T10 with 3%, 4%, and 5% substitution of animal fat were found to be 343.20, 406.87 & 466.70 g, respectively. The treatments T8, T9 & T10 showed significant ($p < 0.05$) improvement in the gumminess value of sausage samples. The increasing value of gumminess might be associated with the substitution of buffalo fat with olive oil. Similar results were claimed by Baek et al. (2016) [35], who replaced pork back fat with other vegetable oils in emulsion sausages and spent layer meat. Youssef and Barbut (2009) [44] also suggested similar findings by replacing animal fat with vegetable oil in meat products.

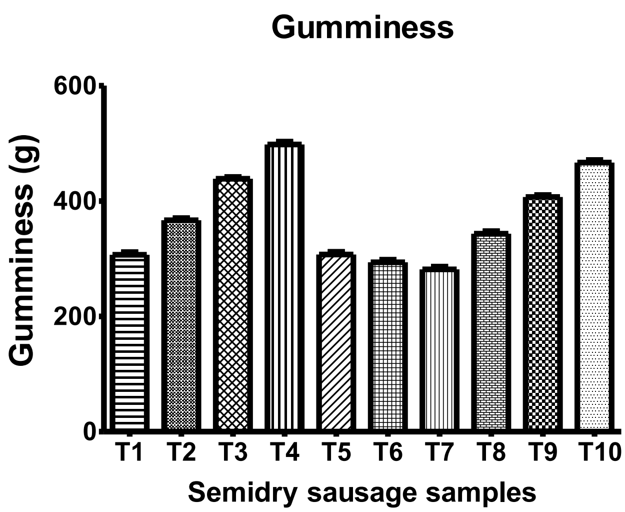


Figure 6: Gumminess values of semidry sausages incorporated with different levels of vegetable oils.

Means ± SD;T1= 20% buffalo fat (control), T2= 17% buffalo fat + 3% canola oil, T3= 16% buffalo fat + 4% canola oil T4= 15% buffalo fat + 5% canola oil, T5=17% buffalo fat + 3% safflower oil, T6=16% buffalo fat + 4% safflower oil, T7=15% buffalo fat + 5% safflower oil, T8=17% buffalo fat + 3% olive oil, T9=16% buffalo fat + 4% olive oil, T10=15% buffalo fat + 5% olive oil

3.2.4 Chewiness

The chewiness value of the control sample (T1) was 306.8 g. The incorporation of canola oil resulted in a clear improvement in the chewing of the treated sample. The chewiness values of treated samples T2, T3 & T4 with 3%, 4%, and 5% substitution of animal fat were found as 366.56, 438.48 & 498 g, respectively. The treatments T2, T3 & T4 significantly ($p < 0.05$) increased the chewiness of sausage samples. The increasing value of chewiness is mainly attributable to substituting buffalo fat with canola oil. Similar results were reported by Baek et al. (2016) [36], who replaced pork back fat with canola oil in emulsion sausages and spent layer meat. Furthermore, several studies have reported higher chewiness values in reduced-fat sausages [34, 36, 39] (Fernandez-Diez et al., 2016; Fonseca et al., 2015; Liaros et al., 2009). From Figure 7, it is clear that the chewiness values of treated samples T5, T6 & T7 with 3%, 4% and 5% substitution of animal fat were found as 242.68, 240.82, and 236.52 g, respectively. The incorporation of safflower oil resulted in a slight increase in the chewiness value of the treated sample T5 and a slight reduction in the chewiness values of the treated samples T6 & T7. However, the change in the chewiness values of treated samples was not significantly different ($p<0.05$). In contrast to the present study, many researchers claimed similar findings of higher chewiness values in reduced-fat sausages (Fernandez-Diez et al., 2016; Fonseca et al., 2015; Liaros et al., 2009) [34, 36, 39]. The incorporation of olive oil resulted in a considerable improvement in the chewiness of treated samples. The chewiness values of treated samples T8, T9 & T10 with 3%, 4%, and 5% substitution of animal fat were found as 277.10, 341.77 & 401.36 g, respectively. The treatments T8, T9 & T10 were significantly ($p < 0.05$) associated with improved chewiness values in sausage samples. The increasing value of chewiness may be attributed to substituting buffalo fat with olive oil. Similar findings were reported by Baek et al. (2016) [45], who replaced pork back fat with other vegetable oils in emulsion sausages, with spent layer meat. Furthermore, several studies have reported higher chewiness values in reduced-fat sausages [34, 36, 39] (Fernandez-Diez et al., 2016; Fonseca et al., 2015; Liaros et al., 2009). The gumminess and chewiness are the dependent textural properties that depend upon hardness, cohesiveness, and springiness properties. The canola and olive oil treatment resulted in a significant ($p < 0.05$) improvement in the textural properties of semidry sausage, viz., hardness, cohesiveness, springiness, gumminess, and chewiness, compared with buffalo back fat. While safflower oil produced a different pattern in the textural properties, i.e., it improved the hardness and springiness values while reducing the cohesiveness and gumminess values. Safflower oil first increases, then decreases, the chewiness of semidry sausage.

