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Improving the sensory and chemical characteristics of functional yogurt fortified with cardamom extract (*Elettaria cardamomum* L.)

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ABSTRACT:

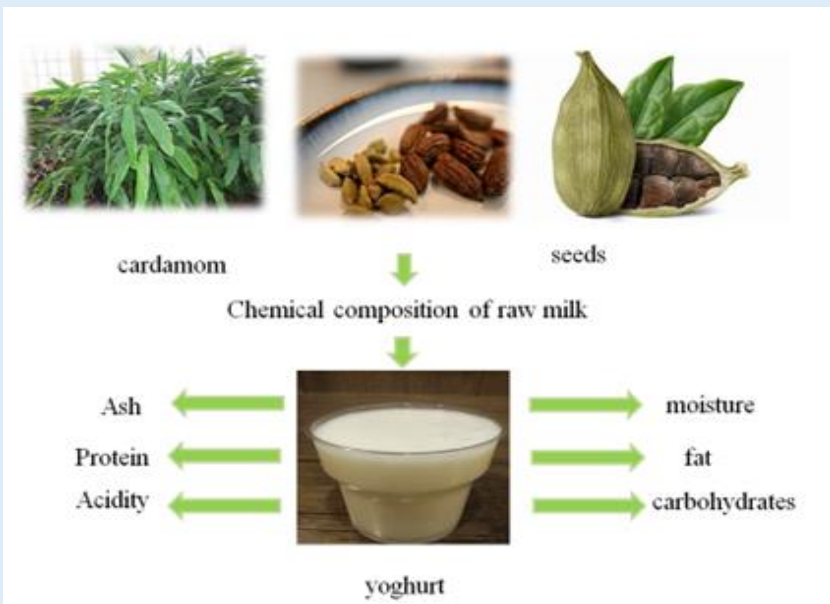
This study aimed to assess the effects of aqueous cardamom extract on chemical and sensory qualities of yogurt fortified with cardamom extract. Four different concentrations of cardamom extract (100, 150, 200, and 250 $\mu g.L^{-1}$) were incorporated into yogurt, along with a control group without adding cardamom. The moisture content, total protein, carbohydrates, pH, peroxide value, and sensory properties (taste, flavor, and smell) were evaluated. The results show that cardamom extract had no significant effect on the moisture, protein, or carbohydrate content of yoghurt when compared to the control. However, a drop in lipid, pH and peroxide value was seen in cardamom-fortified yoghurt, indicating enhanced lipid quality. Treatments supplemented with 200 and 250 $\mu g.L^{-1}$ of extract showed the highest sensory scores. Overall, this study suggests that aqueous cardamom extract holds promise as a functional ingredient to improve yogurt quality and sensory qualities, potentially providing health benefits to consumers.

Background: Yogurt is typically processed from cream, milk, or partially or completely skimmed milk, and may include additional ingredients such as vitamins, skimmed milk powder, lactose, lactalbumin, lactoglobulin, or modified whey. Cardamom encompasses two plant varieties, Elettaria and Amomum, belonging to the ginger family. These types are

triangular in cross-section, bear seeds in bundles, and possess a thin outer membrane encasing black seeds. Whole milk yogurt was fortified with four different concentrations of aqueous cardamom extract. A control group of plain whole milk yogurt without additives was also prepared. The chemical and sensory properties of yogurt types were analyzed immediately after manufacturing and storage for 1, 3 and 7 days at 5 ±1 °C.

Objective: This study aimed to explore the effects of aqueous cardamom extract on chemical and sensory qualities, which are critical for functional foods, of functional yogurt made from raw, whole cow's milk. Four concentrations (100, 150, 200, and 250 $\mu g.L^{-1}$) of cardamom extract were incorporated into yogurt, along with a control group without added cardamom. The moisture content, total protein, carbohydrates, pH, peroxide value, and sensory properties (taste, flavor, and smell) were evaluated.

Materials and Methods: Raw, whole cow's milk was used to make yogurt production in the laboratory. Five kilograms of raw, full-fat cow's milk was heated for 10 minutes at 90 °C, then cooled to 42 °C and divided into two parts. The first was divided into four fractions, each receiving a different concentration of cardamom extract: 100, 150, 200, and 250 µg/L, representing treatments T1, T2, T3, and T4, respectively. The second part remained untreated and served as the control treatment (C) for yogurt production.



