International Food Research Journal 31(6): 1626 - 1636 (December 2024)
Journal homepage: *http://www.ifrj.upm.edu.my*

Cooking qualities, nutritional properties, microstructure, and sensory evaluation of noodles incorporated with *angkung* (*Basella alba* L.) fruit juice

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Article history

Received:
5 September 2023
Received in revised form:
12 November 2024
Accepted:
13 November 2024

Keywords

angkung,
antioxidant,
Basella,
healthy foods,
noodles

Abstract

The significant nutritional potential and widespread availability of *angkung* (*Basella alba* L.) fruit lead to its utilisation as a functional dietary component in noodle fortification. Food fortification is a common approach to reduce the occurrence of micronutrient deficiencies. The present work thus aimed to assess the effects of incorporating *angkung* fruit juice into red violet noodles (RVN) on various responses, including cooking quality, colour, phytochemical properties, antioxidant activity, and sensory evaluation. The RVN was produced by incorporating *angkung* fruit juice at different concentrations: 0% (control), 2% (RVN1), 4% (RVN2), and 6% (RVN3), utilising a completely randomised design (CRD) with one factor and three replications. The present work then assessed the cooking quality indicators, including water absorption ratio (WAR), cooking loss (CL), cooking time (CT), and scanning electron microscope (SEM). Colour measurements were obtained using the L*, a*, and b* parameters, alongside evaluations of total phenolic content, total flavonoid levels, antioxidant activity, and sensory assessment. The WAR in noodles incorporated with *angkung* fruit juice was significantly lower ($p < 0.05$) compared to the control. The WAR values of RVN ranged from 136.41 to 141.86%, while that of the control value was 156.23%. The cooking loss for RVN ranged from 7.14 to 8.43%, while that of the control group was 5.56%. The control and treatment groups demonstrated a statistically significant difference in CT. SEM results indicated that increasing the incorporation of *angkung* fruit juice to RVN led to larger and more porous gel, suggesting that various compounds were dissolved during the process. The cooked RVN exhibited statistically significant differences in L* and b* compared to the control group (L* = 68.53; b* = 20.45). The cooked RVN demonstrated decreased values of lightness and yellowness. The a* value of the cooked RVN was significantly greater than that of the control group (a = 1.09). The RVN samples demonstrated a significantly greater total phenolic content, total flavonoid content, and antioxidant activity compared to the control group. The incorporation of *angkung* fruit juice resulted in a decrease in the sensory evaluation scores for RVN. Results indicated that *angkung* could have significant potential as a commercially viable fruit in the food industry. Future research should incorporate *in-vitro* and *in-vivo* analyses to further assess the bioavailability and potential health impacts of *angkung* fruit juice's antioxidant and phytochemical components. Ultimately, the present work aimed to implement, advertise, and promote the widespread use of RVN as a nutritionally advantageous dietary option.

DOI
https://doi.org/10.47836/ifrj.31.6.20

Introduction

Indonesia is the second-largest consumer of instant noodles worldwide, after China. In 2021, Indonesia experienced an increase in noodle consumption of approximately 4.98% relative to the previous year. Indonesia is expected to remain as the second-largest consumer of instant noodles worldwide, after China/Hong Kong, with an estimated consumption of 13.270 million servings

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(WINA, 2022). Noodles, which include various types that can be quickly prepared for consumption, are widely popular among the Indonesian population. Noodles serve as a dietary staple in many countries, and are created by processing unleavened dough through techniques such as stretching, pressing, or rolling into thin sheets, which are then cut into various geometric shapes. Noodles have gained significant popularity due to their affordability, convenience, long shelf life, and nutritional value. This is primarily due to the significant contribution of noodles as a source of carbohydrates, proteins, and vitamin B (Okoye *et al*., 2008). The primary constituents of instant noodles include flour, particularly wheat flour, starch, water, and salt. Consequently, instant noodles often contain high levels of fats and carbohydrates, while being deficient in other essential nutrients required for daily dietary needs, including fibres, vitamins, and minerals. This explains why they often encounter criticism for being harmful to health (Adejuwon *et al*., 2020). Regular consumption of instant noodles is linked to various negative health effects, including malnutrition, poor dietary habits, and the onset of diet-related conditions and cardio-metabolic diseases, such as obesity, hypercholesterolemia, and metabolic syndrome. The adverse effects can be linked to the insufficient nutritional composition of instant noodles. As consumer demand for instant noodles rises, there is an urgent requirement for the development of healthier alternatives to this product (Koh *et al*., 2022).

