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Effect of Coriander (*Coriandrum sativum*) Smoke on Physicochemical and Sensory Characteristics of Mudaffara Cheese

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ABSTRACT

This study was done to compare physiochemical and sensory attributes of smoked and non smoked Mudaffara cheese using *Coriandrum sativum* seed. Mudaffara cheese was prepared from fresh cow's milk and the resulted cheese was divided into two portions; the treated cheese, which was smoked by *Coriandrum sativum* in a close smoker for about 2 hours. The second portion was left as a control. Both cheeses were packed into labeled plastic containers and stored for five weeks in the refrigerator. The analysis was carried out in the first day, then every week. The result indicated that the smoked Mudaffara cheese was significantly ($P<0.05$) higher in total solids, protein and fat contents compared to the control cheese, which revealed significantly ($P<0.05$) higher acidity compared to the smoked Mudaffara cheese. The study also found significant ($P<0.05$) variations in protein and total solids content and the acidity of Mudaffara cheese during the storage period. The smoked Mudaffara cheese showed higher scores for flavor, salt and overall acceptability as was stated by the panelists, however the better color was recorded for unsmoked Mudaffara cheese. Hence the study concluded that smoking using *Coriandrum sativum* seed improve the keeping quality and acceptability of Mudaffara cheese.

Keywords: Coriandrum sativum; Mudaffara cheese; Smoking; Storage

INTRODUCTION

Most of the cheese varieties are manufactured by common steps that include formation followed by the whey expulsion, acid production salting and ripening (Beresford et al., 2001).

In Sudan, *Gibna bayda*; the white cheese; is the major type that is produced traditionally especially during rainy seasons in rural areas (El Owni & Osman, 2009; Elkhider et al., 2012). The second major type of the local cheese produced is *Gibna mudaffara* (Hamid & El Owni, 2007; Nour El Diam & El Zubeir, 2007; Farah & El Zubeir, 2020). *Gibna mudaffara* is characterized by its ability to withstand for a long period when immersed in the whey (Mohammed Salih et al., 2011). Moreover, the storage of the braided (Mudaffara) cheese in good suitable conditions could be one of the practical methods for preserving the milk into a product with high nutritional value and long shelf life (Farah & El Zubeir, 2020).

Among the recommendations for manufacture of good quality cheese, high quality milk produced by healthy animals, good manufacturing procedures and maintenance of the product quality during both storage and marketing are necessary (Warsma et al., 2006). Also for the improvement of the Sudanese white cheese, it was suggested that the cheese be further processed in order to increase its hygienic quality and the shelf life (Nour El Diam & El Zubeir, 2006).

Ahmed (1995) reported a titratable titriatable acidity of 0.29–0.69%, pH of 3.29–4.30, fat of 6.02–20%, protein of 28.29–31.92%, total solids of 53.63–63.83% and ash of 5.40–7.29% for Mudaffara cheese. The fat, protein, total solids, ash and acidity content of of the same cheese were reported as 17.2±2.13, 21.49±2.53%, 51.89±12.25%, 10.96±9.32 and 0.48±0.06,' respectively (Harun et al., 2015). The mean values were 4.17±0.06%, 22.00±0.28%, 61.69±0.12%, 4.17±0.06% and 0.46±0.29%, respectively (Farah & El Zubeir, 2020).

Currently the focus of food industry is the development of novel functional foods that contain natural ingredients with health promoting properties in order to replace food additives and to avoid their potential hazards (Caleja et al., 2015). The antimicrobial properties of wood smoke were found effective in many foods, moreover. when the cheese was smoked the chance of spoiling by molds growth is less compared to that of unsmoked natural cheeses (Wendorff et al., 1993). The cheese producers' are able to process natural smoked cheeses without any detectable benzo(a)pyrene using the electrostatic precipitation of tars from wood smoke or cold smoke treatment (Riha et al., 1992). Three types of local wood material most commonly used in cheese smoking in Yaman include *Zizyphus spina christi, Acacia asak,* and *Dodonia viscose* (Shaiban et al., 2006). Coriander (*Coriandrum sativum* L.) is one of valuable medicinal plants that is belong to the *Apiaceae* family, which is grown annually worldwide (Duarte et al., 2012; Hassanen et al., 2015).

