

Heating Process in Pasteurization and not in Sterilization Decreases the Iodine Concentration of Milk

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Background: Iodine is a vital component of the thyroid hormones and is required for normal growth, development, and tissue metabolism in humans and animals.

Objectives: This study for the first time compares the effects of heating during pasteurization and sterilization on the iodine concentration of milk for an adequate provision of dietary iodine.

Materials and Methods: This study was carried out on multiparous Holstein Friesian lactating cows. Thirty Holstein dairy cows were fed with a diet containing 10 mg of potassium iodide (KI) per kilogram dry matter of diet. Milk samples were obtained on days 4 and 2 before and again on days 2, 4, 6, and 8 after the inclusion of KI into the total mixed ration diet of the dairy cows. The milk samples were sterilized using ultra-high temperature, following which the effect of the heating process during sterilization on the cows' iodine concentration was compared to that in the only previous documented study from Iran in which milk supplementation with KI was the same as ours. Milk in that study was pasteurized via the high-temperature short-time method, a method which involves temperatures in excess of 73°C for durations longer than 15 seconds.

Results: The inclusion of KI in the diet of the dairy cows in these 2 separate experiments increased their milk iodine levels. Pasteurization decreased the iodine content of the milk ($P < 0.05$), while no significant difference was observed in the iodine concentration of the sterilized milk.

Conclusions: The present study showed that the iodine concentration is not decreased during the heating process in sterilization, indicating that supplemented sterilized milk could be a good alternative vehicle for dietary iodine in the prevention of iodine deficiency.

Keywords: Iodine; Pasteurization; Sterilization; Milk

1. Background

Iodine is a vital component of the thyroid hormones and is required for normal growth, development, and tissue metabolism in humans and animals. Iodine deficiency is one of 4 leading micronutrient deficiencies in the world and can exert a decisive influence on the health status of a population, particularly children and pregnant and lactating women. The most frequent consequences of iodine depletion range from spontaneous abortion, still birth, congenital anomalies, and prenatal mortality in the fetus to impaired mental function, decreased educability, reduced work productivity, goiter, and hypothyroidism in later years (1-4).

It is now well-known that the most effective way to correct iodine deficiency in almost all countries where individuals have insufficient iodine intake is through universal salt iodization as it is feasible, cost-effective, safe, rapidly effective, and widely acceptable (5); however, concerted efforts

are currently underway in many countries to reduce salt intake for the prevention of cardiovascular diseases, which raises the concern that decreasing salt consumption will increase the risk of iodine deficiency (6). In many countries such as the United States of America, New Zealand, Australia, Canada, Denmark, Belgium, Norway, and Germany, dairy products, specifically milk, are considered significant iodine sources for the provision of an adequate dietary iodine intake (7-13).

In Iran, where iodized salt is the only dietary iodine source (14, 15), a recent study revealed that, over 10 years (2000 to 2010), the median daily salt intake had decreased due to the high prevalence of hypertension and cardiovascular diseases and that the decrease was accompanied by an increased percentage of subjects with inadequate iodine nutrition status (16), making it necessary to consider dietary iodine sources other than iodized salt (e.g., milk)

for the prevention of iodine deficiency disorders. On the other hand, for all the previous extensive research on the iodine content of milk (17-20), relatively little definitive and updated information is available on the effects of heat processing during pasteurization or sterilization, or both, on the iodine content of milk (21, 22).

2. Objectives

To the best of our knowledge, the present study is the first of its kind to compare the effects of heating during pasteurization and sterilization on the iodine concentration of milk with a view to providing adequate dietary iodine.

3. Materials and Methods

This report is a part of a study on the association between the iodine content in dairy cows' diet and the iodine content in their milk. In the present study, cow's milk was fortified by supplementing cattle feed potassium iodide (KI) as the source of iodine, introduced for the first time in 2009 by Norouzi et al. (22). Accordingly, the diet was formulated based on the nutrient requirements of dairy cattle (23) for an average cow weight of 600 kg, 140 days in milk and a 30 kg milk yield (3.8% fat and 3.35% protein).

