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The characteristics of noodles produced from tuber and leaf of taro (*Colocasia esculenta L. Schott*)

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Abstract

The tuber and leaves of the taro plant (*Colocasia esculenta L. Schott*) are useful dietary ingredients for patients with diabetes mellitus. Alternatively, dry noodles with taro flour and leaf substitution can also be used as a source of food. This study aimed to analyse the substitution of taro flour (0%, 40%, and 100%) and its leaf (0% and 100%) to obtain six variations of dry noodles using a completely randomized design. The nutrient contents were energy, carbohydrates, fat, protein, water, ash, and dietary fibre. In addition, the starch digestibility (*in vitro*), antioxidant activity (IC_{50}), and glycaemic index were also analysed. The best formula was determined using the De Garmo method's Effectiveness Index. The statistical analysis showed that taro leaf puree affects the glycaemic load, antioxidant activity, and starch digestibility of the noodle. Based on the nutritional content and organoleptic tests, the recommended dry noodles were the D_2 formula with 40% and 100% taro flour and leaf substitution. Therefore, this noodle can be an alternative food for people with diabetes mellitus.

1. Introduction

Diabetes mellitus (DM) is a metabolic disease characterized by hyperglycemia due to defects in insulin secretion and action. It is caused by obesity and an unhealthy lifestyle such as lack of exercise, consuming large amounts of foods with a high glycaemic index, and insufficient intake of fruits and vegetables. The WHO predicted a fairly large increase in the number of people with diabetes in the coming years. Furthermore, Indonesia was predicted to have an increased number of patients from 8.4 million in 2000 to around 21.3 million in 2030 (Soelistijo *et al*., 2015).

Diet regulation by selecting food with complex carbohydrates, protein, fat, and fibre, with a low glycaemic index is useful to control blood sugar levels. Taro tubers and leaf (*Colocasia esculenta L. Schott*) are part of the functional foods used due to their low GI (54) and GL (4) (Foster-Powell *et al*., 2002). They also contained antioxidants such as β-carotene, alkaloids, glycosides, flavonoids, terpenes, saponins, and phenols (Jyothi and Srinivas Murthy, 2019).

The recommended daily consumption of carbohydrates, protein, fat, and fibre was 45-65%, 10-20%, 20-25%, and 20-35 grams/day respectively (Soelistijo *et al*., 2015). Meanwhile, for special medical purposes, the requirements for the nutritional content of processed food consumed were the protein of 2.5-5g/100 kcal, carbohydrates of 11.25-16.25g/100 kcal, fat of 2.22 -2.78g/100 kcal, saturated fat of <0.78g/100 kcal, the fibre of 1-1.75g/100 kcal and cholesterol of <10 mg/100 kcal (Badan Pengawas Obat dan Makanan, 2018).

In addition to rice, noodles are the staple food most often consumed, and may alternatively serve as food for people with DM. The statistical data on food consumption in 2018 showed that the average growth of Indonesian instant noodle consumption was 2.17% from 2014 to 2018 (Komalasari, 2018). The type used as an alternative food was dry noodles due to their lower saturated fat than instant ones. The drying process for instant and dry noodles was conducted through frying and roasting respectively. Dry noodles had a longer shelf life of 3 months compared to wet which only lasted for 36 hrs (Kaushal *et al*., 2012).

The main raw material was wheat flour with a high glycaemic index and may be substituted with various others such as taro flour. Meanwhile, taro leaf was used as a puree to substitute water in making noodles. The content of taro tubers and leaf affected the value of the

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glycaemic index, load, antioxidant activity, and starch digestibility. The background showed the need to create product innovation on food to be consumed by people with type 2 diabetes. Therefore, this study aimed to analyse the taro flour and leaf puree substitution (*Colocasia esculenta L. Schott*) on nutritional content, organoleptic tests, glycaemic index, load, antioxidant activity, and starch digestibility of dry noodles.

