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Research Article

Physicochemical Properties of Bird's Nest Orange Drink Treated Using Different Retort Times and Cooling Processes

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ABSTRACT

Bird's nest drinks are widely recognised as a healthy beverage option. Introducing a bird's nest orange drink represents a promising advancement in food technology, anticipated to offer enhanced health benefits. This study focuses on retort sterilisation, a crucial method for ensuring food safety and quality. However, prolonged retort processing can negatively impact beverage characteristics. This study investigated the effects of varying retort times (3, 5, and 7 minutes at 121°C) and cooling methods (room temperature and ice bath) on bird's nest orange drink properties. The main goal was to find the best processing conditions to maintain product quality. Results showed that retort time significantly ($p < 0.05$) impacted most physical and chemical traits, including moisture, protein, fat, pH, total soluble solids, viscosity, and colour (L^* values). Longer retort times decreased ($p < 0.05$) these properties, while ash and carbohydrate content, and redness/yellowness (a^* and b^* values), increased ($p < 0.05$). Cooling methods had less impact, mainly affecting ($p < 0.05$) viscosity and lightness, with ice water cooling performing slightly better. Crucially, the drink's ability to scavenge free radicals notably ($p < 0.05$) declined with longer retort times, regardless of the cooling method. This shows that heat treatment degrades the antioxidants. The findings highlight a trade-off between ensuring microbial safety and preserving the drink's nutritional and sensory quality, emphasising the importance of optimising thermal processing parameters for bird's nest orange drinks.

Key words: Antioxidant activity, edible bird's nest, orange juice, retort sterilisation, quality preservation

INTRODUCTION

Food is essential for growth and disease prevention, and rising public awareness of functional foods has increased consumer demand for products that offer more than basic nutrition. This surge in demand has pushed the food industry to innovate and create products with therapeutic benefits. Edible bird's nests (*Aerodramus fuciphagus*) are well-known functional foods packed with nutrients such as protein and sialic acid. Their protein hydrolysates are even thought to have antihypertensive properties (Lim *et al.*, 2021).

The global market for edible bird's nests was valued at USD 1 billion in 2024 and is projected to reach USD 1.05 billion in 2025 (Business Research Insights, 2025). These nests are often commercially processed into ready-to-drink beverages using heat treatment and sugar syrup (Amiza *et al.*, 2019). However, it is important to note that excessive sugar consumption is linked to various health problems, including diabetes, stroke, and cardiovascular disease (Keller *et al.*, 2020).

To address this concern, replacing sugar with fruit juice, such as orange juice, presents a healthier and more appealing alternative to bird's nest drinks (Pepin *et al.*, 2019). Orange juice, a popular and nutrient-rich beverage, boosts the immune system. It includes minerals, bioactive components, and antioxidant and anti-inflammatory phenolic compounds (Li *et al.*, 2021). With a global market size valued at USD 6 billion in 2024 (Global Growth Insights, 2025), orange juice offers a significant market potential.

Retort sterilisation is a standard thermal processing method that extends the shelf life of low-acid foods by eliminating microorganisms like *Clostridium botulinum* (Gokhale & Lele, 2014). However, excessive heat treatment can negatively impact a food's sensory and nutritional qualities. There is a significant interest in studying different cooling methods after retort sterilisation because of their crucial impact on product quality, food safety, and process efficiency. Research focuses on optimising cooling techniques to minimise heat damage, ensure sterility, and improve sustainability (Coolbear *et al.*, 2022). This optimisation is vital for delivering high-quality, safe, and cost-effective shelf-stable food products.

Therefore, finding the optimal balance between preservation and quality is crucial for developing a successful bird's nest orange drink. Determining the most effective retort times and cooling processes based on physicochemical properties is essential. While previous studies have explored retort processing for various liquid foods, research specifically on bird's nest drinks remains limited. This study addresses this gap by investigating the impact of different retort times and cooling processes on the physicochemical properties of a bird's nest orange drink.

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MATERIALS AND METHODS

Materials

The edible bird's nest (*Aerodramus fuciphagus*) was sourced from Glyken Sdn. Bhd., Malaysia. Local markets supplied snow fungus (*Tremella fuciformis*), Valencia oranges (*Citrus sinensis*), and rock sugar. Gellan gum was purchased from Sigma Aldrich Sdn. Bhd., Malaysia.

Preparation of orange juice

Valencia oranges were washed, peeled, cut, juiced, and filtered to remove pulp. The resulting juice was then evenly distributed into glass bottles.

