

Standardizing Process for Freeze-Dried Yogurt Fortified with Noni Juice

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Abstract: This study presents a process for producing freeze-dried yogurt with added noni juice using the freeze-drying method. We conducted research to determine the factors that influence the fermentation process of yogurt with added noni juice. This included investigating the ratio of sweetened condensed milk and UHT fresh milk-plain (1:2, 1:4 and 1:6 v/v), fermentation temperature (38°C, 42°C, and 46°C), and incubation time (8 hours, 10 hours, and 12 hours). Our goal was to find the optimal fermentation conditions that would result in freeze-dried yogurt with the best sensory quality and highest fermentation ability. The experimental results indicate that the optimal ratio of sweetened condensed milk to fresh milk for producing high-quality yogurt fortified with noni juice is 1:6 (v/v). Fermenting process at a temperature of 42°C for 10 hours yielded the best result of yogurt. Additionally, freezing the yogurt at -20°C for 4 hours and evaporating it at a temperature of 45°C for 10 hours resulted in a freeze-dried yogurt product with superior chemical composition and sensory properties

Keywords: noni juice, freeze-dried yogurt, fermented milk

I. INTRODUCTION

Yogurt is a popular dairy product that has been enjoyed for centuries. It is made by fermenting milk with live bacteria cultures. The bacteria feed on the lactose in the milk and produce lactic acid, which thickens and curdles the milk, giving yogurt its characteristic tangy flavor and creamy texture. Yogurt is a good source of protein, calcium, phosphorus, potassium and probiotics, which are beneficial bacteria that can help to improve gut health. Probiotics have been shown to have a number of health benefits, including boosting the immune system, reducing inflammation, and improving digestive function [1][2].

Noni juice is a tropical fruit juice that has gained popularity in recent years due to its potential health benefits. It is made from the fruit of the *Morinda citrifolia* tree, which is originated in India and is now distributed in the continents of Asia, Australia, South America and Africa. Noni juice is extracted from the fruit and rich in antioxidants, including vitamin C, beta-carotene, and flavonoids, which help to protect the body from oxidative stress and damage. Previous researches have indicated that noni juice has anti-inflammatory properties that can reduce inflammation in the body and promote better overall health. Moreover, noni juice is believed to support the immune system, enhance digestion, and improve the health of skin and hair. Ultimately, noni juice is a well-liked health drink with potential health benefits and a distinctive taste, enjoyed by many people worldwide [3][4].

Many previous studies have demonstrated that plant extracts effect to improve the quality of yogurts such as increasing antioxidant activity and certain therapeutic properties during refrigerated storage [4; 5]. Therefore, with many nutritional and healthy compounds of yogurt and noni juice, this study aims to fortify a yogurt with traditional fermented noni juice, then first step in developing a freeze-dried yogurt fortified with noni juice. The freeze-dried yogurt has a longer storage time and does not require refrigeration. The product maintains its quality and preserves its taste. Additionally, it is very convenient to carry.

The main processing steps to manufacture yogurt include milk standardization, homogenization, milk heat treatment, incubation, fermentation, cooling, and storage. So, a combination of noni juice and yogurt will be affected by many different factors in processing. The study researches the effect of the different ratio of fresh milk and sweetened condensed milk, incubation time, temperature on pH, titratable acidity and sensorial quality of yogurt fortified noni juice, then first step in processing of freeze-dried yogurt fortified with noni juice.

II. MATERIAL AND METHODS

2.1 Material

Noni juice Bestone, ultra-high temperature Vinamilk fresh milk-plain, Vinamilk sweetened condensed milk were purchased from the local markets in Danang, Vietnam. Starter yogurt culture containing skim milk powder, active bacterial culture (*Lactobacillus casei*, *Bifidobacterium longum*, *Lactobacillus acidophilus*,

Lactobacillus bulgaricus, *Streptococcus thermophiles*) was obtained from Yogourmet, Canada. Chemicals used in this investigation were of analytical grade