2. Materials and methods

This was an experimental study conducted through a completely randomized design with two factors, the taro flour and leaf puree substitution. There were three concentrations of taro flour (0%, 40%, 100%) and leaf puree (0%, 100%). Therefore, there were six different formulas for making noodles with symbols D_0 (0%:0%), D_1 (40%:0%), D_2 (40%:100%), D_3 (100%:0%), D_4 (100%:100%), and D_5 (0%:100%), and each was repeated 2 times. Table 1 shows the composition of the ingredients in each formula.

2.1 Noodle production

Dry noodles were made using wheat (Segitiga Biru®) and taro flour (Hasil Bumiku®), taro leaf (harvested at the age of 2-3 months), eggs, water, and salt. Liquid glucose was used as a standard food for glycaemic index analysis. In the process of making taro leaf puree, it was sliced, washed, and steamed for 15 mins. It was then cooled and 50 g of puree was weighed and added to 100 mL of water. The taro leaf was blended, mixed, and separated into a clean container. In the method of making dry noodles, taro flour, eggs, salt, and taro leaf puree were mixed and stirred until well blended. Also, a grinder with a thickness of 2 mm was used to grind the dough before moulding it into noodle sheets. The noodle was steamed for 10 mins before placing them on a baking sheet and then dried using an oven at 100°C for 50 mins. Rehydrated the dry noodle by boiling them for 4 mins with the addition of water 2 times the weight.

2.2 Nutrient content

Protein, carbohydrates, and fat contents were measured using the Kjeldahl, difference, and Soxhlet methods respectively. The moisture, dietary fibre, and ash contents were measured by an oven, gravimetric, and drying ash methods respectively. The energy was calculated by converting the amount of protein, fat, and carbohydrates.

2.3 Organoleptic test

The organoleptic test included parameters of colour, taste, aroma, and texture of dry noodles with taro flour and leaf puree substitution using four scales, namely 1 = dislike, 2 = slightly like, 3 = like and 4 = very like. The organoleptic test assessment was carried out on 30 trained panellists.

2.4 Test of glycaemic index value and glycaemic load

The implementation of the glycaemic index test involved eight subjects. They fulfilled the inclusion criteria, 20-30 years old, had a normal BMI (18.25-22.99 kg/m2), did not suffer from DM and were in good health, fasting blood sugar 120 mg/dl, did not smoke and drink alcohol, not pregnant, and filled out an informed consent to participate. Subject exclusion criteria were not present at the time of sampling and when the subject died. The day before the intervention, they were asked to fast from 10 pm to 8 am and were only permitted to consume water. The fasting blood sugar (FBS) was taken through the capillaries of the fingertips. Also, they were asked to consume the reference food (pure glucose) and six variations of boiled dry noodles. Furthermore, their blood sugar was taken every 30 mins (at 30, 60, 90, and 120 mins) after consuming the food for 2 hrs. The glycaemic index was tested using a glucometer and the load value was determined using a formula. This study was approved by the Medical/Health Research Ethics Commission, Faculty of Medicine, Universitas Diponegoro No.31/EC/KEPK/FK-UNDIP/III/2020.

2.5 Analysis of antioxidant activity and starch digestibility

The analysis of antioxidant activity and starch digestibility was conducted using the DPPH IC_{50} and in vitro method at CV. Chemix, Yogyakarta.

Table 1. Dry noodle formula with taro flour and leaf puree substitution

Ingredients/Formula	D_0	D_1	D_2	D_3	D_4	D_5
Wheat flour (%)	64.8	38.89	38.89	0	0	64.8
Taro flour (%)	0	25.91	25.91	63.57	62.12	0
Taro leaf puree (%)	0	0	21.81	0	25.5	21.81
Water (%)	21.81	21.81	0	23.3	0	0
Egg (%)	12.74	12.74	12.74	12.5	12.21	12.74
Salt (%)	0.65	0.65	0.65	0.63	0.62	0.65

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2.6 Determination of the best formula

The best formula was obtained by considering the nutritional content (energy, protein, fat, carbohydrates, water and ash content, dietary fibre) and organoleptic quality (colour, taste, aroma, and texture) using the Effectiveness Index (De Garmo). The calculation started by determining the variable weight with a scale of 0-1 on each parameter. Finally, the yield value (Nh) for each variable was calculated, and the best formula selected has the highest total Nh from summing up all the variables.

