

**Study on the production process of Carrot set-type yogurt**Nguyen Ai Thach^{1*}, Duong Thi Thanh Thuy¹, Tran Duy Khang²¹Tien Giang University²Nam Can Tho University*Corresponding author: nguyenaitlach@tgu.edu.vn

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ABSTRACT

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This study investigates the effects of hydrocolloid concentrations (agar: 0.5, 1.0, 1.5, and 2.0%, w/w and gelatin: 0.3, 0.6, 0.9, and 1.2%, w/w), carrot jam supplementation levels (5-20%), incorporation methods (stirred and layered), and incubation temperatures (40.0, 41.5, 43.3, and 45.0°C) on the physicochemical and structural properties of set-type yogurt. The results demonstrated that the agar-to-gelatin ratio is a decisive factor in structural stability, where the combination of agar (0.5–2.0%) and gelatin (0.3–1.2%) significantly enhanced hardness and reduced syneresis. Specifically, the yogurt sample fortified with 15% carrot jam using the stirred-in method (S-15%) achieved optimal quality, characterized by a hardness of 326 gf and superior water-holding capacity with a syneresis rate of only 0.33%. Regarding fermentation conditions, an incubation temperature of 43.3°C promoted the fastest acidification (pH 4.53); however, 41.5°C provided a better balance between fermentation kinetics and gel matrix integrity. The study successfully identified the optimal formulation and processing conditions to produce carrot set-type yogurt with a stable structure and high nutritional value.

1. INTRODUCTION

Yogurt is recognized as the most ancient fermented dairy product, manufactured through the fermentation of milk by lactic acid bacteria (Shishir et al., 2024). Its distinctive nutritional profile, health benefits, and organoleptic properties have established it as one of the most

prevalent dairy commodities, driving sustainable growth within the dairy industry (Hoxha et al., 2023). Notably, *Lactobacillus* and *Streptococcus thermophilus* serve as the core microorganisms in the binary fermentation systems utilized for yogurt production (Gu et al., 2021). The nutritional and functional attributes of yogurt are

positively correlated with the bioactivity of specific starter cultures, including *Lactobacillus* and *S. thermophilus*. The metabolic interactions between these two strains during synergistic fermentation potentially activate the homolactic fermentation pathway, leading to the synthesis of metabolites such as lactate, bioactive peptides, exopolysaccharides, and short-chain fatty acids via the pentose phosphate pathway. Conversely, these metabolites enhance yogurt digestibility, mineral bioavailability, intestinal barrier function, and immunomodulatory effects (Sharma et al., 2023). Consequently, the viable cell count in yogurt remains a critical indicator of its nutritional and functional properties. Consumer acceptance of set-type yogurt is primarily predicated on its sensory attributes and techno-functional properties. This yogurt variant is highly regarded for its stable and firm gel structure, which is indispensable for a desirable mouthfeel and overall consumption experience. A robust water-holding capacity is a critical factor for this product to prevent syneresis, thereby extending shelf life and enhancing sensory appeal. Furthermore, premium-quality yogurt must maintain a consistent texture throughout storage, remaining free from lumps or graininess (Ma & Chen, 2025). The complex molecular architecture of milk proteins, specifically caseins and whey proteins, facilitates excellent water retention, stable gelation, and a smooth, creamy perception, all of which are essential requirements for high-quality set-type yogurt (Lesme et al., 2020). Replicating these functionalities using hydrocolloids poses significant challenges; thus, the selection of the specific type and concentration of hydrocolloids is a pivotal consideration in the formulation of

hybrid yogurts. The fermentation process can further benefit the textural and organoleptic quality by modifying the structural matrix and improving the gelation kinetics, which are vital for the integrity of set-type yogurt. Hydrocolloid stabilizers, such as gelatin, are commonly incorporated into the milk matrix to maintain or enhance yogurt characteristics, including texture, mouthfeel, appearance, viscosity, and consistency, as well as to inhibit whey syneresis (Nguyen et al., 2017). This novel set-type yogurt exhibits superior fracture strength compared to yogurts formulated with other hydrocolloids, such as gelatin and agar-agar, while displaying a brittleness profile comparable to that of gelatin-containing yogurt (Akshit et al., 2025). To further augment its health-promoting properties, researchers have increasingly incorporated various plant-derived ingredients into yogurt formulations. Examples of such functional additives include fruits and vegetables, such as grapes (de Souza de Azevedo et al., 2018), blueberries (Felix da Silva et al., 2017), and radish (Hamidi et al., 2024), as well as agro-industrial by-products like grape pomace (Sabeti et al., 2023) and medicinal herbs such as *Ganoderma lucidum* (Bao et al., 2025). Yogurt has also been fortified with various plant-derived dietary fibers, including soluble fiber from carrots (Dong et al., 2022), grapefruit fiber (Qin et al., 2023), kale fiber (Zhang et al., 2024), modified insoluble dietary fiber from soybean dregs (Tian et al., 2024), and pea fiber (Qin et al., 2025). Despite these advancements, Carrot-fortified yogurt products remain largely underrepresented in the commercial market. The objective of this study was to investigate the effects of various hydrocolloid types, Carrot

incorporation levels, and incubation temperatures on the physicochemical and structural properties of set-type yogurt.