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INTRODUCTION

Functional foods, as defined by the relevant associations, possess several key characteristics. They are not typical daily consumables but occur naturally in food and demonstrate positive effects on specific physiological functions after consumption [1]. These foods must also substantiate their claims and target specific health conditions, ultimately leading to improved well-being [2].

Research into functional foods emerged in the early 1980s in Japan, focusing on preventing or mitigating chronic diseases in the elderly population. Functional foods are formulated to be consumed as part of a meal and contain various bioactive compounds believed to offer significant health benefits [3].

The European and American markets are prominent in the sale of functional foods, employing a specific approval system known as FOSHU (Food for Specified Health Uses) [4]. Fermented dairy products, meat products, and other fermented foods are popular examples of functional foods [5]. Their primary purpose is to reduce the risk of chronic diseases such as high blood cholesterol, atherosclerosis, hypertension, and heart disease, while also boosting the immune system [6]

According to the US Food and Drug Administration, yogurt is defined as a food product prepared by adding a mixture of living organisms (bacteria), such as *Streptococcus thermophilus* and *Lactobacillus bulgaricus,* which produce lactic acid in milk [7-8]. Typically, yogurt contains cream, milk, or partially or completely skimmed milk and may include additional ingredients, such as vitamins, skimmed milk powder, lactose, lactalbumin, and lactoglobulin, [9-10].

Cardamom (*Elettaria cardamomum* L.) encompasses two plant varieties belonging to the ginger family: Elettaria and Amomum [11]. All types of cardamom are triangular in cross-section, bear seeds in bundles, and possess a thin outer membrane encasing black seeds [12]. We hypothesized that Elettaria Cardamomum Maton (Elettaria fruits) are light green, while Amomum fruits are larger and dark brown [13]. Cardamom boasts a pleasant aroma and strong flavor, with versatile applications in coffee, soup, and other culinary formulations [14]. This expensive spice also holds a prominent place in traditional medicine, where it is used to address digestive issues, stimulate appetite, alleviate labor pains, reduce gas discomfort, and treat heartburn and acidity [15].

The captivating aroma and flavor of cardamom seeds stem from the presence of essential oils and aromatic compounds within their composition. These seeds are comprised of approximately 20% water, 10% protein, 2% fat, 42% sugars, and 20% fiber, with the remaining portion consisting of various natural substances [16].

To explore effective methods for addressing nutritional deficiencies and meeting daily requirements, the current study focused on fortifying yogurt, a widely consumed and affordable staple food, with an aqueous extract of cardamom. Whole milk yogurt was enriched with four different concentrations of cardamom extract, while a control group of plain whole milk yogurt without additives was also prepared. The chemical and sensory properties of the created items were analyzed immediately after manufacturing and throughout storage at a temperature of 5±1°C for 7 days. Previous studies indicated that fortifying cheese with herbs such as cardamom and cinnamon contributed effectively to the health of mice and internal organ tissues, such as the liver and kidneys. Additionally, fortifying cheeses with cardamom and cinnamon increased the sensory value compared to the control treatment. In India, cardamom is commonly used in the preparation of many sweets, milk, and dairy products (e.g., khoa, gulabjamun, sandesh, basundi), as well as bakery products, cakes, ice cream, and other products. Native to India and Southeast Asia, cardamom is a medicinal plant with diverse applications. Cardamom contains various compounds that act as stimulants, stimulating the heart and liver. Its seeds are used as antioxidants in foods containing fats [17]. Cardamom contains butylated hydroxytoluene (BHT), butylated hydroquinone (TBHO), and butylated hydroxyanisole (BHA), which are among the most important natural antioxidants found in cardamom [18].

MATERIALS AND METHODS

Raw, full-fat cow's milk obtained from animal fields of the Department of Animal Production at the College of Agriculture, University of Kerbala was used in yogurt production. Cardamom was sourced from local markets.

