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Development of cheese analogue by substitution of milk fat from vegetable fats

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Abstract

The experiment was conducted to develop a cheese analogue by the incorporation of Corn oil or Palm oil to skim milk while comparing with commercial cheese via sensory/chemical evaluations. Four analogues were produced with 2 oil levels (30g/kg and 50g/kg). Produced analogues showed significant difference for taste and appearance. Highest preference was recorded in 50g/kg Corn oil analogue and selected to compare fatty acid composition with commercial sample. Fat content of selected analogue was lower (19%) than the commercial (39%) sample. Commercial sample contained 74.9% and selected analogue contained 23.3% of saturated fatty acids. Unsaturated fatty acid amounts of samples were 25.1% and 75.5% respectively. Poly unsaturated fatty acid contents of selected analogue was higher (44.3%) than commercial sample (1.9%). It was concluded that cheese could be manufactured successfully from Corn oil incorporation with improvable minor drawbacks as a healthy alternative with essential fatty acids.

Keywords: Cheese analogue, Skim milk, Palm oil, Corn oil

1. Introduction

Cheese analogues have increasing demand all over the world due to their cost-effectiveness, simplicity of manufacturing and the replacement of unsaturated milk fats from cheaper low saturated/saturated fats. History of these products goes back to ancient China with a fermented soy curd called "Sufu" [1]. They are defined as products which made by combining individual components, together with non-dairy fats or proteins, to produce a synthetic cheese-like product to meet specific necessities [2]. Increasing of public's awareness regarding nutrition and health and fast food consumption which accompanied with busy life styles made these products more popular in the world. Furthermore, these analogues have potentials to overcome issues accompanied with natural cheeses such as higher costs of production and storage, practical variability and structural and nutritional rigidity [3].

Commercial manufacture of processed cheese took place in Europe and USA between 1910 and 1920 [4]. The replacement of milk fat with mono-unsaturated fatty acids and/or poly-unsaturated fatty acids has been shown to lower the serum cholesterol level in humans [5]. The reduction of the saturated fatty acids level in processed cheese by substitution of milk fat with emulsified vegetable oil is an option for obtaining cheese with healthier saturated/ unsaturated fat balance [6]. Vegetable oils are free of cholesterol and have a high content of unsaturated fatty acids [7]. Corn oil is an excellent source of essential fatty acids; it typically exceeds 60%, contributed predominantly by linoleic (C-18:2) and usually less than 1.5% linolenic (C-18:3) fatty acids. In spite of this high level of unsaturation, corn oil has good oxidative flavor stability, partly attributed to its nonrandom distribution of fatty acids on triglycerides. Palm oil has a characteristic fatty acid composition, quite different from other commodity oils; it contains almost equal portions of saturated and unsaturated fatty acids. It is unique among vegetable oils because a significant amount of the saturated fatty acids (10 to 16%) are in the *sn*-2 position of its triglycerides [8]. Despite of vegetable oil incorporation to produce cheese analogues, many scientists invented different ingredients to produce cheese analogues such as marine micro algae [9], grain starches [10], [3], Lupine paste [11] etc. Reduction of production cost of cheese can be done by promoting of cost effective cheese analogues which made using relatively cheap vegetable oils and fats. The prime objective of this study was to develop a cheese analogue by substituting milk fat from cheap vegetable fats such as Corn oil or Palm oil while improving health and financial aspects.

2. Methodology

2.1 Preparation of cheese analogues

As the initial step of preparation of analogues, the separation of skim milk from whole milk was done using a cream separator. Total of 8 kg of skim milk was used for preparation of 4 types of cheese analogues using Corn oil and Palm oil in two levels (30g/kg and 50g/kg) for the preparation of T2: 30g/Kg of Corn oil, T3: 30g/Kg of Palm oil, T4: 50g/Kg of Corn oil, T5: 50g/Kg of Palm oil. Skim milk was heated up to 55°C and then the desired type and level of the vegetable oil was heated up to 45°C and mixed with each 2 Kg of skim milk. Each sample was homogenized for 5 minutes at 8000-9500 rpm, cooled to 28°C and cheese starter culture (1.5% w/w) was added to each sample. After 30 min of continuous stirring, rennet was added (0.025% w/w) to each sample and again stirred for 5 min. Each sample was allowed to ripe. After the completion of coagulation, the acidity was determined. Whey was separated from each sample by using a muslin cloth. Resulting curd was placed in wooden molds separately with adding (0.01% w/w) salt and kept overnight to remove moisture and whey completely. Finally, each sample was stored into cold room of 85% Relative

Humidity (RH) and 10 -12°C temperature. After 10 days, each sample was waxed and stored in cold room again at 12 -14°C temperature and allowed to ripen for 2 months to obtain 2-month-old natural cheese.