2. MATERIALS AND METHODS

2.1 Materials

Vinamilk fresh milk, Ngoi Sao Phuong Nam sweetened condensed creamer (green label), Vinamilk starter culture (10^5 to 10^6 CFU/g), and fresh carrots were purchased at Bach Hoa Xanh in My Tho, Dong Thap Province. High methoxyl (HM) pectin (degree of esterification >50%) approved for use in food.

2.2 Preparation of yogurt samples

Yogurt making: the milk base was standardized to a formulation consisting of 10% condensed milk and 60% fresh milk. Hydrocolloids, specifically agar (0.5, 1.0, 1.5, and 2.0%, w/w) and gelatin (0.3, 0.6, 0.9, and 1.2%, w/w), were incorporated into the mixture. These concentration ranges of agar and gelatin were selected based on preliminary trials and previous studies reporting their effectiveness in improving yogurt texture, gel stability, and water-holding capacity without causing excessive firmness or undesirable mouthfeel. These ranges were chosen to evaluate the synergistic effects of agar and gelatin on the structural and physicochemical properties of carrot-fortified set-type yogurt. The formulated milk was pasteurized at 80–85°C for 3–5 minutes and subsequently cooled to an inoculation temperature of 40°C. Separately, fresh carrots were peeled, washed, and homogenized into a puree, then processed with sugar to achieve a total soluble solids content of 55°Brix. The prepared carrot jam was incorporated into the milk mixture prior to fermentation at varying supplementation levels of 5, 10, 15, and 20%

(w/w) using two different addition methods: stirred-in (homogeneously blended with the milk) (S) and layered (positioned at the base of the container) (L). The mixture was then inoculated with a lactic acid bacteria starter culture and incubated at varying temperatures (40.0, 41.5, 43.3, and 45.0°C). The fermentation kinetics were monitored by pH reduction, progressing from an initial pH of 6.6 to a target endpoint of 4.5–4.6. Upon reaching the desired acidity, the curd was cooled to 20–25°C. The final products were stored under refrigerated conditions (4–5°C). Quality attributes were analyzed after a storage period of three to four days.

2.3 Determining the physicochemical properties of set-type yogurt

The titratable acidity, expressed as the percentage of lactic acid, was determined via acid-base titration using 0.1 N NaOH as the titrant. The calculations were performed using a conversion factor (K) of 0.009, corresponding to the milliequivalent weight of lactic acid. The pH measured directly in the yogurt curd using a digital pH meter (HI2210, Hanna, Romania) at room temperature. The textural hardness (expressed in grams of force, g_f) of the yogurt was determined at ambient temperature using a Brookfield CT3–1000 texture analyzer (Brookfield Engineering Labs, USA). The instrument operated with a displacement resolution of 0.1 mm, an accuracy of ±0.1 mm, and a travel speed range of 0.1–10 mm/s (speed accuracy of 0.01 mm/s). A specialized TA 4/100 probe was utilized for all textural measurements. Total sugar content (%) was determined by the potassium ferricyanide method. Lipid content (%) was determined using the Soxhlet extraction method (TCVN 8125:2009). Syneresis (%) was

determined by centrifugation using a Sigma 4K15 centrifuge (Strius AG, Gottigen, Germany). Samples (20–25 g) were centrifuged at 5,000 rpm at 4°C for 10 mins (Lee and Lucey, 2010).

2.4 Statistical analysis

All experimental data were subjected to statistical analysis using Statgraphics centurion software (version 16.1). The results were evaluated via analysis of variance (ANOVA), and significant differences between mean values were determined using the least significant difference (LSD) test at a confidence level of $p < 0.05$.