2.7 Statistical analysis

The statistical analysis was performed to determine the significant difference in dry noodles with taro flour and leaf puree substitution on proximate values. They include dietary fibre, glycaemic index, glycaemic load, antioxidant activity, and starch digestibility. It was conducted using the Two-Way ANOVA test and when there was a significant difference, the Tukey post hoc test was used. Meanwhile, the organoleptic test used the Kruskal-Wallis and the Mann-Whitney Tests. The effect of the independent variable on the dependent was considered significant when the value of $p \leq 0.05$.

3. Results and discussion

3.1 Nutritional content

Taro tuber is a carbohydrate source for diabetics and gastrointestinal disorders. This is because it contains complex carbohydrates, slow-digesting starch, and dietary fibre with important nutrients. Taro flour controls blood sugar levels (Kaushal *et al*., 2012). Dry noodles were produced through the process of roasting, and it reduced the value of the glycaemic index, glycaemic load, and fat (Nurdyansyah *et al*., 2019). Nutritional content testing was conducted on rehydrated dry noodles ready to be consumed and it was presented in Table 2. The results of the water content test on taro flour and leaf puree noodle products ranged from 78.54%-75.11%. It showed that the highest water content was found in dry noodles with 0% taro flour and 0% taro leaf puree substitution in sample D_0 which was 78.54%. The lowest water content was in dry noodles with the 40% taro flour and 100% leaf puree substitution in sample D_2, which was 75.11%.

The water is absorbed by the molecules to increase the absorption capacity of a food ingredient. This is also affected by the breaking of hydrogen bonds between molecules since the water is easily absorbed into the food ingredient. The water absorption depends on the amount of starch in the dough and the D_2 formula has the lowest value. The sample with the addition of taro flour and leaf puree had a lower water content because the increased amount of starch decreased water absorption. This was due to the starch content of soluble amylose and insoluble amylopectin. Furthermore, taro starch contains higher amylopectin due to decreased levels of water absorption. According to the Indonesian National Standard (Standar Nasional Indonesia), the maximum water content in noodles with the boiling process was 65% bb (SNI 2987-2015), subsequently, the noodles produced did not fulfil the quality requirements (Standar Nasional Indonesia, 2015), and the boiling process at high temperatures increased water levels. Cooking caused the bonds between the food components to break, while the water content was increased (Salmatia *et al*., 2020).

The test results showed that the ash content of noodle products ranged from 0.83-0.40%. The highest and the lowest were found in the D_5 and D_0 formulas of 0.83% and 0.40% respectively. The amount of ash in a food product depends on the mineral content of the ingredients used. Taro leaves contain minerals and vitamins such as calcium, phosphate, iron, vitamins A, C, B1 (thiamine), B2 (riboflavin), and niacin. Taro flour is gluten-free produced from tubers and contains many minerals such as calcium, phosphorus, and Fe (Fatkurahman *et al*., 2012; Yuliatmoko, 2012). The Indonesian National Standard showed that the maximum ash content in noodles was 3% bb (SNI 8217- 2015). Therefore, the noodles produced in this study had fulfilled the quality requirements.

The carbohydrates, fats, and protein contents of food ingredients determine the energy value. The results of the energy test on taro flour and leaf puree noodle products ranged from 71.10 kcal/100 g to 53.3 kcal/100 g. Meanwhile, the highest and lowest energy content were found in the D_2 and D_5 formula at 71.10 kcal/100 g and 53.39 kcal/100 g respectively.