Currently, Indonesia cultivates a substantial quantity of *angkung* (*Basella alba* L.) plants. *Angkung* is widely cultivated and consumed as a leafy green vegetable due to its significant content of vitamins, minerals, and antioxidants. After harvesting, many farmers opt to abandon the *angkung* fruits. *Angkung* fruits, upon ripening, exhibit a red purple skin and flesh, serving as a natural source of pigmentation. The principal red pigment present in ripe *angkung* fruits is identified as gomphrenin I (GPI), classified within the betalain group. Research by Huang *et al*. (2016) has shown that betacyanin, the compound associated with GPI, displays significant antioxidant and anti-inflammatory properties. Furthermore, Kumar *et al*. (2015) reported that betalains, particularly betacyanin red violet and betaxanthin yellow orange, are rich in phytochemicals, antioxidants, and possess various health-enhancing properties. These compounds play a crucial role as components of functional food ingredients. Due to its significant red-purple pigmentation, *angkung* fruits have seen considerable application in the modern food industry.

The nutritional potential and widespread availability of *angkung* fruits in Indonesia leads to its increased use as a functional dietary component, particularly through the incorporation of *angkung* fruit juice into noodle preparations. Food fortification is a common strategy used to reduce the prevalence of micronutrient deficiencies, playing a vital role in food policy among Asia-Pacific countries. The present work thus aimed to assess the impact of fortifying *angkung* fruit juice on the cooking qualities, microstructure, colour, phytochemical properties, antioxidant activity, and sensory characteristics of red violet noodles (RVN).

Materials and methods

Research materials

The present work employed several raw materials, comprising high protein wheat flour with a protein content of 12 - 14%, salt, eggs, water, and cooking oil. The ingredients were sourced from traditional markets in Malang City, while sodium alginate and *angkung* fruits were acquired from CV. RAJ in Malang City, Indonesia.

Methods

Production of angkung fruit juice

The methodology employed for the production of *angkung* fruit juice was outlined in the study conducted by Patria *et al*. (2022). Briefly, 500 g of ripe *angkung* fruit underwent a thorough cleaning procedure under flowing tap water to remove sand particles and external impurities from the fruit's surface. After 20 min, the *angkung* fruits were washed with distilled water and subsequently drained. Then, the fruits were subsequently processed with a hand press machine (VZ-1, China) for juicing purposes. The juice was subsequently filtered through a filter paper to remove any remaining skin particles. The extraction process resulted in *angkung* fruit juice.

Experimental design

The red violet noodles were prepared with independent variables, specifically the incorporation of *angkung* fruit juice at four levels: 0% (control), 2% (RVN1), 4% (RVN2), and 6% (RVN3), utilizing a completely randomised design (CRD) featuring a single factor and three replications. The present work included variables related to cooking quality parameters, specifically water absorption ratio, cooking loss, and cooking time, alongside colour, total phenolic content, total flavonoid content, antioxidant activity, and sensory evaluation.

Production of red violet noodles

A mixture comprising 1 kg of protein-rich wheat flour, six eggs, 10 g of sodium alginate, two tablespoons of oil, one tablespoon of salt, 200 mL of water, and *angkung* fruit juice were placed in the dough mixer (DMIX 002, Maksindo Malang, Indonesia) following the various treatment conditions. The mixture was then uniformly combined and subjected to a 30-min preconditioning period. Following preconditioning, the dough was introduced into a noodle-production machine (MKS-220, Maksindo Malang, Indonesia) to produce wet red violet noodles (RVN). The wet RVN was then transferred to an oven preheated to 70°C, and allowed to cook for 3 h. The compositions of the dough used for the preparation of the RVN samples are detailed in Table 1.

Table 1. Dough compositions used to prepare red-violet noodles (RVN).

Sample	Dough composition				
	Wheat flour (kg)	***Angkung* fruit juice (mL)**	**Egg**	**Water (mL)**	**Sodium alginate (g)**
Control	1	0	6	200	10
RVN1	1	20	6	180	10
RVN2	1	40	6	160	10
RVN3	1	60	6	140	10

Control: without *angkung* fruit juice; RVN1: 2% *angkung* fruit juice; RVN2: 4% *angkung* fruit juice; and RVN3: 6% *angkung* fruit juice.