Procedure of Manufacturing Yogurt: Yogurt was produced following the method outlined in [19] with slight modifications. Five kilograms of raw, full-fat cow's milk was heated for 10 minutes at 90 °C and cooled to 42 °C. It was then divided into two parts. To prepare the aqueous cardamom extract, cardamom was purchased from the markets, ground using an electric mixer, and sieved. Cardamom powder was added to the milk at a concentration of 100, 150, 200, and 250 µg/L, representing the treatments T1, T2, T3, and T4, respectively. The second part remained untreated and served as the control treatment (C) for yogurt production. The samples were thoroughly mixed using an electric mixer and then inoculated with a starter culture of *Lactobacillus blugaricus* and *Streptococcus thermophilus,* directly added in the specified quantities from Danisco, a French Company. Therapeutic bacteria, obtained from laboratories of the College of Agriculture Engineering Sciences at Baghdad University, were added at a rate of 1%. The mixtures were packaged in 150 mL of plastic bottles and incubated at 42 ± 2° C until coagulation (3.5 hours), resulting in a pH drop of 4.6. After removal from the incubator, the yogurt was chilled at 5±1°C for storage. Study tests were conducted on days 1, 3, and 7 of storage.

Chemical Analyses of Yogurt: The moisture content of yogurt was determined using the method outlined in [20]. Ash content was assessed by direct burning as described in [21]. Total nitrogen and non-protein nitrogen were estimated by the Kjeldahl method, and the fat percentage was determined using the Gerber method [22]. Total titratable acidity was measured as in [23], and pH was directly measured in the yogurt samples using a pH meter after slight dilution with distilled water.

Table 1. Composition of raw milk used in manufacturing yogurt

Moisture	Chemical composition of raw milk%						
	Protein	Fat	Ash	Lactose	pH	Titration acidity	Protein
87.94	3.82	3.23	0.63	4.38	6.40	0.14	87.94

pH of fat: The pH of the fat was assessed as outlined in [23], while the peroxide value was determined using the method described in [24].

Sensory Evaluation of Yogurt: A sensory evaluation was conducted using the sensory evaluation form employed by [21]. Statistical analysis of the data was performed using the SAS Statistical Analysis System (2012) [25].

RESULTS AND DISCUSSION

Yogurt Composition: Table 2 shows the moisture content of yogurt supplemented with cardamom at different concentrations (T1, T2, T3, and T4 treatments) compared to the control treatment. Immediately after production, the control yogurt exhibited a moisture content of 86.01%, which aligns with the findings for yogurt made from whole milk (86.63%) [26]. This result is consistent with the reported moisture content of 87.22% for full-fat yogurt [24]. The moisture content for the cardamom-fortified yogurt treatments was 86.00%, 85.94%, 85.92%, and 85.90% for T1, T2, T3, and T4, respectively. Notably, a decrease in moisture content was observed across all treatments during storage. Table 2 also displays the fat content percentages for the yogurt samples across different treatments. Immediately after production, the control yogurt had a fat content of 3.70%, consistent with the reported fat content of 3.67% in yogurt made from whole milk [27]. The fat content in all cardamom-fortified yogurt treatments was also 3.70%. Interestingly, the fat content remained stable immediately after production for the cardamom-supplemented yogurt compared to the control. However, during storage, an increase in fat

content was observed across all treatments. After seven days of storage, the fat content of the cardamom-fortified yogurt treatments reached 3.77%, 3.78%, 3.82%,
and 3.83% for T1, T2, T3, and T4, respectively, compared to 3.90% for the control treatment. The increase in the content of fat is attributed to a decrease in moisture content and an increase in the concentration of total solids, including fat. Statistical analysis revealed non-significant differences (P < 0.05) in the fat content immediately after production However, significant differences emerged between all treatments at the end of the storage period.

Table 1 shows the carbohydrate percentages for the yogurt samples immediately after production. The control yogurt exhibited a carbohydrate content of 5.60%, consistent with the results reported in [24]. During the storage period, the carbohydrate contents of cardamom-fortified yogurt were 5.62%, 5.64%, 5.65%, and 5.67% for T1, T2, T3, and T4, respectively.

A decrease in carbohydrate content was observed in all treatments and after 7 days. The parameter values of the cardamom-fortified yogurt were 5.56%, 5.52%, 5.53%, and 5.50% for T1, T2, T3, and T4, respectively, compared to the carbohydrate content of the control yogurt of 5.50%. This decrease is attributed to the activity of starter bacteria that ferment lactose into lactic acid. This result is consistent with previous findings indicating a decrease in carbohydrate content in yogurt from 4.42% to 4.07% during 7-day storage periods [28].