The results of the carbohydrate content test on the taro flour and leaf puree noodle products ranged from 14.56 kcal/100 g-10.73 kcal/100 g. The highest and lowest carbohydrate were found in the D_2 and D_5 formula of 14.56 kcal/100 g and 10.73 kcal/100 g respectively. The content increased due to the addition of taro flour. Taro leaf puree also had a carbohydrate content of 0.37 kcal/100 g and taro flour contained 64.67 kcal/100 g. Meanwhile, noodles in this study contained carbohydrates <50%, and foods containing carbohydrates above 50% were known as high-carbohydrate. Therefore, noodles can be consumed by people with DM. Taro plants, especially the leaves, had alpha glucoside inhibitor activity, and it slowed down carbohydrate digestion and delays sugar absorption

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Table 2. Proximate analysis results of dry noodles with taro flour and leaf puree substitution

Nutrition Content	D_0	D_1	D_2	D_3	D_4	D_5	*p* - value
Water (%)	78.54±0.15^{C,ab}	76.18±0.16^{A,bb}	75.11±0.14^{C,cb}	78.13±0.08^{A,db}	76.67±0.36^{C,cb}	77.73±0.10^{B,eb}	$p = 0.000^A$ $p = 0.000^B$ $p = 0.128^C$
Ash (%)	0.40±0.02^{C,a}	0.41±0.00^{A,bb}	0.48±0.02^{C,cb}	0.58±0.02^{A,d}	0.68±0.05^{C,e}	0.83±0.14^{B,f}	$p = 0.011^A$ $p = 0.002^B$ $p = 0.013^C$
Energy (kcal/100 g)	61.43±0.57^{C,a}	67.45±0.40^{A,bb}	71.10±0.41^{C,cb}	58.02±0.18^{A,d}	58.21±1.43^{C,e}	53.39±0.19^{B,f}	$p = 0.000^A$ $p = 0.014^B$ $p = 0.000^C$
Carbohydrate (%)	11.53±0.15^{C,ab}	13.76±0.12^{A,bb}	14.56±0.16^{C,cb}	12.11±0.05^{A,db}	12.20±0.53^{C,eb}	10.73±0.18^{B,fb}	$p = 0.000^A$ $p = 0.835^B$ $p = 0.012^C$
Fat (%)	0.36±0.02^{C,a}	0.34±0.02^{A,b}	0.34±0.02^{C,cb}	0.23±0.01^{A,db}	0.22±0.00^{C,e}	0.27±0.03^{B,f}	$p = 0.001^A$ $p = 0.046^B$ $p = 0.038^C$
Protein (%)	3.23±0.04^{C,a}	2.68±0.03^{A,b}	2.80±0.10^{C,c}	2.18±0.02^{A,db}	2.15±0.15^{C,eb}	2.31±0.19^{B,f}	$p = 0.000^A$ $p = 0.005^B$ $p = 0.001^C$
Soluble fibre	5.578±0.056^{C,a}	6.266±0.012^{A,b*}	6.343±0.023^{C,c}	6.312±0.129^{A,d}	7.632±0.090^{C,e}	7.698±0.003^{B,f}	$p = 0.000^A$ $p = 0.000^B$ $p = 0.000^C$
Insoluble fibre	0.377±0.021^{C,c}	0.375±0.027^{A,a}	0.375±0.20^{C,c}	0.456±0.027^{A,b}	0.443±0.025^{C,c}	0.444±0.24^{B,c}	$p = 0.014^A$ $p = 0.247^B$ $p = 0.120^C$
Total dietary fibre (%)	5.95±0.03^{C,ab}	6.64±0.03^{A,bb}	6.72±0.04^{C,cb}	6.76±0.11^{A,db}	8.07±0.06^{C,eb}	8.14±0.02^{B,fb}	$p = 0.000^A$ $p = 0.000^B$ $p = 0.000^C$

Values are presented as mean±SD. Values with different lowercase superscripts within the same row are significantly different ($p<0.05$).
^{A}taro flour substitution, ^{B}taro leaf puree substitution of taro leaf puree and taro flour, ^{C}interaction between A and B

(Lebosada and Librando, 2017). This was in accordance with the management of the DM diet using complex carbohydrates, and it suppressed blood sugar.