Cooking quality

The water absorption ratio and cooking loss (WAR and CL) measurements were performed with modifications according to Patria *et al*. (2020). Briefly, 5 g of samples was boiled for 4 min with 20 mL of distilled water. Upon completion of the cooking process, the solid components were extracted and subsequently transferred to Petri plates for desiccation at 105°C. The WAR and CL were then calculated using Eqs. 1 and 2, respectively:

$$\text{WAR (\%)} = \left[\frac{\text{Weight of cooked rice - Weight of dry rice (g)}}{\text{Weight of dry rice (g)}} \times 100\%\right] \quad \text{(Eq. 1)}$$

$$\text{CL (\%)} = \left[\frac{\text{Weight of dried supernatant (g)}}{\text{Weight of dry rice (g)}} \times 100\%\right] \quad \text{(Eq. 2)}$$

Cooking time (CT) was determined according to Singh *et al*. (2005) with slight modification. Briefly, 10 g of noodles were cooked in 100 mL of distilled water for 2 min at 100°C. The noodles were then extracted, rinsed, and compressed between two transparent glass plates at intervals of 15 s to determine the presence of a white core. The noodles were deemed perfectly cooked when the opaque, solid core of each piece was no longer distinguishable.

Surface appearance and microstructure

The methodology described by Patria *et al*. (2023) was modified to investigate the surface appearance and microstructure of RVN. The surface of the RVN sample was analysed using a smartphone camera with 1.0× magnification (iPhone series 11, Apple Inc., USA). The microstructures of RVN were examined with a scanning electron microscope (SEM) (S-3000 N, Hitachi High Technologies Co., Japan) at a magnification of 1,000×. Before the microstructural examination, samples were subjected to freeze-drying (FD-1200, EYELA Co., Ltd., China) to reduce moisture content.

Colour measurement

Colour analysis was modified from the method described Patria *et al*. (2021), where the colour of raw and cooked noodle samples was evaluated using a colorimeter (Hunter Lab, Color Quest XE, USA). The L* value represents brightness on a scale ranging from 0 to 100. The a* value represents the red-green coordinates, with negative values denoting green, and positive values denoting red. The b* value represents the blue-yellow coordinates, where negative values denoting blue, and positive values denoting yellow.

Determination of total phenolic content

The analysis of total phenolic content was adapted from the method described by Orak (2007). Briefly, 100 mg of sample was diluted in 10 mL of distilled water to achieve a concentration of 10 mg/mL. A solution of 10 mg/mL produced a volume of 1 mL. Upon the addition of 10 mL of pure water, the concentration of the extract was 1 mg/mL. After adding 0.2 mL of extract, 15.8 mL of distilled water, and 1 mL of Folin-Ciocalteu reagent, the solution was agitated. Later, 3 mL of a 10% sodium carbonate solution was added into the mixture, incubated for 8 min, followed by a 2-h period at room temperature. The absorbance at 765 nm was quantified using a UV-Vis spectrophotometer.

Determination of total flavonoid content

The analysis of flavonoids was performed following the procedures described by Stankovic (2011). Briefly, 100 mg of materials were diluted in 10 mL of ethanol, yielding a concentration of 1,500 ppm. To prepare the solution, 2% $AlCl_3$ and 120 mM potassium acetate was added to a total volume of 1 mL. The specimens underwent incubation at ambient temperature for 1 h. Absorbance was measured at a wavelength of 435 nm using a UV-Vis spectrophotometer.

Antioxidant activity

Employing a modified Koocheki *et al*. (2022) method to evaluate DPPH radical scavenging activity, 2 mL of RVN dispersions, with concentrations between 0.5 and 5 mg/mL, were mixed with 2 mL of freshly prepared DPPH in ethanol at a concentration of 0.15 mol/L. The mixture was blended for 30 min at room temperature in the dark. Absorbance was measured at a wavelength of 517 nm. The DPPH radical scavenging activity was determined using Eq. 3:

$$\text{Activity of DPPH radical scavenging (\%)} = [1 - (A_X - A_{X0} / A_X] \times 100 \quad \text{(Eq. 3)}$$

Sensory evaluation

Fifteen student panellists from National Pingtung University of Science and Technology (NPUST), Taiwan, performed a sensory evaluation through a hedonic test. The hedonic test employed a scale that included the following values: 1 = strong disapproval; 2 = moderate disapproval; 3 = approval; 4 = moderate approval; and 5 = strong approval. Sensory assessment included elements such as flavour, colour, aroma, and texture. (Mardiana *et al*., 2022).