Coriander (*Coriandrum sativum L.*) uses include flavoring of food products, medicine and cosmetics Darughe et al., 2012; Nadeem et al., 2013). Also, coriander prevents food degradation because of its antibacterial, antifungal properties and anti–oxidative activities (Sriti et al., 2011). It is added to the mixtures of other aromatic herbs for the production of herbed cheese and herbed cottage (Kaptan & Sivri, 2018). It is also added to yoghurt, fresh and cream cheese to give aroma and taste (Kaptan & Sivri, 2018). Also the addition of coriander may increase the consumption of cheese and improve consumer health (Turgut & Diler, 2020). Because of its seed popularity and extensive uses in Sudan in many foods, it was selected in this study to produce smoked Mudaffara cheese.

MATERIALS AND METHODS

Sources of materials

About 16 liters of fresh cow's milk were brought from University of Khartoum farm. Rennet tablets (Chr– Hansen's Laboratory, Denmark) were obtained from a private veterinary centre, while the table salt (commercial grade), *Coriandrum sativum*, black cumin (*Nagella sativa*) seed and charcoal were purchased from a local market. The starter culture was a product of CHR–HANSEN, YoFlex® Express 1.0).

Preparation and storage of cheese

The cheese was manufactured at Dairy Production Laboratory in the Faculty of Animal Production, University of Khartoum.

Analysis of milk

The milk which was used for preparation of the cheese, was analyzed using the Lactoscan (Milkotronic LTD, Bulgaria).

Processing of Mudaffara cheese

The cheese was made using the available cheese making equipment at the laboratory as described by Farah & El Zubeir (2020). Briefly, the milk was filtered through a muslin cloth, heated (62^{o} C for 15 minutes) and then cooled to 38.5^{o} C using ice water. The starter culture was added to the milk at a rate of 2%. After mixing gently, the mixture was left to stand for 5 minutes before the addition of rennet. The rennet tablets (2/ 100 kg milk) were dissolved and added to the milk with gentle mixing. It was thoroughly stirred for five minutes and left to stand for 45–60 minutes to allow the coagulation of the milk. A sterile knife was used for cutting the curd to allow whey drainage. Then the cut curd was placed in an incubator at 47 ºC for 2–3 hours to reach 0.67% acidity and the required elasticity. The elasticity test was done by putting small piece of the cheese into warm water at 85 °C for 5 minutes. If the curd stretched, then the rest of the curd was cooking in the warm water (85 ºC) for 5 minutes. The elastic curd was formed into balls and transferred to clean table for stretching into a 4 meters long rope. Black cumin was added at a rate of 0.5% w⁄w to the hot curd before braiding. The braiding of the curd was done using hands by pulling it into long ropes, which were then braided. The braided curd was washed using cold water and then preserved in 10% w⁄w salted whey for 24 hours. The cheese was divided into two parts: one was subjected to smoking using *Coriandrum sativum*, while the second was the control.

The smoking process

Commercial dried sample of *Coriandrum sativum* (coriander) was obtained from a local market, washed and roasted before it was used in smoking of Mudaffara cheese.
Mudaffara cheese was brought to room temperature for 2–3 hours for the formation of a layer outside the cheese to facilitate penetration of the smoke inside the cheese and prevent its melting. Pieces of charcoal were put in the periphery of smoking chamber and *Coriandrum sativum* seeds were put on it. Then Mudaffara cheese was hang on sticks inside the smoking chamber (Figure 1).