Preparation of bird's nest orange drink

Gellan gum, snow fungus, and dried edible bird's nest flakes were added to the prepared orange juice before the bottles were capped (Chantakun *et al.*, 2020). The specific formulation is detailed in Table 1.

Table 1. Formulation of the bird's nest orange drink

Ingredients	Percentage (%)
Orange juice	77.72
Snow fungus	1.00
Rock sugar	1.00
Edible bird's nest	0.20
Gellan gum	0.08
Water	20.00

The drink samples were retort-sterilised at 121°C for 3, 5, or 7 minutes using a 1925X Non-electric Pressure Steam Steriliser (Wisconsin Aluminum Foundry Co., Inc., USA). Each batch was then cooled in a cold room followed by an ice bath or at room temperature. All samples were stored at 4°C for subsequent analysis. The control sample was prepared following the same formulation before it was directly stored at 4°C. Table 2 outlines the sample codes and treatments.

Table 2. Sample codes and treatments

Sample	Retort temperature and time	Cooling process
Control	-	-
3R	121°C for 3 minutes	Room temperature
5R	121°C for 5 minutes	Room temperature
7R	121°C for 7 minutes	Room temperature
3C	121°C for 3 minutes	4°C ice bath
5C	121°C for 5 minutes	4°C ice bath
7C	121°C for 7 minutes	4°C ice bath

Proximate composition

Moisture content

The moisture content was determined using the AOAC standard procedure (2019). An empty crucible was dried and cooled. Approximately 3 g of the sample was weighed and put into the crucible. The crucible was placed in an oven at 105°C overnight before it was cooled and weighed. The moisture content was calculated using the following equation:

$$\text{Moisture content } (\%) = \frac{W_3 - (W_2 - W_1)}{W_3} \times 100$$

where
W_1 = weight (g) of empty crucible
W_2 = weight (g) of crucible with dried sample
W_3 = weight (g) of sample

Ash content

The ash content was determined according to the AOAC standard procedure (2019). An empty crucible was dried, cooled, and weighed. Approximately 3 g of the sample was weighed and put into the crucible. The crucible was placed in a muffle furnace at 550°C overnight before it was cooled and weighed. The ash should be white or light grey. If not, further ashing is required. The ash content was calculated using the following equation:

$$\text{Ash content } (\%) = \frac{W_2 - W_1}{W_3} \times 10$$

where
W_1 = weight (g) of empty crucible
W_2 = weight (g) of crucible with its ash content
W_3 = weight (g) of sample

Crude protein content

Protein content was determined using the Kjeldahl method (AOAC, 2019). A 0.15 g sample was digested with concentrated sulfuric acid (H_2SO_4) and a catalyst mixture and then neutralised with 45% sodium hydroxide (NaOH). The released ammonia was distilled into a 2% boric acid (H_3BO_3) solution and titrated with 0.05 N H_2SO_4. The crude protein content was calculated using the following equations:

$$\text{Nitrogen content}\left(\%\right) = \frac{(V_1 - V_2) \times N \times 1.4}{W} \times 100$$

$$\text{Crude protein content } (\%) = \text{Nitrogen content} \times 6.25$$

where
V_1 = volume (mL) of 0.05 N H_2SO_4 used in sample titration
V_2 = volume (mL) of 0.05 N H_2SO_4 used in blank titration
N = normality of H_2SO_4
W = weight (g) of sample
6.25 = protein-nitrogen conversion factor for fish and its by-products

Fat content

Fat content was determined using the AOAC standard procedure (2019). A 5 g sample was extracted with petroleum ether using a magnetic stirrer and then separated in a separatory funnel. The petroleum ether extract was evaporated using a rotary evaporator, dried in an oven, cooled, and weighed. The fat content was calculated using the following equation:

$$\text{Fat content } \left(\%\right) = \frac{W_3 - W_2}{W_1} \times 100$$

where
W_1 = weight (g) of sample
W_2 = weight (g) of empty conical flask
W_3 = weight (g) of extracted oil

Carbohydrate content

Carbohydrate content was calculated by subtracting the sum of moisture, ash, protein, and fat content from 100%.

pH value

The pH of the samples was measured using a Jenway 3505 pH Meter (Bibby Scientific Ltd., United Kingdom).

Total soluble solid content

A few drops of each sample were placed on the film of an H196801 Digital Refractometer (Hanna Instruments (M) Sdn. Bhd., Malaysia) to measure their total soluble solid content.