Statistical analysis

Results were mean of triplicate ± standard deviation. The data underwent analysis through a One-way analysis of variance (ANOVA) using SPSS (Statistical Package for the Social Sciences, Version 22.0, SPSS Inc., Chicago, IL, USA). Data demonstrating statistical significance with a 95% confidence interval ($p < 0.05$) were acquired through Duncan's multiple range test (DMRT).

Results and discussion

Water absorption ratio (WAR)

The water absorption ratio (WAR) indicates the amount of water absorbed by food during cooking, and is an essential parameter for assessing cooking quality and the degree of product cooking (Patria *et al*., 2021). Table 2 shows that the WAR in RVN with the incorporation of *angkung* fruit juice was significantly lower ($p < 0.05$) than that of the control. The values of RVN1, RVN2, and RVN3 ranged from 136.41 to 141.86%, while the control value was 156.23%. This indicated that an increase in *angkung* fruit juice incorporation into RVN decreased the water absorption capacity, which could have been due to the predominant presence of soluble phytochemical compounds and soluble dietary fibres in *angkung*. Kumar *et al*. (2016) reported that in 100 g of fresh, seedless *Basella* fruit, the composition included 1.64 g of total carbohydrates, 51 mg of proteins, 1.38% of total lipids, 81.76% of water, 0.5 mg of niacin, 89.33 mg of ascorbic acid, and 1.24 mg of total tocopherol. The total dietary fibre content was 32.52 g, with soluble dietary fibre being 12.34 g/100 g. Sirichokworrakit *et al*. (2015) indicated that increasing the proportion of riceberry flour in noodle production decreased the gluten content, thus diminishing the water retention capacity of the noodles. Consequently, an increase in rice berry flour content decreased the functional characteristics and cooking quality of the dough.

Table 2. Cooking quality of red-violet noodles prepared with 0 - 6% incorporation of *angkung* fruit juice.

Sample	Water absorption ratio (%)	Cooking loss (%)	Cooking time (min)
Control	156.23 ± 0.5[a]	5.56 ± 0.2[d]	8.00 ± 0.5[a]
RVN1	141.86 ± 2.1[b]	7.14 ± 1.4[bc]	7.50 ± 0.3[b]
RVN2	138.72 ± 1.6[bc]	7.96 ± 2.2[ab]	7.00 ± 0.1[bc]
RVN3	136.41 ± 1.2[cd]	8.43 ± 1.5[a]	6.33 ± 0.3[cd]

Means with different lowercase superscripts in similar column are significantly different ($p < 0.05$) by DMRT test. Control: without *angkung* fruit juice; RVN1: 2% *angkung* fruit juice; RVN2: 4% *angkung* fruit juice; and RVN3: 6% *angkung* fruit juice.

Cooking loss

The cooking loss is directly proportional to the quantity of dry noodles lost during the cooking process. Cooking loss quantifies the amount of solids released into boiling water, reflecting the extent of damage to the noodles, and their ability to maintain structural integrity during cooking (Devkatte *et al*., 2018); therefore, cooking loss serves as a predictor for the overall quality of cooked noodles. The cooking loss for noodles exhibiting high cooking quality should be below 10% (Kumalasari *et al*., 2021).

In the present work, the cooking loss in RVN with the incorporation of *angkung* fruit juice was significantly higher ($p < 0.05$) than that of the control, recorded at 5.56%, while the values for RVN1, RVN2, and RVN3 ranged from 7.14 to 8.43% (Table 2). The cooking loss values of the RVN exceeded that of the control; however, they remained acceptable as they were below 10%. As the quantity of *angkung* fruit juice increased, the cooking loss value correspondingly increased. This might have resulted from various compounds in *angkung* that did not effectively bond with the noodle dough. The incorporation of *angkung* fruit juice introduced various soluble compounds, including anthocyanins, resulting in a decrease in the gluten ratio in the noodles. Ongkowijoyo *et al*. (2018) stated that anthocyanins are water-soluble coloured pigments derived from phenolic compounds. Anthocyanin contributes to the vibrant coloration observed in various plant parts, including flowers, leaves, and particularly fruits, which exhibit red, blue, and purple hues. Koten and Ünsal (2021) indicated that cooking loss would arise from an inadequate starch-protein matrix or the degradation of the starch-protein matrix. The incorporation of terebinth (*Pistacia terebinthus*) to noodles may yield comparable effects, and the observed shrinkage during cooking could be attributed to a relative decrease in gluten content, potentially resulting from the incorporation of terebinth.