Thirty Holstein Friesian dairy cows (30.1 ± 4.5 kg/day of milk yield and 120 ± 22 days in milk) were used. The experiment duration was 3 weeks, and the cows were kept in a common pen with free access to water. First, 10 mg of KI per kilogram dry matter of diet was mixed with the total mixed ration (TMR) and fed to the experimental dairy cows. Milk samples were thereafter obtained on days 4 and 2 before and on days 2, 4, 6, and 8 after the inclusion of KI into the TMR. Also, on days 2 and 4 after the removal of KI from the TMR, milk samples were again taken from the experimental dairy cows and sterilized via the ultra-high temperature (UHT) technology, a method which involves temperatures in excess of 135°C for durations longer than 1 second.

It is important to note that the ultimate aim of the current study was to investigate the effect of the heating process during sterilization on cows' iodine concentration and to compare the results with those documented by a previous study from Iran in which milk supplementation (with KI) was the same as that in our study, even though the doses of iodine supplementation were different (22). In that study, milk was pasteurized via the high-temperature short-time (HTST) method, which involves temperatures in excess of 73°C for durations longer than 15 seconds.

3.1. Laboratory Measurement

Iodine concentration in raw, pasteurized, and sterilized milk samples was measured via the acid digestion test (24). Briefly, 2000 mL of digestion acid solution was added to the milk samples in 16×160 mm test tubes. After the plastic caps were covered, the tubes were placed into the wells of a heating block for 10 min at 230°C in a fume hood. Subsequently, 50 mL of the digested samples was transferred to the wells of a polystyrene 96-well microtiter plate. An ar-

senious acid solution (100 mL) was added to the wells and mixed, and 50 mL of a ceric ammonium sulfate solution was then added quickly by using a multichannel pipette. The absorbance was measured at 405 nm immediately after 20 min with a microplate reader.

3.2. Statistical Analysis

The paired *t*-test was used to determine the iodine content of the milk before and after the heating process using statistical package for the social sciences (SPSS) for Windows (version 16.0, 2006, SPSS Inc, Chicago, IL). A *P* < 0.05 was considered statistically significant.

4. Results

In our study, feeding KI to the dairy cows increased their milk iodine content significantly (*P* < 0.05) (Table 1). Following KI removal from the dairy cows' diet, their milk iodine concentration decreased, regressing to its original level before the inclusion of KI to the TMR (Table 2). The heating process during sterilization increased the milk iodine content, compared to raw milk (Table 2). The average iodine concentration in the raw and sterilized milk was 309.4 ± 100.57 µg/L and 327.10 ± 100.7 µg/L, respectively.

Similar to our findings, the aforementioned study also showed that supplementation of the basal diet with KI increased the milk iodine content significantly (*P* < 0.05). However, the pasteurization process caused a decrease in the iodine content of the milk (Table 2). The average decrease in iodine after pasteurization was 75.2 ± 15.6 µg/L (52.7%) for the controls and 126.4 ± 72.3 µg/L (21.3%) for the KI-treated cows.

Table 1. Ingredients and Chemical Composition of the Base Diet Used in Both Experiments ^a

Ingredients	Basal Diet
Ingredients, g/kg DM	
Alfalfa hay	210
Corn silage	230
Barley grain	140
Corn grain	120
Cottonseed meal	95
Soybean meal	80
Wheat bran	70
Sugarcane bagasse	45
Urea	2
Limestone	4
Vitamin and mineral Supplementation ^b	2
Salt	2
Chemical composition, g/kg DM	
Crude protein	156
NDF	349
ADF	204
NFC	360
Iodine content, mg/kg DM	
Experiment 1	0.534
Experiment 2	0.527

^a Abbreviations: ADF, acid detergent fiber; DM, dry matter; NDF, neutral detergent fiber; NFC, non-fibrous carbohydrates.

^b Contained common supplementation of minerals and vitamins.

Table 2. Changes in Raw and Sterilized Milk Iodine Content During the Experimental Day ^a

Experimental Day	Iodine Concentration, $\mu\text{g/L}$	
	Raw	Sterilized
Before KI inclusion		
-4	74.56	95.56
-2	312.93	355
After KI inclusion		
2	379.29	378.81
4	267.03	314.13
8	350.00	421.20
After KI removal		
10	315.24	295.81
12	82.54	80.83

^a Abbreviation: KI, potassium iodide.