Viscosity

The viscosity of the samples was measured using a RheolabQC Rotational Rheometer (Anton Paar USA, Inc., USA) at 100 rpm and 25°C.

Colour

The colour of the samples was measured using a CR-410 Chroma Meter (Konica Minolta, Inc., Japan), calibrated with a standard white plate. The *L**, *a**, and *b** values were recorded.

DPPH free-radical scavenging activity

The DPPH free-radical scavenging activity of the samples was determined using the method described by Farahani *et al.* (2023). A 2-mL aliquot of a 1 mg/mL sample solution was mixed with 1 mL of 0.1 mM DPPH solution in 96% ethanol and incubated in the dark for 30 minutes. The absorbance was measured at 517 nm using a UV-Vis spectrophotometer. The DPPH free-radical scavenging activity was calculated using the following equation:

$$\text{DPPH free-radical scavenging activity}\left(\%\right) = \frac{A_1 - A_2}{A_1} \times 100$$

where
A_1 = absorbance of blank
A_2 = absorbance of the sample

Statistical analysis

All experiments were conducted in triplicate. A one-way ANOVA followed by Tukey's HSD test was used to analyse the data at a 0.05 significance level. Means and standard deviations were calculated to compare differences between treatments.

RESULTS AND DISCUSSION

Proximate composition

Table 3 shows a significant ($p < 0.05$) decrease in moisture content with increasing retort time. The moisture content of the bird's nest orange drink aligns with commercial orange juice (88.20-94.50%) and Valencia orange juice (86.00-89.10%) (Yarkwan & Oketunde, 2016). The control sample had the highest moisture content, which is consistent with moisture evaporation during heat treatment (Onwurafor *et al.*, 2022).

Table 3. Proximate composition of bird's nest orange drink subjected to varying retort times and cooling methods

Sample	Moisture (%)	Ash (%)	Protein (%)	Fat (%)	Carbohydrate (%)
Control	93.77 ± 0.02^{a}	0.34 ± 0.09^{a}	0.67 ± 0.01^{a}	1.40 ± 0.05^{a}	3.83 ± 0.59^{e}
3R	92.66 ± 0.19^{b}	0.34 ± 0.02^{a}	0.57 ± 0.16^{abc}	1.22 ± 0.06^{a}	5.17 ± 0.27^{d}
5R	91.32 ± 0.11^{c}	0.36 ± 0.05^{a}	0.56 ± 0.16^{abc}	1.36 ± 0.38^{a}	6.40 ± 0.58^{bc}
7R	90.25 ± 0.16^{d}	0.32 ± 0.04^{a}	0.37 ± 0.01^{bc}	1.36 ± 0.11^{a}	7.69 ± 0.30^{a}
3C	92.64 ± 0.28^{b}	0.36 ± 0.02^{a}	0.66 ± 0.02^{ab}	1.10 ± 0.01^{a}	5.24 ± 0.13^{d}
5C	91.45 ± 0.19^{c}	0.39 ± 0.02^{a}	0.56 ± 0.15^{abc}	1.47 ± 0.11^{a}	6.14 ± 0.16^{cd}
7C	90.60 ± 0.08^{cd}	0.32 ± 0.03^{a}	0.37 ± 0.00^{c}	1.44 ± 0.07^{a}	7.27 ± 0.52^{ab}

Data are given as mean values ± standard deviation (n = 3). Different letters within the same column indicate significant differences ($p < 0.05$) between mean values. 3R, 5R, and 7R represent 3, 5 and 7 minutes retort time with room temperature cooling, while 3C, 5C, and 7C represent 3, 5 and 7 minutes retort time with ice bath cooling.

Retort time did not significantly ($p > 0.05$) affect ash content, which is consistent with findings on watermelon juice (Kumar *et al.*, 2017). The results show that the mineral components were unaffected by the thermal treatments. Retort sterilisation, regardless of duration or subsequent cooling method, does not lead to the degradation, loss, or increase of the inorganic mineral content in the sample. Such findings are typical for ash content in food products subjected to thermal processing, as minerals are heat stable and do not readily decompose or evaporate under these conditions.