Cooking time

Table 2 presents the results showing significant differences in cooking times ($p < 0.05$) between the control and treatment groups. The cooking time for RVN incorporated with *angkung* fruit juice ranged from 6.33 to 7.50 min, while the control group had a cooking time of 8.00 min. RVN exhibited a lower gluten ratio compared to the control, resulting in a shorter cooking time relative to the control. Quick-cooking noodles are favoured in the context of sustainability (Tan *et al*., 2018). The cooking times for noodles produced from rice, mung bean, corn starch, and sweet potato flour ranged from 7.2 to 9.2 min (Qazi *et al*., 2014).

Surface appearance and microstructure

Angkung may enhance the density and cohesion of the food matrix. Its incorporation may lead to a denser network, thereby enhancing the structural stability of the product. This may result in a firmer texture for noodles. Anthocyanins and other bioactive compounds in *angkung* interact with proteins and starches within the noodle matrix. This interaction can improve gel formation, leading to a more uniform and smoother microstructure. Figure 1 illustrates that following the cooking process, an increase in the incorporation of *angkung* fruit juice to RVN results in a larger and more porous gel, suggesting that numerous compounds were dissolved during cooking.

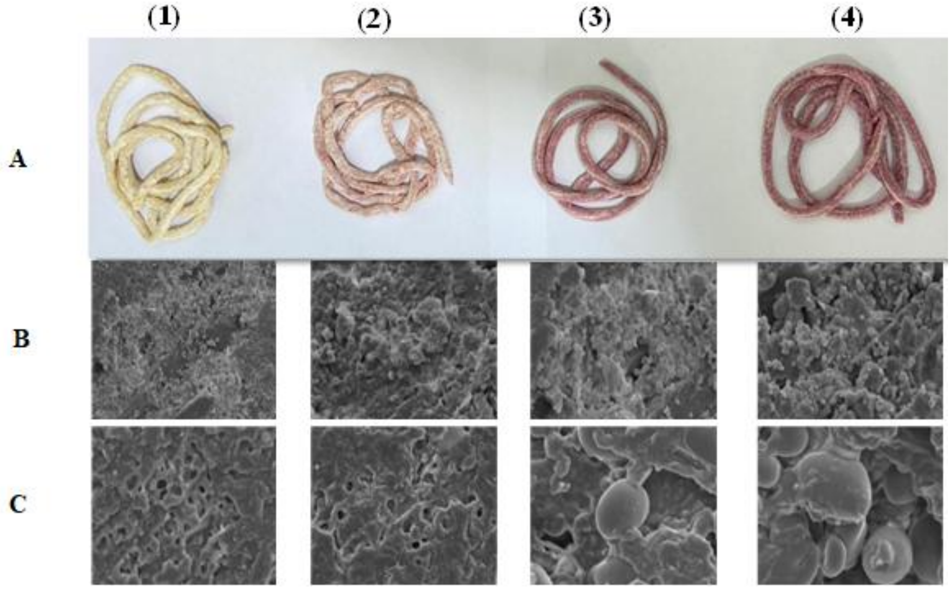

Figure 1. (A) surface appearance of raw RVN, **(B)** microstructure of raw RVN, and **(C)** microstructure of cooked RVN. **(1)** control, **(2)** RVN1, **(3)** RVN2, and **(4)** RVN3.

Colour

Colour is an important attribute that influences the quality of noodles. Figure 1 illustrates the appearance and colour of wet RVN. Table 3 indicates that all formulated cooked red violet noodles (RVN) exhibited significantly lower lightness values (L* = 67.06, 66.78, and 64.32) and yellowness values (b* = 15.43, 15.21, and 15.14) compared to the control (L* = 68.53; b* = 20.45). There was no significant difference ($p > 0.05$) in RVN with the incorporation of *angkung* fruit juice. However, redness values (a* = 3.43, 4.17, and 6.25) were significantly higher ($p < 0.05$) than the control (a* = 1.09). An increase in *angkung* fruit juice concentration resulted in a darker hue of the RVN, attributed to the betacyanin pigment present in ripe *angkung* fruit. In comparison to raw RVN (a* = 5.94 - 9.08), the dark colour of cooked RVN (a* = 3.43 - 6.25) diminished, attributed to the degradation of the betacyanin pigment due to elevated temperatures.

Table 3. Colour properties of raw and cooked red-violet noodles prepared with 0 - 6% incorporation of *angkung* fruit juice.