Another sample set was prepared to get 15 days old natural cheese with the same procedure without adding any vegetable oil for production of processed cheese. Two months old natural cheese and 15 days old natural cheese of each sample type (1:1) were melted using Kettle with emulsifying salts, Citric acid, Salt, Potassium sorbate and Sodium benzoate at 90°C for 4 min. After melting, the samples were poured into four metal trays and each tray was kept at 10°C temperature for 8h. A representative local market available control sample (T1) was used for comparison of properties of made analogues.

2.2 Sensory analysis

For the selection of most appropriate blend of low fat processed cheese analogues T2, T3,T4 and T5 were evaluated for appearance, color, taste, flavor, and overall acceptability on 5-point hedonic scale where 5 representing extremely like and 1 representing extremely dislike by using randomly selected 30 untrained panelists. And also, another sensory evaluation was conducted along with commercial cheese sample as a reference sample and the 4 developed cheese analogues.

2.3 Compositional analysis

For gross compositional analysis, all the 5 cheese samples were analyzed for total solid, moisture %, fat % (Gerber method), crude protein content (Kjeldhal method), ash content pH and acidity using standard AOAC methods. Fatty Acid profile of commercial cheese and best selected analogue from sensory evaluation was determined by using Gas Chromatography by preparation of fatty acid methyl esters (FAMEs) from cheese samples [12].

2.4 Statistical analysis

Sensory evaluation non-parametric data were statistically analyzed using Kruskal-Wallis test and data from the proximate composition analysis were analyzed using One-Way Analysis of Variance (ANOVA) at 95% confidence interval by using Minitab-17 software. All the parametric measurements were taken in triplicates and reported as mean ± Standard deviation.

3. Results and Discussion

3.1 Results of sensory analysis

Table 1: Sensory attribute comparison of different cheese analogues

Attribute	T2	T3	T4	T5
Appearance	68.05^{a}	57.71^{ab}	43.83^{b}	72.35^{a}
Color	59.5^{a}	56.05^{a}	51.51^{a}	74.93^{a}
Taste	51.2^{b}	55.1^{ab}	77.16^{a}	58.53^{ab}
Aroma	52.18^{a}	60.65^{a}	65.16^{a}	64^{a}
Overall Acceptability	55.66^{a}	54.93^{a}	67.7^{a}	63.7^{a}

*Means with different superscript letters along rows are significantly different at ($p<0.05$) level

(T2:30g/kg Corn oil, T3: 30g/kg Palm oil, T4: 50g/kg Corn oil and T5: 50g/kg Palm oil)

Comparison of sensory attributes of vegetable oil based skim milk cheese analogues are shown in Table 1. Highest mean rank for appearance was obtained by T5 (72.3). The T3 (57.7) and T2 (68) samples do not show significant ($p>0.05$) difference with T5 for appearance. The T4 (43.8) sample has the lowest mean rank value and it significantly ($p<0.05$) differs from T2 and T5 but not from T3. Increment of Corn oil proportion has lead to the appearance dislike towards lowest mean and increment of Palm oil proportion has led to improvement of appearance towards highest mean. Similar scenario can be seen in comparison of color of treatments. Increment of Corn oil proportion has lead the analogue towards color dislike (T4) and increment of Palm oil has lead towards enhancement of color (T5) of analogues but no significance ($p<0.05$) within treatments. Corn oil has improved the taste of analogue (77.1) at its upper level (T4) and its lower level (T2) has the lowest preference for taste (51.2). Two treatments of Palm oil (T5 and T3) have the second and third highest preferences for taste (58.5 and 55.1) respectively. The tastes of T4, T3 and T5 were not significantly differ ($p>0.05$) from each and also T2, T3 and T5 followed the same insignificance ($p>0.05$). Two levels of Corn oil (30g/kg and 50g/kg) showed significant difference ($p<0.05$) for taste representing the highest and lowest preferences. Highest preference for aroma was obtained by T4 (65.1) and the lowest by T2 (52.1). All treatments did not show any significant difference ($p>0.05$) for colour, aroma and overall acceptability. Except for color and appearance, T4 analogue showed the highest mean rank for taste, aroma and overall acceptability. Since the color does not show any significant difference with other treatments, 50g/kg Corn oil incorporation can be concluded as the best treatment condition for the development of cheese analogues.