Protein content varied with retort time and cooling methods. The control sample contained the most protein. Retorting for 3 and 5 minutes significantly reduced protein content ($p < 0.05$), with a greater reduction at 7 minutes. High temperatures denature and degrade the edible bird's nest glycoproteins, primarily causing this reduction (Maurya *et al.*, 2025). Increased sterilisation time intensifies protein breakdown, cleaving peptide bonds and forming smaller peptides and amino acids. This extensive thermal degradation affects the product's texture, colour, and nutritional profile. Interestingly, the cooling method influenced protein content at shorter retort durations, specifically at 3 minutes. Ice bath cooling better preserved protein compared to room temperature cooling. This suggests that rapid cooling might mitigate some initial protein degradation or aggregation. However, at extended retort times, the severe thermal impact overshadowed any protective effect of rapid cooling, resulting in similarly low protein levels regardless of the cooling method.

Retort time did not significantly ($p > 0.05$) affect fat content, which is consistent with findings on watermelon juice (Kumar *et al.*, 2017). While the absolute changes in fat content are relatively small ($p > 0.05$), the underlying mechanisms of lipid degradation because of thermal processing are likely occurring. These chemical changes can impact the quality of the fat even if the total percentage remains similar. Gellan gum likely stabilizes the minor lipid phase, preventing fat separation, especially with rapid cooling (Vilela & Cunha, 2016). This contributes to the overall physical stability of the sample.

Carbohydrate content significantly ($p < 0.05$) increased with retort time, mirroring the trend observed in *Ficus capensis* drinks (Onwurafor *et al.*, 2022). This shows a direct relationship between the duration of heat treatment and the perceived carbohydrate concentration. This increase is primarily attributed to a concentration effect resulting from the significant loss of moisture during the prolonged high-temperature retort process. As water evaporates, the remaining solid components, including carbohydrates, become proportionally more concentrated. Although the main ingredients are heat-stable, some carbohydrate breakdown into simpler sugars might occur, possibly increasing the overall measurement (Gularte & Rosell, 2011). Finally, according to Table 3, the cooling process did not significantly ($p > 0.05$) affect any parameters of the proximate composition.

pH value

Table 4 presents the pH values of the bird's nest orange drink with varying retort times and cooling methods. As Maskat and Tan (2011) noted, pH is a crucial factor influencing the flavour and taste of fruit drinks. The control sample exhibited an acidic pH of 3.75, aligned with commercial orange juices, which typically range from 3.54 to 3.84 (Lee *et al.*, 2019). This acidity is primarily attributed to organic acids like citric, malic, and ascorbic acids (Silva *et al.*, 2020).

Table 4. pH, total soluble solid content, and viscosity of bird's nest orange drink under different retort times and cooling methods

Sample	pH	Total soluble solid content (°Brix)	Viscosity (mPa.s)
Control	3.75 ± 0.01^{d}	13.60 ± 0.00^{c}	5.47 ± 0.15^{e}
3R	3.81 ± 0.01^{c}	13.63 ± 0.06^{c}	6.27 ± 0.06^{d}
5R	3.85 ± 0.01^{b}	13.67 ± 0.06^{c}	7.20 ± 0.20^{c}
7R	3.92 ± 0.01^{a}	13.73 ± 0.13^{c}	8.10 ± 0.20^{b}
3C	3.81 ± 0.01^{c}	13.67 ± 0.06^{c}	6.37 ± 0.15^{d}
5C	3.87 ± 0.01^{b}	13.93 ± 0.06^{b}	7.47 ± 0.15^{c}
7C	3.93 ± 0.01^{a}	14.13 ± 0.06^{a}	8.57 ± 0.06^{a}

Data are given as mean values ± standard deviation (n = 3). Different letters within the same column indicate significant differences ($p < 0.05$) between mean values. 3R, 5R, and 7R represent 3, 5 and 7 minutes retort time with room temperature cooling, while 3C, 5C, and 7C represent 3, 5 and 7 minutes retort time with ice bath cooling.

The pH values of the samples increased significantly ($p < 0.05$) with longer retort times compared to the control sample. This increase is linked to the degradation of organic acids during heat treatment, resulting in reduced acidity. Similar findings have been reported in studies on thermally treated orange juice (Alhaji, 2018). Maskat and Tan (2011) also observed a similar trend in heat-treated *mengkudu* extract. Notably, the cooling methods did not significantly ($p > 0.05$) affect the pH values of the samples.