3. RESULTS AND DISCUSSION

3.1 Influence of agar and gelatin concentrations on the quality attributes of set-type yogurt

Table 1 indicates that the ratio of agar to gelatin is a decisive factor in determining the

textural and structural stability of the product. As the agar concentration increased from 0.5% to 2.0%, there was a substantial and significant rise in hardness, reaching a maximum value of 1136 gr at a 2.0:1.2 ratio. This confirms that agar acts as the primary structural framework; however, high agar levels (2.0%) coupled with low gelatin (0.3%) led to the highest syneresis rate of 16.96%. Optimal water-holding capacity was achieved at a 1.0:0.6 ratio, which yielded the lowest syneresis of 0.5% while maintaining a moderate hardness of 444 gr. These results suggest that a synergistic balance between the rigid agar network and the elastic gelatin matrix is essential to minimize whey separation.

Table 1. Effect of different agar and gelatin ratios on yogurt quality

Ratio agar:gelatin (%, w/w)	Hardness (gr)	pH	Total acid content (%)	Syneresis (%)
0.5:0.3	161 ^a	4.88 ^{ab}	0.30 ^{ab}	4.63 ^{cd}
0.5:0.6	137 ^a	4.95 ^{ab}	0.33 ^{ab}	2.83 ^{abc}
0.5:0.9	120 ^a	4.88 ^{ab}	0.29 ^{ab}	5.76 ^d
0.5:1.2	115 ^a	4.94 ^{ab}	0.34 ^{ab}	6.50 ^d
1.0:0.3	369 ^b	4.91 ^{ab}	0.23 ^{ab}	13.31 ^e
1.0:0.6	444 ^{bc}	4.74 ^a	0.38 ^b	0.50 ^a
1.0:0.9	354 ^b	4.75 ^a	0.23 ^{ab}	14.83 ^{ef}
1.0:1.2	359 ^b	4.87 ^{ab}	0.26 ^{ab}	1.40 ^{ab}
1.5:0.3	755 ^c	4.90 ^{ab}	0.225 ^{ab}	6.26 ^d
1.5:0.6	711 ^c	4.97 ^{ab}	0.135 ^a	2.53 ^{abc}
1.5:0.9	590 ^d	5.02 ^b	0.151 ^{ab}	3.40 ^{bc}
1.5:1.2	485 ^{cd}	4.97 ^{ab}	0.210 ^{ab}	3.17 ^{bc}
2.0:0.3	798 ^c	4.92 ^{ab}	0.225 ^{ab}	16.96 ^f
2.0:0.6	820 ^c	4.88 ^{ab}	0.225 ^{ab}	14.23 ^e
2.0:0.9	1015 ^f	4.92 ^{ab}	0.26 ^{ab}	1.13 ^{ab}
2.0:1.2	1136 ^g	4.8 ^{ab}	0.151 ^{ab}	1.83 ^{ab}

(Note: Values followed by different letters within each column are significantly different ($p < 0.05$))

3.2 Impact of incubation temperature on yogurt quality attributes

The incubation temperature also played a critical role in modulating product quality (Table 2). An incubation temperature of 43.3°C resulted in the lowest pH (4.53) and the highest total acid content (0.40%), suggesting optimal metabolic activity of the lactic acid bacteria. However, this rapid acidification was associated with the highest syneresis rate (9.80%), which may be attributed to a more porous gel structure formed

during accelerated fermentation. While both 40.0°C and 45.0°C yielded the highest hardness values (405 g_f), the intermediate temperature of 41.5°C appeared to offer a balanced acidification rate with relatively low syneresis (6.50%). Collectively, these findings suggest that a controlled incubation thermal conditions is optimal for maintaining the structural integrity and minimizing whey separation in set-type yogurt.

Table 2. Effect of varying incubation thermal conditions on the physicochemical of yogurt

Incubation temperature (°C)	Hardness (g _f)	pH	Total acid content (%)	Total sugar content (%)	Syneresis (%)
40.0	405 ^{ab}	4.75 ^b	0.18 ^a	14.29 ^a	6.91 ^a
41.5	303 ^a	4.68 ^b	0.30 ^{ab}	16.22 ^{ab}	6.50 ^a
43.3	336 ^{ab}	4.53 ^a	0.40 ^b	17.15 ^b	9.80 ^b
45.0	405 ^b	4.69 ^b	0.19 ^{ab}	15.71 ^{ab}	6.63 ^a

(Note: Values followed by different letters within each column are significantly different ($p < 0.05$))