Sample	L		a		b	
	Raw*	Cooked	Raw*	Cooked	Raw*	Cooked
Control	66.78 ± 1.03^{a}	68.53 ± 2.21^{a}	2.05 ± 0.15^{d}	1.09 ± 0.52^{d}	25.01 ± 0.12^{b}	20.45 ± 0.32^{b}
RVN1	65.29 ± 1.01^{b}	67.06 ± 1.65^{b}	5.94 ± 0.53^{c}	3.43 ± 0.48^{c}	19.92 ± 0.82^{a}	15.43 ± 0.53^{a}
RVN2	64.47 ± 1.10^{c}	66.78 ± 1.05^{c}	7.92 ± 0.18^{b}	4.17 ± 0.51^{b}	19.86 ± 0.52^{a}	15.21 ± 0.47^{a}
RVN3	60.82 ± 1.05^{d}	64.32 ± 1.08^{d}	9.08 ± 0.61^{a}	6.25 ± 0.56^{a}	19.81 ± 0.99^{a}	15.14 ± 0.51^{a}

*Patria *et al*. (2022). Means with different lowercase superscripts in similar column are significantly different ($p < 0.05$) by DMRT test. Control: without *angkung* fruit juice; RVN1: 2% *angkung* fruit juice; RVN2: 4% *angkung* fruit juice; and RVN3: 6% *angkung* fruit juice.

A study conducted by Bassama *et al*. (2020) investigated the impact of temperature (60 - 90°C) on the degradation of betacyanin in cactus pear juice. The degradation of betacyanin during storage is positively correlated with temperature. In industrial applications, pasteurisation at 90°C for 36 s sufficiently retains the quality and safety of the final product. Tsai *et al*. (2010) found that the half-life significantly decreased at temperatures exceeding 60°C, suggesting that the heat treatment temperature for *djulis* (*Chenopodium formosanum*) red seeds containing betacyanin pigment should be maintained below 60°C, along with an optimal pH range. Also Lin *et al*. (2010) indicated that ripe *angkung* fruit, characterised by its deep purple skin, serves as a potential source of natural dye. The primary red pigment is recognised as gomphrenin I. Its quantity increases as the fruit ripens. In addition to gomphrenin I, betanidindihexose has also been identified.

Total phenolic content

The total phenolic content of RVN was assessed with the incorporation of *angkung* fruit juice, which resulted in a higher level compared to the control. The total phenolic content in RVN exhibited a significant increase ($p < 0.05$) with higher percentages of *angkung* fruit juice (Table 4). The lowest total phenolic content in raw control noodles was negative or undetectable, whereas the highest content was recorded in raw RVN3 samples at 0.62%. The total phenolic content of cooked control noodles (negative) was significantly lower ($p < 0.05$) than that of cooked RVN, with values ranging from 0.21 to 0.41%. The increase in *angkung* fruit juice concentrations correlated with the increase in total phenolic content of RVN. After cooking, the total phenolic content of the noodles decreased significantly in comparison to the raw state. The decrease in total phenolic content could have been due to the cooking temperature. Kumar *et al*. (2015) reported the presence of phenolic compounds in ripe *angkung* fruit extract, including generic, sinapic, ferulic, and coumaric acids, as well as chlorogenic acid. Kessy *et al*. (2016) suggested that the release of phenolic compounds resulting from the combination of oven-drying and steam blanching may be linked to the inactivation of oxidative enzymes and the induction of structural changes in the seed coat matrix, which facilitates the release of both extractable and non-extractable phenols. The degradation of phenolic compounds in lychee (*Litchi chinensis*) peel is associated with the activity of endogenous enzymes, such as anthocyanoses, which facilitate the oxidation of these compounds.

Table 4. Total phenolic content, total flavonoid content, and antioxidant activity of raw and cooked red-violet noodles prepared with 0 - 6% incorporation of *angkung* fruit juice.

Sample	Total phenolic (%)		Flavonoid (%)		Antioxidant activity (%)	
	Raw	Cooked	Raw	Cooked	Raw	Cooked
Control	-	-	-	-	2.37 ± 0.52^{d}	-
RVN1	0.44 ± 0.21^{c}	0.21 ± 0.42^{c}	0.19 ± 0.31^{c}	0.09 ± 0.12^{c}	12.86 ± 0.41^{c}	5.43 ± 0.64^{c}
RVN2	0.54 ± 0.45^{b}	0.34 ± 0.17^{b}	0.24 ± 0.54^{b}	0.13 ± 0.56^{b}	17.92 ± 0.68^{b}	8.71 ± 0.52^{b}
RVN3	0.62 ± 0.13^{a}	0.41 ± 0.33^{a}	0.32 ± 0.32^{a}	0.16 ± 0.44^{a}	24.46 ± 0.34^{a}	12.04 ± 0.41^{a}

Means with different lowercase superscripts in similar column are significantly different ($p < 0.05$) by DMRT test. Control: without *angkung* fruit juice; RVN1: 2% *angkung* fruit juice; RVN2: 4% *angkung* fruit juice; and RVN3: 6% *angkung* fruit juice.