The smoking chamber was covered by muslin cloth. The smoking was done for 2-3 hours until the surface of the cheese sample had a nice brown colour all over and imparted a characteristic aroma and flavor (Michalski & Germuska 2003; Shaiban et al. 2006). After that the smoked cheese (Figure 2) was left at room temperature for 12 hours and packed in a plastic package. The smoked Mudaffara cheese was stored in the refrigerator at 5 °C together with the control Mudaffara cheese before analysis.

Examination of Mudaffara cheese

Coagulation time, yield, chemical composition and sensory characteristics of Mudaffara cheese were estimated at the laboratory at day 1, 8, 15, 22, 29, and 35.

Mudaffara cheese yield

Cheese yield was calculated by dividing the weight of cheese over the weight of milk and expressed on a percentage basis.

Chemical analysis of the cheese

The Gerber method was used for the determination of the crude fat, while Kjeldahl method was used for the estimation of crude protein of Mudaffara cheese (AOAC, 2003). The modified method of AOAC was used for the determination of the total solids. The ash content was determined by gravimetric method and the titratable acidity was determined by the titration determined described in AOAC (2003).

Sensory evaluation

A panel of 10 semi–trained staff and students from the Dairy Department that were familiar with cheese evaluated the sensory attributes of Mudaffara cheese using

5 point hedonic scale as described by Lim (2011). Where 5 was for *excellent*, 4 was for *very good*, 3 was for *good*, 2 was for *acceptable* and 1 was for *poor*. The sensory results were reported as the sum of scores of individual evaluators**.**

Statistical analysis

Statistical Package for Social Sciences (SPSS, version 16) was used. Analysis of variance (ANOVA). The means were separated by Duncan´s Multiple Range Test.

RESULTS AND DISCUSSION

Effect of *Coriandrum sativum* smoke on physico–chemical properties of Mudaffara cheese

The milk coposition from which Mudaffara cheese was made had 9.33%, 4.71%, 3.64%, 4.97% and 1.033 g/cm3 14.14%.for solids not fat, fat, protein, lactose and densiy, and total solids respectively.

Three kilograms of Mudaffara cheese were produced from 16 L of milk. Thus, the cheese yield of 18.75%. The obtained values were higher that the net weights of Mudaffara cheese estimated by Harun et al. (2015) who reported 11% and 12.5% for cheeses produced by *Solanum dubium* and chymosin, respectively.

Table 1 summarizes the composition of the cheese. There were more (p<0.01) total solids (61.46% vs. 56.32%), fat (28.92% vs. 22.85%) and protein (31.62% vs. 27.41%) in the smoked Mudaffara cheese compared to the control. However, the ash content was 10.99% and 10.57% (Table 1). The acidity (0.32%) of smoked Mudaffara cheese was significantly (p<0.01) lower than the control Mudaffara cheese (0.38%).

The higher composition of the smoked Mudaffara cheese proved the efficiency of Coriander in preserving the cheese. Coriander has been used for nutrition, medicine, flavoring, smoking and other industrial uses as well (Nadeem et al., 2013). Moreover, coriander seed essential oils can be used as natural antimicrobial and antioxidant in industrial food and drugs (Hassanen et al., 2015). Ahmed (1995) found similar values for total solids and crude protein, higher crude fat and lower ash content. With the exception of ash, higher values of crude fat, crude protein and total solids were observed in this study (Table 1) than those reported for Mudaffara cheese made using chymosin and Solanum dubium coat extract (Harun et al., 2015) and Mudaffara cheese using 0.3 or 0.5% Syrian thyme (El gabali et al., 2023). Riha et al. (1992) reported that the cheese processors limited the use of natural vaporous smoke only to cold smoking treatments in order to avoid free fat on the surface of the finished smoked cheese due to the high concentration of milk fat in cheese and its low melting point. The acidity of the cheese in this study was within the range reported by Ahmed (1995). However, Harun et al. (2015) reported a higher titratable acidity of 0.48±0.06%. Also, El gabali et al. (2023)reported higher acidity content of Mudaffara cheese flavored with Syrian thyme at 0.3% (0.74±0.11%) and 0.5% (0.71±0.9%) and black cumin (0.6±0.12%). The variation could be due to the antifungal properties in smoked cheese because the wood smoke components contain the primary antifungal properties (Wendorff et al., 1993).