2.2 Methods

2.2.1 Preparation of yogurt fortified noni juice

The different ratios of ultra-high temperature Vinamilk fresh milk-plain with Vinamilk sweetened condensed milk were mixed, followed by the addition of traditional noni juice at 3% (v/v). After mixing well, the mixtures were heated to 90-95^oC about 10 minute and cooled to 42^oC and then inoculated with 0.5% w/v of a mixed yogurt freeze-dried culture Yogourmet. Following inocubation, the product was stirred for 5 min to ensure uniform distribution of the cultures. The inoculated milk was incubated at different temperatures for the different period untill the desired acidity is attained. The yogurt samples were cooled at 4^oC to stop the fermentation and analyzed further after 1 day of refrigerated storage. The yogurts were packed in sterilized glass cups.

2.2.2 Physicochemical properties of noni juice and yogurt

Noni juice and freeze-dried yogurt fortified with noni juice were analyzed for moisture, protein, ash and carbohydrates according to AOAC standard method. The pH value of the samples was determined during fermentation and storage using a pH meter at room temperature. The samples' titratable acidity (TA) was assessed through titration with 0.1N NaOH and expressed as a percentage of lactic acid [7].

2.2.3 Sensory Evaluation

A total of twenty-one untrained panelists, who were students of the Food Engineering program at the University of Technology and Education, The University of Danang (Danang, Vietnam), were selected to participate in the sensory evaluation of yogurts. The purpose of this evaluation was to assess the organoleptic characteristics, such as color, flavor, taste, and texture, of yogurt fortified with noni juice. The assessment was conducted using a five-point hedonic scale that ranges from "dislike extremely" (score 1) to "like extremely" (score 5), following the guidelines outlined in TCVN 10565-3:2015. The presentation order of the samples was randomized both among and within the assessors. The selection of panelists was based on their willingness, availability, and motivation.

2.2.4. Data analysis

Descriptive analysis was performed on the physical and sensory characteristics data. Fisher's test was used to compare the groups and detect significant differences. Stargraphics Centurion XVI was the software used for data processing, and Microsoft Excel 2019 was used for graphical representation.

III. RESULTS AND DISCUSSION

3.1 Properties of noni juice, sweetened condensed milk and fresh milk

Table 1 shows proximate compositions of noni juice that we have studied, as well as sweetened condensed milk and UHT fresh milk-Plain based on product information published by Vinamilk.

Table 1. Composition of noni juice and cow milk

Parameters	Noni juice	Sweetened condensed milk	Fresh milk-Plain
Moisture (%)	94.07		
Carbohydrates (%)	3.43	55.2	4.6
Proteins (%)	2.36	4.8	3
Ash (%)	0.59		
Fat (%)	0	11.3	3.5

Noni juice has a moisture content of approximately 94.07% without fat. The carbohydrate content in noni juice is relatively low, comprising around 3.43% of its composition, primarily in the form of natural sugars like fructose and glucose. Protein, while present in noni juice at approximately 2.36%, do not significantly contribute to its nutritional value. The ash content, at about 0.59%, reflects the mineral content of noni juice.

Sweetened Condensed Milk has significantly higher carbohydrate and fat content due to added sugars and the concentration process. UHT Fresh milk-Plain provides a balance of carbohydrates, proteins, fats, minerals, and vitamins.

So, there was significant difference in nutrient content of noni juice and milk. The purpose of finding the nutritional composition was to study the effect of milk on physico-chemical as well as sensory qualities of

product. Based on our prior research, a 3% (v/v) noni juice concentration was added for the production of yogurt in this study.

3.2. Effect of different ratio of sweetened condensed milk and fresh milk on physico-chemical properties and sensory qualities of yogurt fortified with noni juice

Three different ratios of fresh milk and sweetened condensed milk were used in this research, including 1:2, 1:4, and 1:6 (v/v). Fig 1 presents the physico-chemical properties of yogurt fortified with noni juice, including pH and titratable acidity, under different ratios of sweetened condensed milk to fresh milk.