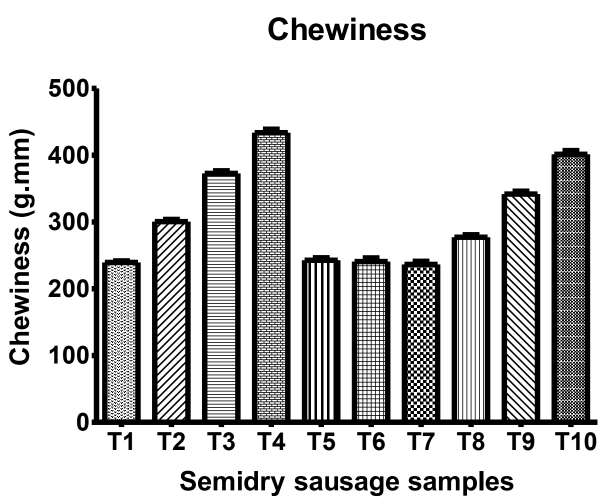


Figure 7: Chewiness values of semidry sausages incorporated with different levels of vegetable oils.

Means ± SD; T1= 20% buffalo fat (control), T2= 17% buffalo fat + 3% canola oil, T3= 16% buffalo fat + 4% canola oil T4= 15% buffalo fat + 5% canola oil, T5=17% buffalo fat + 3% safflower oil, T6=16% buffalo fat + 4% safflower oil, T7=15% buffalo fat + 5% safflower oil, T8=17% buffalo fat + 3% olive oil, T9=16% buffalo fat + 4% olive oil, T10=15% buffalo fat + 5% olive oil.

4. Conclusions

The results of studies on partial substitution of animal fat with varying levels of canola oil in semidry fermented buffalo meat sausage improved color, texture, and sensory properties compared to the control. The vegetable oil treatment successfully improved the tenderness of the sausage samples. The palatability of the sausages was found to be comparable to that of the control sample. However, the product's instrumental color and texture are significantly affected. The instrumental color values, viz., lightness, redness, and yellowness, improve in the canola oil-treated samples. The instrumental textural properties, viz., hardness, cohesiveness, gumminess, springiness, and chewiness, were also improved by the animal fat replacement with canola oil. Substituting animal fat with canola oil improved the product's fatty acid profile, which will surely help reduce the frequency of noncommunicable diseases.

Author Contributions

Conceptualization: Irfan Khan, Tariq Khan

Methodology: Tariq Khan

Analysis: Sameer Ahmad

Writing: Irfan Khan, Tariq Khan

Review and Editing: Tariq Khan, Sameer Ahmad

Ethics Statement

Not applicable.

Informed Consent

Not applicable.

Data Availability

Data are publicly available at the specified repository and link.

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None

Conflicts of Interest

None

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