Total flavonoid content

The total flavonoid content in raw RVN was significantly higher ($p < 0.05$) than that of the raw control, ranging from 0.19 to 0.32%, whereas the raw control exhibited negative or undetectable levels (Table 4). The increase in the concentration of *angkung* fruit juice correlated with the increased levels of flavonoids in the noodles. The cooked RVN total flavonoid content decreased by 0.09 - 0.16% relative to raw RVN. This might have resulted from the cooking process of the noodles. Kumar *et al*. (2015) identified myricetin, quercetin, luteolin, apigenin, and kaempferol as the flavonoids present in the extract of ripened *angkung* fruit. Chaaban *et al*. (2017) demonstrated that flavonoids, including rutin, naringin, mesquitol, eriodictyol, luteolin, and luteolin-7-O-glucoside, exhibit thermal-sensitivity. The degradation of flavonoids increases with both the area and duration of heating, exhibiting differential thermal stability based on the structural characteristics of the flavonoids. Middleton *et al*. (2000) found a correlation between flavonoid intake and decreased mortality rates from coronary heart disease. Flavonoids are recognised for their anti-allergic, anti-inflammatory, antiviral, anti-proliferative, and anti-cancer properties. Therefore, *angkung* could contribute to the reduction or mitigation of the aforementioned diseases.

Antioxidant activity

The incorporation of *angkung* fruit juice led to significant differences in the antioxidant activity of both raw and cooked noodle samples (Table 4). The free radical scavenging activity of RVN was assessed using the DPPH test. Raw RVN exhibited significantly higher antioxidant activity, ranging from 12.86 to 24.46%, in contrast to the control group, which showed an activity of 2.37%. The higher bioactive and betalain content in *angkung* fruit juice compared to control may account for this difference. However, the antioxidant activity of all samples decreased after cooking. The significant decrease in antioxidant content post-cooking suggested that the noodles may not provide substantial health benefits in their final product, which should be considered for future product development. Reshmi *et al*. (2012) demonstrated that betacyanin derived from *angkung* fruit exhibited a significant capacity for hydrogen release, and effectively scavenged DPPH radicals. The data indicated a significant correlation between the contents of phenolic and hydroxyl groups in betacyanin, and their ability to scavenge free radicals. The antiradical activity of phenolic compounds relies on their molecular structure, the accessibility of phenolic hydrogen, and the ability to stabilise the phenoxy radicals generated by hydrogen loss. Ioannou *et al*. (2020) found that the degradation rates of rutin, eriodictyol, and quercetin vary following heat treatment and light exposure. Normal polymers undergo curing through temperature, while molecular splitting takes place following several days of light exposure. Rocchetti *et al*. (2018) indicated that the decrease in antioxidant activity in noodles post-cooking resulted from the thermal degradation of phenolic compounds *via* oxidation or polymerisation. Various parameters, including temperature, pH, and water ratio, influence the antioxidant activity of a final product (Alizadeh Behbahani *et al*., 2017). The primary cause of the red violet colour in *angkung* fruit is betalain, specifically gomphrenin, a class of water-soluble pigments known for their antioxidant properties. Betalains exhibit high sensitivity to heat and pH fluctuations, leading to their degradation during cooking, which markedly diminishes their antioxidant properties. In accordance with the findings of Kumorkiewicz and Wybraniec (2017), heating *angkung* fruit juice to 85°C resulted in the formation of various decarboxylated gomphrenin derivatives. 2-, 17-, and 2,17-decarboxy-gomphrenins represent significant products. Decarboxylation of gomphrenin molecules results in the loss of carboxyl groups, altering the pigment's structure, and reducing its antioxidant capacity.

Sensory evaluation

The sensory evaluation parameters including taste, colour, aroma, and texture of RVN incorporated with *angkung* fruit juice are presented in Figure 2. The RVN were assessed using a rating scale from 1 to 5.