The significant (P<0.01) increase in the total solids and crude protein of Mudaffara cheese till day 22 of storage period was obseved, then a reduction was found as the storage was progressed (Table 2). Similarly, the total solids and crude protein of Mudaffara cheese were increased gradually at week 2 and then decreased at the end of the storage period (El gabali et al., 2023). Slight reduction was observed in the total solids, while storing of Mudaffara cheese by Farah & El Zubeir (2020). Also, the coriander was found to affect significantly (P<0.05) the pH

and dry matter during the storage. Moreover, sensory scores declined during the storage period; but even on day 60, the samples were favourably scored (Turgut & Diler, 2020). Simlarly, Harun et al. (2015) found that the total solids were increased at week 2 (53.61%) before decreasing at week 3, and then increased to 58.45% at the end of the storage. However, a gradual decrease was reported in the protein of Mudaffara cheese till week 3 (19.29%) before it was increased to 21.61% by the end of the storage period.

The expulsion of moisture content from the cheese curd was possibly the reason for the increase of its total solids (Harun et al., 2015). The texture of cheese was influenced by both compositional and processing parameters (Wium et al., 2003). A significant ($P<0.01$) increase in acidity was observed till day 29 of storage. The titratable acidity was maximum at day 21 (0.57%) followed by a decrease to 0.50% at the end of the period of storage (Harun et al., 2015). The increase in the titratable acidity of Mudaffara cheese could be attributed to the growth of lactic acid bacteria leading to increase the lactic acid content of the cheese (Harun et al., 2015). In a similar study, the acidity of Mudaffara cheese showed significantly ($P<0.001$) lower values at day 0 and 7, then a sharp increase at day 21 (1.30±0.29%) towards the rest of storage period (Farah & El Zubeir, 2020).

This study reported flucationation in the fat and ash contents ($P>0.01$) during the staoge of Mudaffara cheese till day 21. to high moisture loss during the storage. Reduction in the fat content was also reported in Mudaffara cheese during the storage period (Altahir et al., 2014; Farah & El Zubeir, 2020). The high moisture loss during the storage was the reason for the apparent increase in crude fat, while the decrease in the fat content at end of storage period might be because of the breakdown of fat by microorganisms (Harun et al., 2015). However, El gabali et al. (2023) found significant ($P<0.001$) increase in the crude fat and non significant effect for the ash content of Mudaffara cheese during the storage period.of Mudaffara cheese during the storage period.

Non significant variation was found for the ash (Table 1 and 2). However, significantly ($P<0.001$) higher ash was found at day 0 (4.17±0.06%) and day 7 (4.08±0.06%) of Mudaffara cheese. Similarly, significantly ($P<0.01$) lower ash was found at day 35 (Farah & El Zubeir, 2020). An increase in the ash content at day 14 (15.59%) and day 28 (17.18%) was also reported (Harun et al., 2015). Abdalla & Mohamed (2009) reported that the total solids, fat and protein contents of cooked and vacuum packaged of white soft cheese was found to decrease with the progress of the storage period, however, the ash and titratable acidity showed continuous increase throughout storage period.

Effect of smoking on the sensory evaluation of Mudaffara cheese

The sensory acceptability of the Mudaffara cheeses are shown in Figure 1. The flavour, acid taste, saltiness and the overall acceptability showed increasing scores till day 15, then reduced at day 22 and 29 and increased again at day 35. According to Altahir et al. (2015), saltiness continuously increased ($P\leq0.05$) with the advancement in storage of Mudaffara cheese. Moreover, during the storage period, significant ($P<0.05$) variations were found in the texture, acidity, flavor, taste and general acceptability scores of Mudaffara cheese (El gabali et al., 2023).