Table 2: Sensory attribute comparison of cheese analogues with different treatments

Attribute	T1	T2	T3	T4	T5
Appearance	123.33^{a}	71.20^{b}	60.56^{b}	45.66^{b}	76.73^{b}
Color	125.48^{a}	61.91^{b}	57.71^{b}	53.61^{b}	78.76^{b}
Taste	128.98^{a}	51.95^{b}	56.11^{b}	80.60^{b}	59.85^{b}
Aroma	117.53^{a}	55.31^{b}	65^{b}	69.98^{b}	69.66^{b}
Overall Acceptability	129.17^{a}	56.73^{b}	57^{b}	69.43^{b}	65.16^{b}

*Means with different superscript letters along rows are significantly different at ($p<0.05$) level

(T1: Control-commercial, T2:30g/kg Corn oil, T3:30g/kg Palm oil, T4: 50g/kg Corn oil and T5:50g/kg Palm oil)

Table 2 shows the sensory attribute analysis of cheese analogues in the presence of a commercially available cheese as a control treatment (T1). All attributes of market available cheeses had obtained the highest mean values and was significantly different ($p<0.05$) from the vegetable oil incorporated skim milk cheese analogues. Besides the market available sample, other samples followed the same sensory preference pattern of Table 1 and all the other analogues except T1 showed more or less similar mean values within each category. The differences between taste scores can be mainly related to a difference in short-chain fatty acid compositions of the milk fat and the vegetable oil fats [13]. Sensory attributes of cheese solely depend on cheese making process and specially at ripening. The cheese analogues lose the properties of natural cheese at the process of cream separation and start to show different properties than whole milk cheese by acquiring characteristics of incorporated vegetable fat constituents. Loss of beta carotene from milk during cream separation is majorly responsible for change of color in analogues. The pigments and other nutrients of incorporated

foreign vegetable fat give significantly different appearance and color to cheese analogue.

Cunha *et al.* [13] reported that the traditional processed cheese and the cheese analogue with 50 % vegetable fat received similar scores for the attribute of overall acceptability. Lobato-Calleros *et al.*, [6] concluded that a totally or partially Canola oil substituted cheese analogue showed an open micro structure with looser, more disrupted protein matrix in the cheese from observations of Scanning Electron Micrographs (SEM). Moreover, the increase of emulsifiers increased the values of all textural characteristics of cheeses. The textural characteristics as hardness, chewiness and adhesiveness were lower than that of whole milk cheese which the fat fractions were filled by more numerous, smaller and lower melting point canola oil droplets than milk fat. According to Stampanoni & Noble [14], higher amounts of fat formed softer, less springy, more cohesive and adhesive cheese analogues. Moreover, increasing citric acid or NaCl formed significant reduction of cohesiveness and springiness and surge of firmness. Adding salt may result a strong of texture via ionic bonds [15]. Since commercial producers use different ingredients such as emulsifiers and additives and different ripening periods other than compared treatments, may be the cause for a consumer-friendly appearance and color resulted the higher sensory preference. As the most important negative property of cheese analogues, the taste completes the acceptance or rejection of consumer in collaboration with aroma. By addition of appropriate enzymes or microbes in the process and ripening at encouraging temperatures, cheese analogues of any taste and aroma can be manufactured [16].

3.2 Proximate and chemical composition

Table 3: Chemical properties of different cheese analogues

Treatment	Fat (%)	Moisture (%)	Total solids (%)	Protein (%)	Ash (%)	pH	Acidity (%)
T1 (Control)	39.00 ± 1.00^{a}	77.69 ± 1.19^{a}	$22.30 \pm 1.18c$	$22.99 \pm 0.04c$	5.67 ± 0.02^{bc}	5.87 ± 0.09^{b}	0.30 ± 0.00^{a}
T2 (30g/Kg Corn oil)	18.6 ± 1.15^{c}	73.99 ± 2.24^{ab}	26.01 ± 2.24^{b}	30.51 ± 0.04^{a}	5.65 ± 0.02^{bc}	6.31 ± 0.06^{a}	0.27 ± 0.01^{a}
T3 (30g/Kg Palm oil)	15.00 ± 0.00^{d}	71.60 ± 0.82^{c}	28.39 ± 0.82^{a}	29.17 ± 0.02^{b}	5.18 ± 0.05^{c}	6.24 ± 0.03^{a}	0.20 ± 0.01^{c}
T4 (50g/Kg Corn oil)	19.00 ± 1.73^{c}	76.25 ± 1.00^{ab}	23.74 ± 1.00^{b}	30.16 ± 0.89^{a}	6.34 ± 0.49^{a}	6.26 ± 0.02^{a}	0.26 ± 0.01^{ab}
T5 (50g/Kg Palm oil)	26.30 ± 1.15^{b}	76.42 ± 0.25^{a}	23.57 ± 0.25^{c}	29.41 ± 0.17^{b}	6.07 ± 0.47^{ab}	6.31 ± 0.06^{a}	0.22 ± 0.04^{bc}

*Means with different superscript letters along columns are significantly different at ($p<0.05$) level

Fat is the most important constituent of a cheese formation. The lowest fat content (15%) was recorded by T3 (Table 3), the lowest palm oil inclusion analogue (30g/kg palm oil) and the highest fat content (39%) was recorded in commercial (T1) cheese sample. Fat % of all treatments were significantly different from control (T1). The selected best treatment analogue (T4: 50g/Kg corn oil) from sensory evaluation has significantly lower fat % (19%) than the commercial (T1) sample and it can be regarded as consumer health friendly cheese analogue.