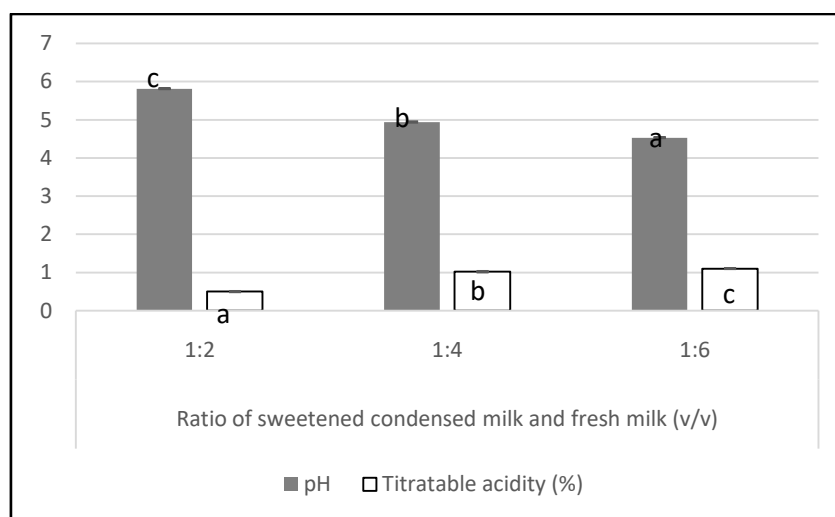


Fig 1. pH and titratable acidity in yogurt fortified noni juice under different ratios of sweetened condensed milk and fresh milk. Different superscripts within the same column indicate a highly significant difference ($p < 0.05$)

The results demonstrate a clear trend: as the proportion of fresh milk in the formulation increases, the pH decreases and the titratable acidity increases. This shift in pH and titratable acidity is significant. The pH values range from 5.81 (1:2 ratio) to 4.53 (1:6 ratio), while the titratable acidity values increase from 0.50% (1:2 ratio) to 1.10% (1:6 ratio). The increase in titratable acidity corresponds with the decrease in pH, indicating that the lesser addition of sweetened condensed milk enhances the yogurt's acidity. The possible cause could be the high amount of condensed milk added, which increases the sucrose content in the mixture. This, in turn, reduces the water activity and partially inhibits the fermentation ability of lactic bacteria, leading to a slower fermentation process [8]. The yogurt fortified with noni juice reaches the stopping point of yogurt fermentation at a ratio of 1:6 [9].

Table 2 presents valuable insights into the sensory qualities of yogurt fortified with noni juice, considering variations in the ratio of sweetened condensed milk to fresh milk. Sensory qualities, including texture, color, flavor, and taste, are critical factors influencing consumer acceptance and overall product quality.

Table 2. Sensory qualities of yogurt fortified with noni juice

Sensory parameters	Ratio of sweetened condensed milk and fresh milk (v/v)		
	1:2	1:4	1:6
Texture	1.905±0.700a	4.143±0.655b	4.524±0.512b
Color	2.476±0.680a	4.143±0.727b	4.381±0.669b
Flavor	1.81±0.602a	4.238±0.768b	4.286±0.717b
Taste	1.571±0.598a	3.429±0.676b	4.095±0.768c

Different superscripts within the same parameter indicate a highly significant difference ($p < 0.05$). Value is expressed as means ± standard deviation.

The data shows a clear trend of increasing texture scores as the proportion of fresh milk in the yogurt formulation rises. Specifically, texture scores range from 1.905 (1:2 ratio) to 4.524 (1:6 ratio). Color scores

follow a similar trend, with values ranging from 2.476 (1:2 ratio) to 4.381 (1:6 ratio). Flavor scores rise from 1.81 (1:2 ratio) to 4.286 (1:6 ratio). Taste scores vary from 1.571 (1:2 ratio) to 4.095 (1:6 ratio). These upward trends signify that higher proportions of fresh milk contribute to creamier textures, improved visual appeal, and more pronounced and preferred flavors and tastes. These sensory enhancements can lead to increased consumer acceptance and marketability of yogurt products. This could be due to the properties of fresh milk, which contribute positively to the overall sensory experience of the yogurt fortified with noni juice [10]. The sensory quality of yogurt fortified with noni juice is optimal at the ratio of 1:6.