Table 2. Effect of cardamom on the chemical composition of yogurt at 5±1°C for 7 days

Treatments	% The Components						
	Yogurt age (day)	**Moisture**	**Fat**	**Carbohydrates**	**Ash**	**Portion**	**NPN**
Control	1	85.00	3.70	5.66	0.54	4.14	0.0210
	3	84.90	3.74	5.64	0.60	4.13	0.0216
	7	84.86	3.76	5.58	0.64	4.15	0.0234
T1	1	86.00	3.72	5.66	0.56	4.14	0.0210
	3	84.91	3.73	5.60	0.60	4.13	0.0214
	7	84.70	3.74	5.58	0.72	4.16	0.0227
T2	1	85.00	3.70	5.66	0.54	4.14	0.0210
	3	84.82	3.73	5.62	0.64	4.16	0.0207
	7	84.70	3.75	5.60	0.72	4.18	0.0223
T3	1	85.00	3.70	5.66	0.54	4.14	0.0210
	3	84.80	3.72	5.63	0.68	4.15	0.0206
	7	84.75	3.74	5.54	0.70	4.18	0.0212
T4	1	85.00	3.70	5.66	54 .0	4.14	0.0210
	3	84.80	3.70	5.63	0.66	4.18	0.0203
	7	84.70	3.77	5.58	0.70	4.19	0.0211
L.S.D (0.05 > P)	-	7.8644^{ns}	*0.0275	1.44^{ns}	*0.0341	*0.0408	*0.0006

* All numbers in the table represent an average of three replicates; NS, non-significant difference; *0.05 < P, significant difference; Treatments: C, Control: T1,100, T2,150, T3, 200, T4, 250.

The results of the statistical analysis revealed no significant differences in carbohydrate percentage between the control treatment and all other treatments, both after manufacturing and at the end of the storage period.

Table 1 shows the ash content percentages for the different treatments of yogurt fortified with cardamom. Immediately after production, the ash content was 0.56%, 0.54%, 0.54%, and 0.54% for treatments T1, T2, T3, and T4, respectively, compared to 0.54% for control yogurt. These results approach those reported (0.70%) for yogurt made from whole milk [28].

Table 1 also displays the protein content percentages for the cardamom-fortified yogurt treatments as 4.14%, 4.16%, 4.15%, and 4.18% for T1, T2, T3, and T4, respectively, compared to the control treatment (4.14%) immediately after production. These results are consistent with results for yogurt made from whole milk 4.34 [29]. During storage, the protein content increased in all yogurt treatments after 7 days The values of the cardamom-fortified yogurt treatments were 4.16%, 4.18%, 4.18%, and 4.19% for T1, T2, T3, and T4, respectively, compared to the control yogurt. These findings agree with previous results [30which found that protein content in yogurt increased from 4.76% at manufacturing to 4.80% after 15 days of storage. Similarly, another study reported an increase from 4.34% to 4.44% after 14 days of storage [30,32]. This rise can be attributed to a reduction in moisture content, resulting in a higher concentration of total solids, including protein. Statistical analysis revealed no significant changes ($P < 0.05$) in protein content between all treatments, both immediately after manufacture and after the 7-day storage period [33,8].

Table 1 also shows the non-protein nitrogen content percentages for all yogurt treatments. Immediately after production, the treatment values for cardamom-fortified yogurt were 0.0210%, 0.0207%, 0.0203%, and 0.0200% for T1, T2, T3, and T4., respectively, compared to 0.0210% for the control yogurt. Statistically significant differences were observed between all treatments. During storage, an increase in the non-protein nitrogen content was observed. The percentage of non-protein nitrogen increases slightly due to the loss of moisture and the action of heat-resistant protease enzymes produced by psychrotrophic bacteria [8]. After 7 days, the non-protein nitrogen content in the cardamom-fortified yogurt treatments reached 0.0227%, 0.0223%, 0.0212%, and 0.0211% for the T1, T2, T3, and T4 treatments, respectively, and 0.0234% for the control yogurt. Similar findings were previously reported [34].

pH Values: Table 2 shows the pH values of the cardamom-supplemented yogurt treatments and the reference yogurt immediately after production. The pH values of 4.62 for the cardamom-supplemented yogurt treatments and 4.62 for the reference yogurt, consistent with previous reports (4.63 and 4.62, respectively) [35, 36]. After 7 days, the pH decreased in all treatments, with values of 4.59, 4.59, 4.58, and 4.59 for T1, T2, T3, and T4, respectively, and 4.58 for the control yogurt. This decrease is due to the continued activity of starter bacteria, albeit at a slower rate, producing lactic acid during storage. This result is consistent with earlier reported results [37].