Total soluble solid content

In orange juice, the soluble solids primarily comprise sugars, organic acids, inorganic ions, and vitamins. Table 4 shows that retort time did not significantly ($p > 0.05$) affect the total soluble solid content of the bird's nest orange drink. Heat treatment's minimal impact on total soluble solids in fruit juices and extracts is consistent with prior research (Pandiselvam *et al.*, 2020; Pulissery *et al.*, 2023). Conversely, a significant difference ($p < 0.05$) was noted between the samples with different cooling methods. This can be attributed to sucrose crystallisation, favoured by slower cooling rates and hindered by rapid cooling. Speranza *et al.* (2023) explain that sucrose crystallisation reduces the amount of soluble solids remaining in the liquid phase.

Viscosity

Viscosity is a crucial quality attribute in fruit drinks, affecting texture and the ability to suspend solid particles (Colbert *et al.*, 2022). Table 4 presents the viscosity of the bird's nest orange drink subjected to different retort times and cooling methods. The control sample exhibited a viscosity of 5.47 mPa.s. Both retort time and cooling method significantly ($p < 0.05$) influenced viscosity. Longer retort times increased viscosity, likely because of water evaporation and subsequent absorption by the water-absorbent snow fungus (Lan *et al.*, 2021). Higher total soluble solid content, resulting from increased soluble solids concentration, also contributed to higher viscosity (Bozdogan, 2015). Rapid cooling in the ice bath resulted in a higher viscosity than gradual cooling at room temperature for samples with the same retort time. This aligns with Humphrey and Narine (2007), who suggested rapid cooling can induce higher viscosity.

Colour

Colour is a crucial factor in consumer appeal and can indicate quality, chemical changes, and nutritional profile (Aghajanzadeh *et al.*, 2021). The CIELAB colour system, widely used in the food industry, provides accurate colour measurements. Table 5 presents the L^*, a^*, and b^* values of the bird's nest orange drink subjected to various retort times and cooling methods. L^*, a^*, and b^* define a colour space where L^* represents lightness, and a^* and b^* describe the colour's chromaticity along red-green and yellow-blue axes, respectively.

Table 5. Chromatic parameters of bird's nest orange drink under different retort times and cooling methods

Sample	L^*	a^*	b^*
Control	64.59 ± 0.25^{a}	0.17 ± 0.02^{e}	43.82 ± 0.26^{e}
3R	62.60 ± 0.22^{b}	1.00 ± 0.09^{d}	44.82 ± 0.26^{cd}
5R	59.63 ± 0.21^{d}	2.54 ± 0.06^{bc}	47.77 ± 0.48^{b}
7R	58.80 ± 0.22^{e}	3.57 ± 0.06^{a}	51.19 ± 0.51^{a}
3C	62.76 ± 0.13^{b}	1.47 ± 0.06^{d}	43.96 ± 0.32^{de}
5C	60.96 ± 0.32^{c}	2.15 ± 0.30^{c}	45.38 ± 0.18^{c}
7C	59.31 ± 0.28^{de}	2.83 ± 0.32^{b}	47.99 ± 0.24^{b}

Data are given as mean values ± standard deviation (n = 3). Different letters within the same column indicate significant differences ($p < 0.05$) between mean values. 3R, 5R, and 7R represent 3, 5 and 7 minutes retort time with room temperature cooling, while 3C, 5C, and 7C represent 3, 5 and 7 minutes retort time with ice bath cooling.

Retort processing significantly ($p < 0.05$) reduced L^* values. A lower L^* value indicates reduced brightness. This trend aligns with findings on retorted apple juice, where decreased L^* values were linked to non-enzymatic browning. Room temperature-cooled samples showed significantly lower L^* values ($p < 0.05$) than ice bath-cooled samples. This suggests that slower cooling increased ascorbic acid degradation and browning. (Zhu *et al.*, 2019).

Table 5 also shows significant increases in a^* and b^* values with retort time for both cooling methods. A higher a^* value indicates increased redness, while a higher b^* value indicates increased yellowness. The increase in a^* and b^* values is likely because of reduced ascorbic acid content (Aghajanzadeh *et al.*, 2021) and increased brown compound accumulation (Kreungngern *et al.*, 2019). The 7R and 5R samples exhibited higher a^* and b^* values than their ice-bath-cooled counterparts, indicating more pronounced browning because of prolonged heat exposure. These results are consistent with findings by Huang *et al.* (2015) and Hajar-Azhari *et al.* (2018).

Heat treatment degrades ascorbic acid because of its thermolabile nature (Alhaji, 2018). Ascorbic acid oxidation forms unstable dehydroascorbic acid (DHA), which hydrolyses into 2,3-diketogulonic acid (DKG). DKG decarboxylation produces reactive carbonyl compounds, leading to non-enzymatic browning (Yin *et al.*, 2022). Acid-catalysed sugar degradation leads to non-enzymatic browning, mainly by creating 5-hydroxymethyl furfural (HMF) from glucose and fructose (Buvé et al., 2021).