3.3. Effect of incubation temperature on physico-chemical properties and sensory qualities of yogurts fortified with noni juice

The production of yogurt is a highly controlled process where various parameters, such as temperature, play a crucial role in determining the physical-chemical properties and overall quality of the final product. Fig 2 illustrates the impact of different temperatures on two parameters: pH and titratable acidity in yogurt fortified with noni juice.

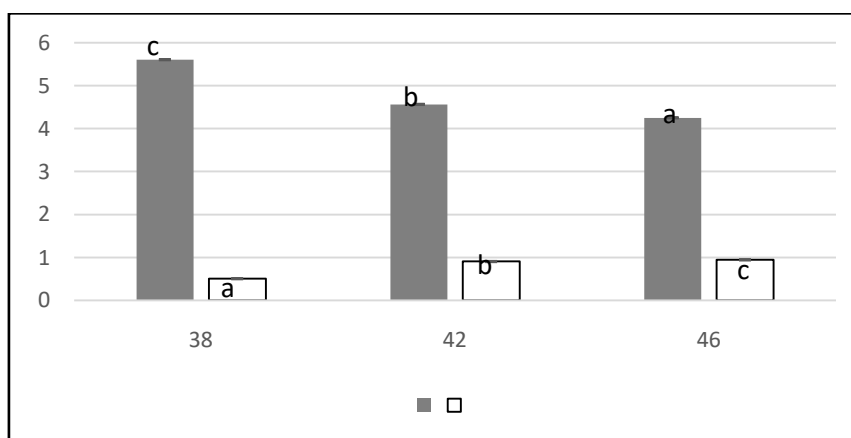


Fig 2. pH and titratable acidity in yogurt fortified noni juice under different incubation temperatures. Different superscripts within the same column indicate a highly significant difference ($p < 0.05$)

The data clearly shows a consistent trend: as the incubation temperature increases, the pH decreases significantly and the titratable acidity increases substantially. This observed trend in pH and titratable acidity can be attributed to the increased activity of lactic acid bacteria (LAB) at higher temperatures during the fermentation process. These bacteria produce lactic acid, which accumulates in the yogurt, resulting in lower pH values and higher titratable acidity [11].

The lowest pH and highest titratable acidity occur at a temperature of 46°C. However, the optimal stopping point for yogurt fermentation is a pH of 4.6 at 42°C. Therefore, further investigation is needed to understand the effect of temperature on the sensory qualities of yogurt, in order to precisely control the acidity level and meet specific consumer preferences.

The sensory qualities of yogurt fortified with noni juice at different incubation temperatures are presented in Table 3.

Table 3. Sensory qualities of yogurt fortified with noni juice (\pm SD)

Physical parameters	Effect of temperature on sensory qualities of yogurt fortified with noni juice		
	38	42	46
Texture	3.57 \pm 0.60a	4.29 \pm 0.56c	4.05 \pm 0.74bc
Color	3.90 \pm 0.89a	4.10 \pm 0.77b	4.00 \pm 0.71a
Flavor	3.76 \pm 0.62b	3.86 \pm 0.65b	3.33 \pm 0.80a
Taste	2.76 \pm 0.70a	3.81 \pm 0.75c	3.10 \pm 0.70ab

Different superscripts within the same parameter indicate a highly significant difference ($p < 0.05$).

Value is expressed as means \pm standard deviation.

The data highlights the significant impact of incubation temperature on texture, color, flavor, and taste attributes. Increasing the incubation temperature to 42°C leads to a noticeable improvement in sensory attributes, with a score of 4.29 \pm 0.56c for texture, 4.10 \pm 0.77b for color, 3.86 \pm 0.65b for flavor, and 3.81 \pm 0.75c

for taste. This improvement is likely due to increased microbial activity, resulting in more efficient fermentation and better gel formation, which leads to the production of various flavor compounds [12]. However, at 46°C, there may be a slight decline in sensory attributes due to the potential negative impact of excessive heat on yogurt quality.