The appearance, flavour, taste, texture and saltiness of Mudaffara cheese were reported to vary during storage (Farah & El Zubeir, 2019). Similarly, increasing acceptability scores for flavour and the overall acceptability of cheeses were during their ripening period (Nour El Diam & El

Zubier, 2007; Tarakci & Kucukoner, 2006). Also Abdalla & Mohamed (2009) reported that the flavour, taste, saltiness and the overall acceptability of cooked and vacuum packaged cheeses were gradually improved throughout storage. However, the best score for colour was reported in the non–smoked cheese (control) as shown in Figure 1.

The maximum smoking temperature of Mudaffara cheese should be 30 °C for 3 hours (Shaiban et al., 2006) or until light brown (Michalski & Germuska, 2003). This because the concentration of B(a)P strongly depends on the time and temperature of processing as the optimal temperature should be 25 °C–30 °C and that time processing should not exceed 2 hours (Michalski & Germuska, 2003). Riha et al. (1992) reported that the use of commercial smoking in the cheese products has a positive effect to control the deposition of 3, 4–benzo(a) pyrene; which is potential carcinogen; resulting from the smoking process. B(a)P is one of polycyclic aromatic hydrocarbons (PAHs), which is carcinogenic and mutagenic that are formed by the incomplete combustion of the organic matter and are widely believed to contribute in the occurrence of human cancer (Michalski & Germuska, 2003). However, when cold smoked with natural vaporous smoke, cheese was reported almost free of the potential carcinogen; 3, 4– benzo(a) pyrene level of detection at 0.1 ppb) (Riha et al., 1992). Thus, the use of coriander for smoking cheese could reduce the harmful potential carcinogen. The health benefits of coriander include antibacterial and anticancer activities (Bhat et al., 2014; Yildiz, 2015). Additionally, the essential oil and other various extracts of coriander possess some medicinal properties such as antibacterial, antioxidant, antidiabetic, anticancerous, antimutagenic and free radical scavenging activities (Sreelatha et al., 2009; Zoubiri & Baaliouamer, 2010).

The colour of the cheese revealed the best scores at the beginning (day 1) of the storage, then it decreased from day 8 until day 29 (Figure 1). Similarly, Farah & El Zubeir (2019) reported higher scores for appearance for the fresh Mudaffara cheese during day 0 and day 7 and lower scores duration storage. Caleja et al. (2015) found the incorporation of fennel–based ingredients to keep the yellowness color after 7 days of storage. Furthermore, the addition of a fennel phenolic–enriched extract improved the antioxidant properties of the cottage cheese for up to 14 days of storage. However better scores were reported at end of the storage period (Figure 1). El Owni & Hamid (2008) reported similar findings the Sudanese white cheese. In contrast, Abdalla & Mohamed (2009) reported that the colour and body of cooked and vacuum packaged cheese was constant throughout the duration of the storage.

CONCLUSION

Using *Coriandrum sativum* seed smoking was found to improve the keeping quality and acceptability of Mudaffara cheese.

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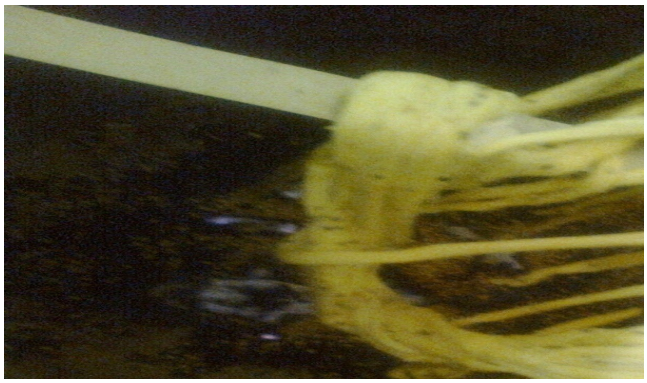

Figure 1. Mudaffara cheese hanging on stick inside the smoking chamber

Figure 2. Smoked Mudaffara cheese

Table 1. Effect of *Coriandrum sativum* smoke on physico–chemical properties of Mudaffara cheese