The Maillard reaction condenses reducing sugars and amino acids and can also contribute to browning. However, acidic conditions and high water activity in citrus juices suppress the Maillard reaction. Instead, Maillard-associated reactions involving reactive carbonyl compounds from ascorbic acid degradation or sugar degradation with amino acids become more prominent (Buvé *et al.*, 2021).

DPPH free-radical scavenging activity

The DPPH free-radical scavenging assay measures antioxidant capacity by monitoring the reduction of the stable DPPH molecule to a less stable DPPH-H radical. This reduction, caused by donating hydrogen atoms from antioxidants, decreases absorbance at 517 nm (Baliyan *et al.*, 2022). Fruit juices like orange juice contain antioxidants, such as phenolic acids, flavonoids, and stilbenes, that benefit human health (Todaro *et al.*, 2023). These antioxidants neutralise free radicals by donating electrons (Kumar *et al.*, 2022).

Table 6. DPPH free-radical scavenging activity of bird's nest orange drink under different retort times and cooling methods

Sample	DPPH free-radical scavenging activity (%)
Control	71.48 ± 1.15^{a}
3R	68.11 ± 0.60^{b}
5R	61.76 ± 0.62^{c}
7R	57.86 ± 0.36^{d}
3C	67.43 ± 0.67^{b}
5C	62.63 ± 1.42^{c}
7C	58.69 ± 1.01^{d}

Data are given as mean values ± standard deviation (n = 3). Different letters within the same column indicate significant differences ($p < 0.05$) between mean values. 3R, 5R, and 7R represent 3, 5 and 7 minutes retort time with room temperature cooling, while 3C, 5C, and 7C represent 3, 5 and 7 minutes retort time with ice bath cooling.

Table 6 presents the DPPH free-radical scavenging activity of the bird's nest orange drink treated with various retort times and cooling methods. Studies have found that commercial orange juices can have varying antioxidant activities (Sarvarian *et al.*, 2021). This loss of antioxidant activity is consistent with findings on maoberry juice (Kemsawasd & Chaikham, 2021). Similar trends have been observed in other studies, such as kinnow and pomelo juices (Kumar *et al.*, 2023) and pomegranate juice (Mena *et al.*, 2013). As used in pasteurisation and retort processes, heat treatment can significantly decrease antioxidant activity, especially in orange juice (Escudero-López *et al.*, 2016).

Orange juice contains various bioactive antioxidants, including carotenoids, ascorbic acid, and flavonoids, contributing to its health benefits (Abuajah *et al.*, 2015). Ascorbic acid, a heat-sensitive compound, degrades upon heat treatment (Alhaji, 2018). Flavonoids, such as flavanone-O-glycosides and flavanone-O- or -C-glycosides, are also susceptible to thermal degradation, particularly at temperatures above 90°C (Chaaban *et al.*, 2017). Therefore, the longer the retort time, the greater the loss of antioxidants and the lower the antioxidant activity of the samples.

CONCLUSION

This study evaluated the effects of different retort sterilisation times and cooling methods on the physicochemical characteristics of a bird's nest orange drink. The findings underscore that retort time is a critical factor influencing most quality attributes. Extended heat exposure led to significant alterations, including a reduction in moisture, protein, fat, pH, total soluble solids, viscosity, and lightness, while ash, carbohydrate content, redness, and yellowness increased. These changes suggest a degradation of heat-sensitive components and potential non-enzymatic browning reactions.

While cooling methods played a lesser role, ice bath cooling showed a slight advantage in preserving viscosity and lightness, indicating its potential to mitigate some heat-induced quality deterioration post-retort. A notable observation was the significant decrease in DPPH free-radical scavenging activity with increasing retort time across all cooling methods. This highlights the susceptibility of the drink's antioxidant compounds to thermal degradation during sterilisation.

In conclusion, optimising retort processing for bird's nest orange drinks requires a delicate balance. While longer retort times ensure microbial safety and extend shelf life, they concurrently compromise nutritional quality and sensory attributes, particularly antioxidant capacity. To preserve the drink's quality, retort time should be minimized while ensuring commercial sterility. Rapid cooling methods, such as ice water, should be used.

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ETHICAL STATEMENT

Not applicable.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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