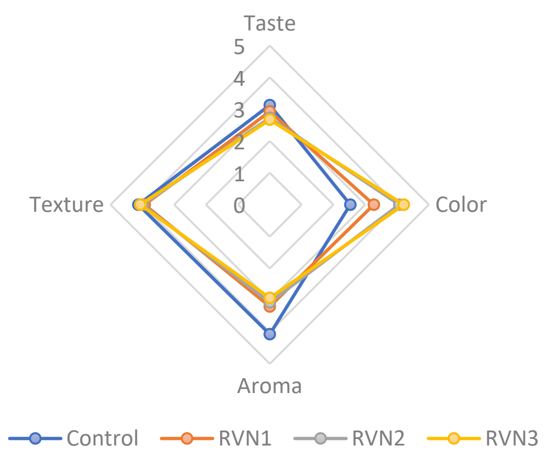

Figure 2. Sensory evaluation of red-violet noodles prepared with 0 - 6% incorporation of *angkung* fruit juice.

The sensory results indicated a significant difference in taste value ($p < 0.05$) between the control and RVN incorporated with *angkung* fruit juice, which was measured at 2.67 - 3.13. As the concentration of *angkung* fruit juice increased, the panellists' perception decreased due to an enhanced bitterness in RVN. Issaoui *et al*. (2021) indicated that numerous endogenous food compounds, such as phenolics, play a role in the flavour of food. The bitter flavour is primarily associated with the presence of phenolic compounds in the food matrix.

The colour value demonstrated a statistically significant difference ($p < 0.05$) between the control and RVN incorporated with *angkung* fruit juice, with a range of 2.53 to 4.21. The panellists noted that the incorporation of *angkung* fruit juice improved their perception of the RVN colour. The red-violet colour of the noodles explains this phenomenon. Mitraa and Dasb (2015) indicated that *angkung* serves as a notable source of betalain, with its fruit having potential applications in food colouring, cosmetics, paper colours, acid-base indicators, and nutraceuticals owing to its vibrant colour.

The aroma value exhibited a statistically significant difference ($p < 0.05$) between the control group and RVN incorporated with *angkung* fruit juice, with values ranging from 2.93 to 4.03. The panellist observed that the incorporation of *angkung* fruit juice led to a reduced perception of RVN aroma. The incorporation of *angkung* fruit juice reduced the aroma of the noodles due to the presence of phenols and flavonoids. Perez-Jiménez *et al*. (2019) demonstrated that phenolic compounds from sources such as grape seed extract and red grapes significantly influenced the release of mouth odour during wine tasting. The findings indicated that grapes enriched with phenolic and flavonoid extracts led to a reduction in oral release.

Significant differences in texture values ($p < 0.05$) were observed between the control and RVN incorporated with *angkung* fruit juice. RVN1 - RVN3 exhibited no significant differences ($p > 0.05$) with values ranging from 3.93 to 4.13. The panellists assessed that the incorporation of *angkung* fruit juice led to a diminished evaluation relative to the control group. As its concentration increased, the incorporation of *angkung* fruit juice did not influence the panellists' perceptions. It has also been reported that *angkung* fruit juice did not significantly reduce the hardness level in the noodles (Patria *et al*., 2022). Hydrocolloids, including *Alyssum homolocarpum* seed gum, can be utilised to improve texture, especially in terms of elasticity (Hesarinejad *et al*., 2015).

Conclusion

The present work examined the effect of incorporating *angkung* fruit juice on the quality of noodles in varying quantities. The incorporation of *angkung* fruit juice into the noodle formulation decreased the cooking qualities, but increased the total phenolic content, total flavonoid content, and antioxidant activity of the samples. The red-violet hue of ripe *angkung* fruit juice enhanced the depth and richness of the noodles, resulting in a deeper red and purple appearance. The incorporation of *angkung* fruit juice may reduce the sensory evaluation of red violet noodles by the panellists. All panellists indicated that they could still consume noodles if *angkung* fruit juice was incorporated. *Angkung* thus demonstrated significant potential as a commercial fruit in the food sector. The incorporation of ripe *angkung* fruit juice into the noodle formulation enhanced its nutritional value, indicating that *angkung* can be utilised to fortify noodles. Future research should incorporate *in-vitro* and *in-vivo* analyses to assess the bioavailability and potential health impacts of *angkung* fruit juice's antioxidant and phytochemical components.

Acknowledgement

The authors acknowledge the Food Pilot Plant, National Pingtung University of Science and Technology for providing the research facilities, and CV. RAJ, Malang City, Indonesia, for providing the research materials, *angkung* (*Basella Alba* L.).

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