3.3 Influence of carrot supplementation levels and incorporation methods on yogurt quality

The experimental results indicate that both the carrot supplementation level and the incorporation method significantly influenced the yogurt's quality attributes (Table 3). Regarding textural properties, the Hardness of stirred-in samples (S) reached a peak at the 15% concentration (326 g_f), suggesting that the dietary fiber from carrots effectively reinforced the casein matrix at this level. However, a decline in hardness at 20% (292 g_f) suggests a "dilution effect" where excessive plant solids disrupt the continuity of the protein network. As the pH approaches the isoelectric point of casein (approximately 4.6), casein micelles aggregate to form a three-dimensional gel structure

responsible for yogurt firmness. However, high levels of insoluble carrot fibers and plant particles can physically obstruct casein-casein interactions by occupying space within the gel matrix and reducing direct protein aggregation. In addition, excessive carrot incorporation lowers the relative concentration of milk proteins and decreases the density of protein junctions within the network. Carrot fibers also possess high water-holding capacity, which may compete with casein proteins for available water and alter protein hydration during gel formation. These combined effects result in a less compact and more heterogeneous gel structure, ultimately reducing yogurt hardness. Interestingly, the layered method (L) maintained a high hardness at 15% (325 g_f), likely because the upper yogurt curd

remained undisturbed by the jam particles during gelation. The Syneresis (whey separation) data serves as a critical indicator of gel stability. The S-15% sample demonstrated the most superior water-holding capacity, with a syneresis rate of only 0.33%. This suggests a strong synergistic interaction between the hydrocolloids (agar/gelatin) and the carrot fibers, which effectively entrapped the aqueous phase. In contrast, higher syneresis in the 5% and 20% stirred samples indicates a less stable gel structure. Chemically, the pH values remained within the optimal range of 4.65 to 4.89, which is

near the isoelectric point of casein required for stable curd formation. The total acid content peaked in the L-15% sample (0.525%), potentially due to the localized concentration of sugars at the base promoting higher metabolic activity of the lactic acid bacteria. Furthermore, the Total Sugar Content increased proportionally with the jam concentration, reaching its highest levels in the 15–20% range, which enhances the product's caloric value and sensory sweetness. Overall, the S-15% formulation appears to be the most balanced, providing maximum structural firmness and minimal whey separation.

Table 3. Effect of carrot dosage and inclusion format on the physicochemical and textural properties of yogurt

Combination form - % carrot jam	Hardness (g)	pH	Syneresis (%)	Total sugar content (%)	Total acid content (%)	Lipid (%)
S - 5%	282 ^{cd}	4.71 ^{ab}	7.50 ^b	14.98 ^a	0.098 ^a	2.01 ^{ab}
S - 10%	306 ^{cd}	4.80 ^{ab}	4.60 ^{ab}	16.00 ^{ab}	0.187 ^{ab}	2.36 ^{ab}
S - 15%	326 ^d	4.89 ^b	0.33 ^a	17.39 ^b	0.397 ^{bc}	1.32 ^a
S - 20%	292 ^{cd}	4.71 ^{ab}	7.06 ^b	16.34 ^{ab}	0.105 ^a	2.24 ^{ab}
L - 5%	208 ^{ab}	4.78 ^{ab}	5.00 ^{ab}	15.06 ^{ab}	0.262 ^{abc}	4.26 ^{ab}
L - 10%	158 ^a	4.76 ^{ab}	4.50 ^{ab}	15.67 ^{ab}	0.247 ^{abc}	2.82 ^{ab}
L - 15%	325 ^d	4.65 ^a	6.10 ^b	14.83 ^a	0.525 ^c	4.61 ^b
L - 20%	260 ^{bc}	4.69 ^{ab}	5.33 ^{ab}	17.02 ^{ab}	0.262 ^{abc}	4.32 ^{ab}

(Note: Values followed by different letters within each column are significantly different ($p < 0.05$). S: stirred; L: layered)

4. CONCLUSION

The study successfully demonstrated the feasibility of producing carrot-fortified set-type yogurt with desired structural and physicochemical attributes. The selection of hydrocolloid concentrations and the plant-based ingredient incorporation method proved to be pivotal factors: the homogeneous blending of

carrot jam at a 15% ratio, combined with a synergistic agar-gelatin stabilizing system, produced a robust gel network and minimized whey separation. Furthermore, controlling the incubation temperature between 41.5°C and 43.3°C ensured the metabolic activity of lactic acid bacteria and the formation of a uniform curd. These findings provide a significant technical

foundation for developing functional fermented dairy products that leverage the natural benefits of carrots to meet increasing consumer demand for health-oriented foods. Further research should incorporate sensory evaluation to assess consumer acceptance and establish correlations between sensory perception and the observed structural and physicochemical characteristics of the yogurt products, while also exploring the economic value and sustainability of utilizing locally available agricultural products such as carrots in the dairy processing industry to support value-added food production and reduce post-harvest losses.

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