Treatment	Total solids (%)	Fat (%)	Protein(%)	Ash (%)	Acidity (%)
Control cheese	56.32	22.85	27.41	10.57	0.381
Smoked cheese	61.46	28.92	31.62	10.99	0.320
Means	58.89	25.33	29.52	10.87	0.351
Standard error	0.599	0.45	0.319	0.85	0.008
Level of significant	**	**	**	NS	**

** = P<0.01

NS = Not significant

Table 2: Effect of storage period on physico–chemical properties of smoked and Non–smoked Mudaffara cheese

Storage period	Total solids (%)	Fat (%)	Protein (%)	Ash (%)	Acidity (%)
Day 1	54.32	25.5	21.05	10.82	0.300
Day 8	56.95	24.00	27.35	11.200	0.290
Day 15	56.100	26.40	30.32	10.77	0.325
Day 22	64.400	26.75	33.95	10.72	0.362
Day 29	61.87	24.87	31.10	10.87	0.415
Day 36	59.73	24.49	33.34	10.93	0.411

** = P<0.01
NS = Not significant.

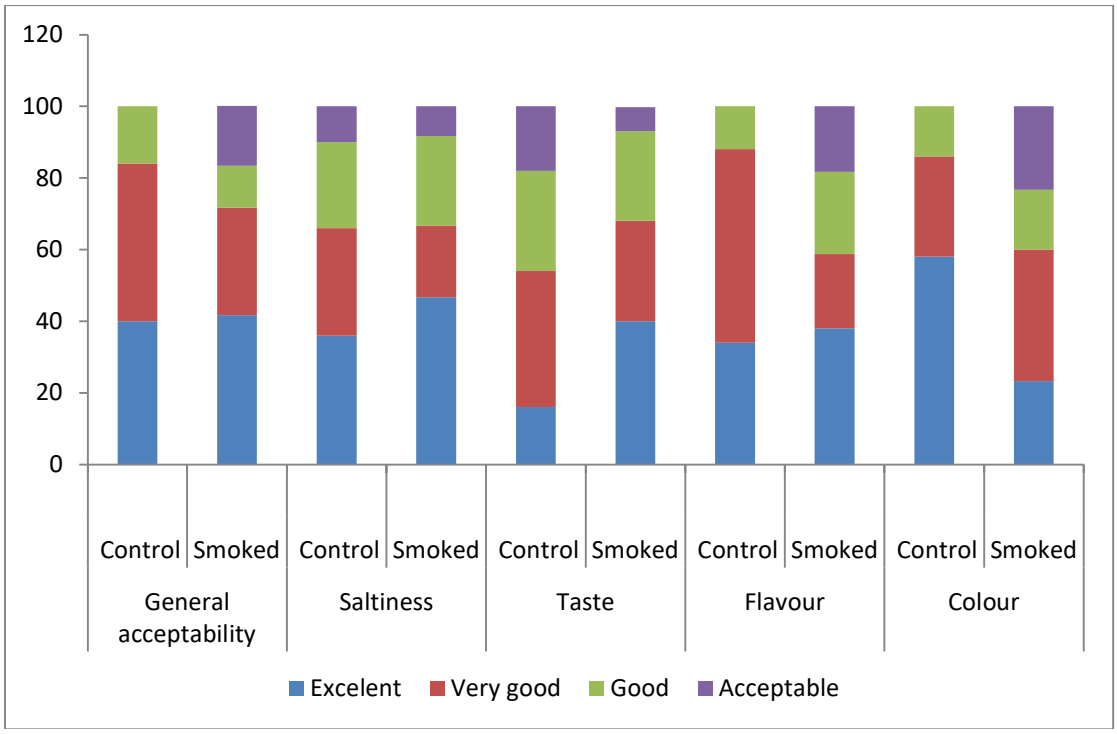

Figure 3. Variations of sensory evaluation of smoked and Non–smoked Mudaffara cheese