The results of the fat content test on taro flour noodle products and the leaf puree ranged from 0.36%-0.22%. The highest and lowest fat content was found in the D_0 and D_4 formula at 0.36% and 0.22% respectively. The fat content in taro flour was 0.12% and the leaf puree was 0.29%, while in wheat flour, it was 1.95%. The fat content in taro leaf noodles were relatively low because taro flour was lower than wheat flour.

The results of the analysis of protein content showed that the greater the number of substitutes for taro flour, the lower the protein content of wet noodles. The test results for the protein content of taro flour noodle products and the leaf puree ranged from 3.23% to 2.15%. The highest and lowest content were in the D_0 and D_4 formulas at 3.23% and 2.15% respectively.

The analysis results on the protein content in noodles showed that more substitutions of taro flour and leaf puree caused a decrease due to the protein constituents. The taro flour consists of proteins that have water-soluble properties such as proteases and albumin. Meanwhile, in wheat flour, the constituent protein is gluten which has water-insoluble properties. Substitution of taro flour and leaf puree caused a decrease in protein levels, and some were dissolved in water during cooking.

Based on the test results, the total fibre content in taro flour and leaf puree noodle products ranged from 8.14%-5.95%. The highest and lowest total fibre content were found in the D_5 and D_0 formula of 8.14% and 5.95% respectively.

Food ingredients are classified into fibre sources

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containing 3 g/100 g dietary fibre, high fibre sources containing 4-6 g/100 g dietary fibre, and very high fibre sources containing more than 6 g/100 g dietary fibre (Yolanda *et al.*, 2018). Based on this classification, noodles D_1, D_2, D_3, D_4, and D_5, were included in very high-fibre food sources because they contained total fibre of D_1 (6.64%), D_2 (6, 72%), D_3 (6.76%), D_4 (8.07%), D_5 (8.14%), while D_0 noodles were a high fibre source (5.95%).

The recommended fibre intake for people with T2DM was 25 g/day (Soelistijo *et al.*, 2015) and the content in each serving of noodles was 150 g with the D_0 formula of 8.93 g/100 g. Based on the calculated fibre content, each serving of D_0 noodles could fulfil the fibre needs of 35.72%. Meanwhile, the content with formula D_1 was 9.96 g/100 g could fulfil the fibre needs of 39.84%, and formulas D_2 and D_3 were 10.1 g/100 g can fulfil 40.4%. The D_4 formula was 12.1 g/100 g could fulfil 48.4%, while the D_5 was 12.2 g/100 g could fulfil 48.8%.

The test results showed that the soluble fibre content was greater than that of insoluble. The soluble fibre content in taro flour and leaf puree noodle products ranged from 5.57%-7.69%. It had an effect on lowering blood sugar levels. High soluble fibre improved blood sugar levels, related to the speed of food absorption, especially carbohydrates into the bloodstream, known as the glycaemic index (GI).

3.2 Organoleptic test

To determine the acceptance of rehydrated dry noodles, an organoleptic test was conducted on colour, aroma, texture, and taste parameters. The value was obtained from the panellist's assessment score range of 1 -4. Table 3 shows the result of the dry noodle organoleptic test. Based on the panellists' assessment, the most likely noodle related to the colour parameter was formula D_1, and it was light brown.

The heating process at high temperatures caused a Maillard reaction between reducing sugars from starch and amino acids, and it resulted in the formation of a brown colour. D_4 noodle formula had the lowest score in terms of colour by panellists, and the most liked aroma was in formula D_5, while the least was D_4. This was because taro flour produced a sharper aroma compared to wheat (Lestari and Susilawati, 2015) and the most liked noodle textures were formulas D_0 and D_3. The noodle texture will become inelastic along with the addition of taro flour. Taro flour did not had gluten since the resulting dough was difficult to blend and did not provide elastic properties.