3.4. Effect of incubation time on physico-chemical properties and sensory qualities of yogurts fortified with noni juice

The data presented in Fig 3 illustrates the impact of varying incubation times on the pH and titratable acidity of yogurt.

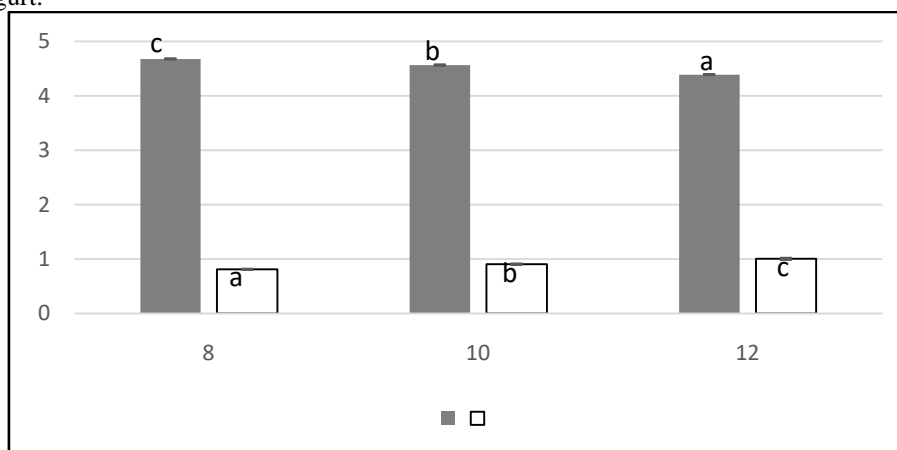


Fig 3. pH and titratable acidity in yogurt fortified noni juice under different incubation times. Different superscripts within the same column indicate a highly significant difference ($p < 0.05$)

A longer incubation time leads to a noticeable drop in pH, indicating a significant increase in titratable acidity. These trends align with the prolonged activity of lactic acid bacteria (LAB) during fermentation. As the incubation time extends, LAB continue to metabolize lactose, resulting in the production of lactic acid, which accumulates in the yogurt. This accumulation of lactic acid is responsible for the observed decrease in pH and the increase in titratable acidity [13]. Yogurt incubated for 10 hours reaches a pH of approximately 4.6, which indicates the end point of yogurt fermentation.

Understanding the impact of incubation time on sensory qualities is crucial for optimizing the production process and ensuring consumer satisfaction. Table 4 presents the effects of different incubation times (8 hours, 10 hours, and 12 hours) on the sensory qualities of yogurt fortified with noni juice.

Table 4. Sensory qualities of yogurt fortified with noni juice in different of incubation time

Parameters	8 hours	10 hours	12 hours
Texture	3.05±0.59a	4.29±0.56c	3.86±0.48b
Color	3.43±0.60a	4.10±0.77c	3.81±0.51ab
Flavor	3.24±0.70a	3.86±0.65b	3.57±0.51ab
Taste	3.19±0.68a	3.81±0.75b	3.33±0.86ab

Different superscripts within the same parameter indicate a highly significant difference ($p < 0.05$). Value is expressed as means ± standard deviation.

The yogurt incubated for 10 hours demonstrated significantly higher texture scores (4.29±0.56c), the most vibrant color (4.10±0.77c), an enhanced flavor profile (3.86±0.65b), and an optimal taste (3.81±0.75b) compared to both 8 hours and 12 hours. These results suggest that a 10-hour incubation period improves the sensory qualities of noni juice-fortified yogurt. This duration appears to strike a balance, resulting in a creamier texture, vibrant color, and a well-rounded flavor and taste profile. A 10-hour incubation may facilitate better integration of noni juice compounds with the yogurt matrix, thereby enhancing overall sensory appeal.

3.5. Process of freeze-dried Yogurt Fortified with Noni Juice

The freezing time is a crucial factor in determining the quality and energy cost of freeze-dried products. If the freezing time is too short, the yogurt may not reach the desired frozen state, which will impact the subsequent freeze-drying process. On the other hand, a prolonged freezing time will increase energy costs.

In this study, the yogurt was frozen at -20°C , and the sensory characteristic of the yogurt at different freezing times during cold winter conditions are presented in Table 5.