Table 4: Comparison of fatty acid compositions Commercial (T1) and Corn oil 50g/kg (T4) incorporated cheese analogue

Fatty Acids	T1 (g/100g of fat)	T4 (g/100g of fat)
Saturated Fatty Acids	74.9	23.3
Unsaturated Fatty Acids	25.1	75.5
Mono Unsaturated Fatty Acids	23.2	31.2
Poly Unsaturated Fatty Acids	1.9	44.3
Unknown Fatty Acids	0	1.2
Omega 3 and Omega 6 Fatty Acids	1.9	44.3

The commercial sample (T1) contains 74.9% and T4 contains 23.3% of saturated fatty acids (Table 4). The unsaturated fatty acid amounts of T1 and T4 were 25.1% and 75.5% respectively. Since saturated fats linked with heart diseases and cholesterol problems, the T4 cheese analogue seems to be safe for health within its fat parameters. Omega 3 (C18:3) and Omega 6 (C18:2) contents of T1 and T4 samples were 1.9% and 44.3% respectively. Besides the T4 analogues health benefits, the higher Omega 3 and 6 contents add a sound alternative for nutrition. Increment of Corn oil proportion can be done to increase the unsaturated fatty acid contents, Omega 3 and Omega 6 contents of analogue and flavor reduction can be overcome by artificial flavor additions.

Considering the proximate and chemical analysis of the cheese analogues, moisture % of T4 (76.25%), T2 (73.99%) and T5 (76.42%) were not significantly different from the control (77.69%) which means the substitution of milk fat did not affect the moisture content of samples significantly. When considering the total solid contents, mean value for control treatment (22.3%) and T5 (23.57%) were not significantly different from each other and also T2 (26.01%) and T4 (23.74%) seems same within each. Lowest mean value for total solid occur in control treatment and highest mean value for total solid contain in T3 (28.39%). Since the selected best T4 sample contains higher total solid amount than the commercial (T1) sample it seems to be a better alternative.

Protein content of analogues seems higher than the commercial sample (22.99%) and differs significantly (Table 3). Treatment 2 (T2) (26.01%) and T4 (23.74%) were not significantly different from each other, and also T3 (29.17%) and T5 (29.41%) were not significantly different from each other. This

shows that the added amount of vegetable oils did not affect the protein content of the analogue but the type of oil affected.

Mineral matter considerations from ash % showed that the control treatment (5.67%) T2 (5.65%) and T3 (5.18%) did not have significant difference from each other (Table 3). Treatment 4 (6.34%) has been shown highest mean value for the ash % than all other treatments which means a higher mineral content than other samples. Moreover, the control treatment and T4 had significant difference of ash %. All samples were in acceptable pH range. The processed analogues T2, T3, T4 and T5 did not show a significant difference (6.31, 6.24, 6.26 and 6.31 respectively) within each other but showed with control treatment (5.87). The commercial sample shows lowest mean value for pH and however all samples were in acceptable range of pH level. Moreover, the pH is low in commercial sample, it shows the highest acidity value (0.3%) of all treatments. The control treatment, T4 (0.26%) and T2 (0.27%) were not significantly different within each other. Lowest mean value for acidity shows T3 (0.20%) analogue.

4. Conclusion

Incorporation of vegetable oils to manufacture cheese analogues was successful and 50g/kg Corn oil incorporated cheese analogue showed highest sensory evaluation results than other treatments. At the comparison with the commercially available cheese, all analogues show insignificance within each ($p>0.05$) for sensory attributes but showed significantly lower preference than commercial product. Corn oil (50g/kg) incorporated cheese analogue showed lower saturated (23.3%) and higher unsaturated (75.5%) fatty acid contents than commercially available cheese (74.9 and 25.1% respectively). Higher presence of Omega 3 and Omega 6 (44.3%) was observed within the chemical parameters than commercial sample (1.9%). By addition of flavor enhancers, this analogue can be improved further as healthy, nutritionally and economically sound global alternative.

5. References

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