The most liked noodle taste was the formula D_0 and the preference level was decreased along with the addition of taro flour. The increased taro flour produced a bitter aftertaste which was different from the noodle products in the market, and it was still not acceptable to consumers. Furthermore, the very disliked formula was D_3 and from the organoleptic test results, dry noodles substituted for taro flour and leaf puree D_0 was the most liked sample by the panellists. Meanwhile, the dry noodles substituted for taro flour and leaf puree D_4 had the lowest mean organoleptic results.

3.3 Glycaemic index and glycaemic load

The results of statistical analysis showed that Ho was accepted ($p>0.05$), which meant that there was no significant effect of the substitution of taro flour and leaf puree on the glycaemic index (GI) value of noodles. However, the noodles had a lower GI value than those without substitution (D_0). The results of statistical analysis showed that there was a significant effect ($p<0.05$) of substitution of taro leaf puree on the

Table 3. Analysis of rehydration dry noodle organoleptic test

Formula	Acceptance (Mean±SD)			
	Taste	Aroma	Colour	Texture
D_0	3.5±0.63 (very like)	2.77±0.86 (like)	3.00±0.82 (like)	3.27±0.73 (like)
D_1	2.57±0.99 (like)	2.50±0.77 (like)	3.17±0.78 (like)	2.83±0.86 (like)
D_2	2.33±0.88 (dislike)	2.23±1.02 (dislike)	2.40±0.85 (dislike)	2.37±0.84 (dislike)
D_3	2.07±0.89 (dislike)	2.03±0.89 (dislike)	2.17±0.97 (dislike)	2.07±0.95 (dislike)
D_4	2.13±0.92 (dislike)	1.87±0.85 (very dislike)	1.77±0.72 (very dislike)	2.17±0.88 (dislike)
D_5	2.93±0.94 (like)	2.83±1.05 (like)	2.97±0.75 (like)	3.33±0.79 (like)
p	0.000	0.000	0.000	0.000

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glycaemic load (GL).

The GI in food is divided into three categories low (<55), medium (56-69), and high (≥70) (Marsh *et al*., 2011; Istiqomah and Rustanti, 2015). Table 4 shows that formula D_2 noodle had the lowest glycaemic index of 35.19% and is included in the low category. Meanwhile, formula D_0 had the highest glycaemic index of 64.17% and is included in the medium category. Three of the six noodle variations, namely formulas D_0, D_1, and D_4 were included in the medium GI category. Meanwhile, the rest were included in the low category. However, the glycaemic index value was not linear with the starch digestibility. Table 4 shows the index of noodles with taro flour and leaf puree substitution.

In formulas D_5, D_3, and D_4, there were an increase in the GI value, while a decrease was found in D_2. This non-linear GI value was caused by extreme responses in some subjects. Furthermore, this response occurred in one of the subjects that consumed D_1 noodles. The area under the curve becomes larger affecting the GI value of D_5, D_3, and D_4 noodles to be higher than D_2 due to the response.

The glycaemic index (GI) is affected by several factors, including the type of sugar (fructose or glucose), starch (amylose and amylopectin), starch gelatinization, starch digestibility, fibre (soluble and insoluble fibre), processing method, fat, and protein (Venn and Green, 2007; Hartono, 2011; Marsh *et al*., 2011). The low GI value was caused by taro flour and leaf substitutions. Both of these ingredients reduced the GI value because they contain antioxidants and fibre.

The glycaemic index of D_4 noodles was slightly higher than D_3. This value was caused by the higher total sugar content compared to D_3 noodles. Similarly, the starch digestibility of D_4 rehydration noodles (44.09%) was higher than D_3 (43.28%). In D_4, the total sugar was 1.69%, and in D_3, it was 0.84% due to the sugar content in the taro leaf. The study conducted by Zhu *et al* (2018) showed that the leaf contained sugar such as sucrose, fructose, and glucose and its levels increased or decreased depending on age. Table 4 shows the glycaemic load value of noodles with taro flour and leaf puree substitution.