Table 5. Sensory characteristic of freeze-dried yogurt fortified with noni juice at different freezing times.

Freezing Time	Sensory Evaluation
1 hour	The sample begins to freeze on the surface, with small ice crystals appearing. The lower part remains liquid and has not frozen yet.
2 hours	The upper part of the sample is more frozen, with more ice crystals formed, while the lower part remains liquid.
3 hours	The sample starts to freeze solid, with more crystals appearing, but it is still not fully solid in terms of hardness.
4 hours	The sample is completely frozen, with a certain level of hardness, and can be easily removed from the mold.

Based on the results in Table 5, the hourly observations demonstrate the gradual freezing process of yogurt during cold winter conditions. The uneven freezing during the initial hours suggests potential textural inconsistencies in the frozen product. However, by the fourth hour, the yogurt achieves a desirable texture, indicating that a minimum of 4 hours of freezing is necessary for the production of properly frozen yogurt in these conditions.

Freeze drying is a critical stage that determines the product's quality and energy costs. Temperature and drying time are two important parameters, and it is necessary to select the optimal parameters to ensure the best product quality. Based on previous studies, we selected a drying temperature of 45°C and a drying time of 10 hours [14].

3.6. Properties of freeze-dried yogurt fortified with noni juice

The table 6 indicates that freeze-dried yogurt fortified with noni juice has low moisture (2.76%) and significant amounts of carbohydrates (88.73%), proteins (2.67%), and minerals (2.5%), contributing to its quality and health benefits.

Table 6. Composition of freeze-dried yogurt fortified with noni juice

Moisture (%)	2.76±0.19
Carbohydrates (%)	88.73±0.47
Proteins (%)	2.67±0.50
Ash (%)	2.50±0.20

Value is expressed as means ± standard deviation.

Furthermore, based on the sensory evaluation presented in Table 7, freeze-dried yogurt fortified with noni juice demonstrates excellent sensory qualities. The texture of the freeze-dried yogurt is rated as 4.57 ± 0.50 , indicating a desirable mouthfeel and consistency. The color of the freeze-dried yogurt is visually appealing, with a score of 4.19 ± 0.75 . The flavor of the freeze-dried yogurt is well-developed, achieving a score of 4.38 ± 0.49 , suggesting a balanced and pleasant taste profile. Lastly, the taste of the freeze-dried yogurt is highly rated at 4.52 ± 0.51 , indicating a delicious and enjoyable sensory experience.

Table 7. Sensory qualities of freeze-dried yogurt fortified with noni juice

Texture	4.57±0.50
Color	4.19±0.75
Flavor	4.38±0.49
Taste	4.52±0.51

Value is expressed as means ± standard deviation.

Therefore, chemical properties and sensory evaluation of freeze-dried yogurt fortified with noni juice demonstrates its potential as a desirable and appealing product. The excellent sensory qualities make it a promising option for consumers seeking a delicious and nutritious yogurt experience.

IV. CONCLUSION

When fermenting yogurt, the ratio of sweetened condensed milk to UHT fresh milk-Plain greatly affect the final product. With a ratio of condensed milk to fresh milk of 1:6, the product is considered the best, meeting the requirements for a harmonious taste of yogurt. In addition, during the yogurt fermentation process, attention should be paid to two factors: fermentation temperature and incubation time. Experimental results have shown that fermenting at a temperature of 42°C for 10 hours yields the best quality. Freezing at a temperature of -20°C for 4 hours and freeze-drying at a temperature of 45°C for 10 hours are also optimal.

This research significantly contributes to the development of innovative and groundbreaking new products. By expanding and diversifying the range of available products, it aims to cater to a wider audience and meet the growing demands of consumers who prioritize their health and well-being. Furthermore, this research plays a crucial role in promoting consumer health by providing them with access to a diverse selection of products that are rich in nutritional value and beneficial for their overall well-being. However, to develop a complete product, we will conduct further research on the changes in antioxidant compounds of noni juice when it is added to yogurt during the fermentation process and cold storage.

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