Total Acidity: Table 3 displays the titratable acidity values, expressed as lactic acid percentage, for the yogurt samples across different treatments. Immediately after production, the control yogurt exhibited a titratable acidity of 0.82%, agreeing with previous findings (0.80% and 0.78%, respectively) [36]. The titratable acidity percentages for the cardamom-fortified yogurt treatments were also 0.82%. Notably, cardamom fortification did not significantly impact the titratable acidity values of the treatments compared to the control on the first day of production, as reported [38].

Table 3. Effect of cardamom on pH and acidity (%) of yogurt at 5±1 °C for 7 days

Treatments	Yogurt age(day)	ADV milliequivalents/100 grams	PV mmEq/kg
Control	1	0.40	0.20
	3	0.54	0.48
	7	0.70	0.50
T1	1	0.34	0.18
	3	0.40	0.28
	7	0.46	0.30
T2	1	0.36	0.19
	3	0.44	0.27
	7	0.48	0.35
T3	1	0.36	0.16
	3	0.38	0.21
	7	0.40	0.30
T4	1	0.32	0.18
	3	0.36	0.20
	7	0.39	0.30
L.S.D (0.05 > P(	–	*0.0285	*0.0291

*Each number in the table represents the average of three replicates. *(0.05 < P), significant difference. C: Control, T1:100, T2:150, T3:200, T4:250

Acid Degree Value (ADV): Table 4 shows the Acid Degree Values (ADV) of yogurt, which expresses the degree of fat decomposition in various yogurt treatments immediately after production. The ADV values for the cardamom-fortified treatments T1, T2, T3, and T4 were 0.34, 0.36, 0.36, and 0.32 mEq/100 g of fat, respectively, which is lower than the ADV in the control yogurt (0.40 mEq/100 g of fat). However, ADV values increased during storage for all treatments. After 7 days, the ADV value for the control yogurt reached 0.70 mEq/100 g of fat. This increase can be attributed to the activity of lipolytic enzymes originating from either the starter bacteria used in yogurt production or the psychrotrophic bacteria that survive at pasteurization temperatures.

Peroxide Value (PV): Table 4 also presents the changes in peroxide values (PV) for the different yogurt treatments. Immediately after production, the control yogurt exhibited a PV of 0.20 mEq/kg yogurt, which is higher than the PV values observed in the cardamom-fortified yogurt treatments (0.18, 0.19, 0.16, and 0.18 $mEq.kg^{-1}$ yogurt for T1, T2, T3, and T4, respectively). During storage, PV values increased, reaching 0.50 mEq/kg yogurt for the control treatment after 7 days. The PV values for the cardamom-fortified yogurt treatments after 7 days were 0.30, 0.35, 0.30, and 0.20 mEq/kg for T1, T2, T3, and T4, respectively. Interestingly, the cardamom-supplemented treatments exhibited lower PV values compared to the control treatment after 7 days of storage. This suggests that cardamom plays a significant role in mitigating the increase in PV and preventing the formation and proliferation of free radicals due to its potent antioxidant properties.

Table 4. Effect of cardamom on the values of ADV and PV of yogurt manufactured and stored at 5±1°C for 7 days.

Treatments	Yogurt age(day)	ADV milliequivalents/100 grams	PV mmEq/kg
Control	1	0.40	0.20
	3	0.54	0.48
	7	0.70	0.50
T1	1	0.34	0.18
	3	0.40	0.28
	7	0.46	0.30
T2	1	0.36	0.19
	3	0.44	0.27
	7	0.48	0.35
T3	1	0.36	0.16
	3	0.38	0.21
	7	0.40	0.30
T4	1	0.32	0.18
	3	0.36	0.20
	7	0.39	0.30
L.S.D (0.05 > P)	–	*0.0285	*0.0291

*Each number in the table represents the average of three replicates. *(0.05 < P), significant difference. C: Control, T1:100, T2:150, T3:200, T4:250

The results of the statistical analysis revealed significant differences (P<0.05 between the cardamom-added treatments and the control treatment, both immediately after manufacturing and after a 7-day storage period.