Table 3. Differences in Iodine Concentrations of Raw and Pasteurized Milk

Item	Diet		P Value
	Control	KI ^a	
Raw milk, $\mu\text{g/L}$	142.6 \pm 22.5	593.3 \pm 85.3	< 0.01
Pasteurized milk, $\mu\text{g/L}$	67.4 \pm 12.4	466.9 \pm 94.2	< 0.01
Difference, μg	75.2 \pm 15.6	126.4 \pm 72.3	-
Difference, %	52.7	21.3	-

^a KI, basal diet supplemented by 7.5 mg of potassium iodide per kilogram dry matter of diet; Control, basal diet (no potassium iodide).

5. Discussion

To the best of our knowledge, this is the first study of its kind to compare the effect of the heating process on the iodine concentration of milk during pasteurization and sterilization with a view to assessing iodine adequacy in the diet consumed. Our results indicated a decrease in the iodine concentration of pasteurized milk for both control and KI-treated groups, whereas sterilization increased the iodine content of milk.

Different studies have demonstrated that several factors influence the iodine content of cow's milk such as iodine content and level of iodine supplementation of feed, iodine source, iodine antagonists in feed, farm management, teat dipping with iodine-containing substances, and milk processing (heating treatments in particular) (25). Indeed, milk pasteurization and/or sterilization are the inevitable steps of milk processing. Moreover, various values for iodine concentration losses during pasteurization have been reported. Norouzzian et al in 2 studies (22, 26), investigating the high-temperature short-time pasteurization method on the iodine content of milk, reported that the average

(ranges) for the drop in the iodine concentration in milk were 34% (21.2 - 53.1) and 27.4% (17.6 - 37.6). Similarly, Pedriali et al. and Wheeler et al reported that pasteurization resulted in decreases of between 20% and 40% in the iodine concentration of milk (27, 28). However, in a study by Aumont et al. pasteurization, UHT pasteurization, and spray drying had no impact on the iodine concentration of milk (29), which chimes in with our results following the sterilization heating process. The reason for iodine losses during treatment is the sublimation characteristic of the element, because more than 90% of iodine in milk is inorganic. The iodine losses during pasteurization could also be one reason for the differences in the iodine concentrations of raw milk, in bulk milk or in milk samples from the food retail sector (25). There is a paucity of data on the effect of higher degrees of temperature during the heating process on the iodine content of milk. The present study is the first to investigate this effect; and contrary to our predictions, heating during sterilization did not decrease the iodine concentration in the milk. This may be explained, in part, by condensation and reduction in the volume of milk due to the high temperature during sterilization, as compared to pasteurization, although the duration of heating for sterilization was lower than that for pasteurization.

International agencies recommend universal iodization of salt as the best way of guaranteeing an adequate amount of iodine in the diet (30). This measure has led to the eradication of iodine deficiency in most parts of the world. Nonetheless, because of the influence of salt intake in cases of hypertension and cardiac diseases, public health recommendations on healthy nutrition include reduction in daily salt intake, resulting in a decrease in iodine intake in certain individuals (10, 16, 31). Therefore, alternative vehicles to salt for iodine fortification need to be explored specifically for high-risk groups (i.e., children and pregnant and lactating women). On the other hand, as is seen in most industrial countries, where the consumption of iodized salt is limited, the increase in the urinary iodine concentration of the population may depend on the presence of iodine in foods, especially milk and dairy products. Surveys on individual consumption reveal that the frequency of milk consumption is associated in a dose-dependent manner with urinary iodine concentrations. Therefore, as has been shown in several countries, milk may be a good vehicle to contribute to an adequate iodine intake, but concern has been raised in this regard to standardize the concentrations of iodine and, thus, ensure iodine sufficiency (7-13).

In conclusion, the present study demonstrated that, compared to pasteurization, iodine concentration in milk does not decrease during the heating process in sterilization, indicating that supplemented sterilized milk is a good vehicle to provide iodine sufficiency, not least in countries with limited consumption of iodized salt.

Authors' Contributions

Pantea Nazeri contributed to the design, data analysis, and writing of the manuscript. Mohammad Ali Norouzian contributed to the design of the study and writing, reading, and final approval of the manuscript. Parvin Mirmiran contributed to the design of the study and writing of the manuscript. Mehdi Hedayati contributed to the design of the study and writing of the manuscript. Fereidoun Azizi contributed to the design of the study and writing, reading, and final approval of the manuscript.

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