Sensory Evaluation Results: Table 5 displays the results of sensory evaluation of yogurt samples from different treatments. The scores for flavor, texture, color, appearance, and acidity were consistently higher for the cardamom-supplemented yogurt treatments compared to the control yogurt. These differences were statistically significant at all evaluation time points (1, 3, and 7 days of storage). The addition of cardamom enhanced the overall acceptance of the product, contributing to improved sensory qualities. Notably, the yogurt treated with 150 micrograms per liter (T2) of cardamom extract achieved the highest total score of 97.50 out of 100 on the first day after production.

Table 5. Sensory evaluation of yogurt supported by gel at 5±1°C for a period of 7 days

Treatments	Yogurt age (day)	°45 Flavor	Texture° 25	°10 Colour	Appearance 10°	Acidity 10°	The total 100°
C	1	40.0	21.0	8.40	10.0	9.00	88.4
	3	38.0	21.0	8.40	10.0	8.80	86.2
	7	35.0	20.5	8.00	9.00	8.00	80.5
T1	1	42.0	23.0	9.10	10.0	9.40	93.5
	3	41.0	20.5	9.00	10.0	9.00	91.9
	7	40.0	22.5	8.80	9.80	8.80	89.5
T2	1	44.0	24.0	10.0	10.0	9.60	97.6
	3	43.0	23.5	9.80	10.0	9.40	95.7
	7	42.0	22.5	9.40	9.80	9.20	92.9
T3	1	40.0	22.5	9.40	10.0	9.20	91.1
	3	40.5	22.0	9.00	10.0	9.00	90.5
	7	39.6	21.5	8.70	9.00	8.80	87.6
T4	1	42.0	23.5	9.40	9.80	9.40	94.1
	3	41.0	23.0	9.20	9.40	9.20	91.8
	7	40.5	22.5	9.00	9.20	9.00	90.2
L.S.D	–	*0.5468	*1.4197	*0.2539	*0.218	*0.2402	*0.2748

*Each number in the table represents an average of three replicates, *(0.05 < P) significant difference. C: Control, T1:100, T2:150, T3 :200, T4 :250

In direct comparison, the control treatment received a total score of 88.4, while the cardamom-supplemented treatments at concentrations of 100, 150, and 200 micrograms/liter achieved total scores of 93.5, 97.6, and 94.1, respectively. The cardamom-fortified yogurt consistently obtained higher sensory evaluation scores, potentially due to the stimulating effect of cardamom, which contributed to a desirable texture and firmness. This finding aligns with the observations of [39], who reported that cardamom-fortified cheese received higher sensory evaluation scores for texture, appearance, and aroma compared to the control cheese.

During storage, treatment T2 (150 micrograms of cardamom extract /liter) consistently outperformed all other treatments, maintaining the highest sensory evaluation scores throughout the storage period, with a final total score of 97.6. The remaining treatments (T1, T3, and T4) exhibited similar sensory evaluation scores throughout storage, reaching final scores of 93.5, 91.1, and 94.1, respectively. In contrast, the control treatment experienced a decline in sensory evaluation scores, reaching a final score of 80.5 at the end of the storage period. Statistical analysis confirmed a significant difference (P<0.05) between the control treatment and the cardamom-supplemented yogurt treatments. Additionally, significant differences were observed between different time points within each treatment [40].

CONCLUSION

Adding cardamom extract led to an increase and improvement in the sensory and physicochemical properties of the compound yogurt. The study found that cardamom extract had no significant effect on the moisture, protein, or carbohydrate content of yogurt compared to the control. However, a decrease in pH and peroxide value was observed in cardamom-enriched yogurt, indicating enhanced lipid quality. Overall, this study suggests that aqueous cardamom extract shows promise as a functional ingredient to improve yogurt quality and sensory qualities, potentially providing health benefits to consumers.

Abbreviations: peroxide value, PV: Non-Protein Nitrogen, NPN: Acid Degree Value, ADV

Authors Contribution: Firas Najm Ismael: Formal analysis; Methodology; Project administration; Zainab Hadi Abbas Alameri: Funding acquisition; Validation; Ali Abdulraheem Kadhim: Writing-original draft. Ahmed Abdulameer Hussein: Data curation; Formal analysis; Methodology; Saleh Abed Al Wahed Mahdi: Project administration; Jasim Mohammed Awda; Supervision; Resources; Validation; Sara Thamer Hadi: Writing-review and editing.

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