Glycaemic load (GL) indicates the amount of carbohydrate content in one serving of food (AlGeffari *et al*., 2016) and it is categorized into three, low (≤10), medium (11-19), and high (≥20). (Istiqomah and Rustanti, 2015). Table 4 shows that the lowest glycaemic load value was found in formula D_2 noodle at 6.15% and the highest was found in D_0 at 12.54%. Furthermore, statistical results showed that there was a significant difference in the noodle glycaemic load from taro leaf puree substitution. The glycaemic load of food provides more complete information regarding the effect of actual consumption on increasing blood sugar levels. The glycaemic load is directly proportional to the carbohydrate of the food. The glycaemic value and the carbohydrate are directly proportional. Therefore, the food does not cause spikes in blood sugar (Yalçın and Neslişah, 2017).

3.4 Antioxidant activity

Statistical results showed that Ha was accepted ($p<0.05$) and there was a significant effect of taro flour and leaf puree substitution on the antioxidant activity of dry noodles and dehydrated ones. This showed that the treatment caused an increase in noodle antioxidant activity.

Table 5 shows D_3 had the lowest IC_{50} value of 5569.81 ppm compared to D_0 with the highest value of 6814.14 ppm. The boiling or rehydration process caused an increase in the IC_{50} value, and the lowest was found in D_5 rehydrated dry noodles at 11990 ppm. Meanwhile, the highest value was found in D_0 at 15168.34 ppm. The antioxidant activity was also divided into four categories of very strong (less than 50 ppm), strong (5-100 ppm), weak (100-150 ppm), and very weak (151-200 ppm). Therefore, the lower the IC_{50} value, the stronger the antioxidant activity (Prayitno and Rahim, 2020). The six

Table 4. Glycaemic index of noodle with taro flour and leaf puree substitution

Test Food	Glycaemic Index			Glycaemic Load		
	Value	*Category	*P*	Value	*Category	*P*
D_0	64.17^{C}	Medium	0.444^{A}	$12.54±4.21^{C,b}$	Medium	0.444^{A}
D_1	59.45^{A}	Medium		$11.07±6.51^{A,b}$	Medium	
D_2	35.19^{C}	Low	0.123^{B}	$6.15±2.74^{C,a}$	Low	0.123^{B}
D_3	54.00^{A}	Low		$8.02±3.00^{A,b}$	Low	
D_4	55.29^{C}	Medium	0.362^{C}	$8.70±4.47^{C,a}$	Medium	0.362^{C}
D_5	52.93^{B}	Low		$7.55±3.57^{B,a}$	Low	

Values with different lowercase superscripts within the glycemic load column are significantly different ($p<0.05$).
*Category: Low (<55), Medium (55-69), High (≥70)
[A]taro flour substitution, [B]taro leaf puree substitution of taro leaf puree and taro flour, [C]interaction between A and B

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Table 5. Antioxidant activity and starch digestibility of dry noodles with taro flour and leaf puree substitution

Test Food	Antioxidant Activity				Starch Digestibility			
	Dry noodle		Rehydration Dry Noodles		Dry noodle		Rehydration Dry Noodles	
	Mean±SD	p	Mean±SD	p	Mean±SD	p	Mean±SD	p
D_0	6814.14±25.85[a]	0.000[A]	15168.34±95.23[b]	0.000[A]	9.45±0.01[b]	0.000[A]	59.37±0.74[a]	0.000[A]
D_1	6560.21±113.64[a]		14842.17±14.38[a]		10.00±0.16[a]		50.76±0.81[a]	
D_2	5640.25±59.93[a]	0.000[B]	14211.50±61.98[a]	0.000[B]	9.62±0.00[a]	0.000[B]	48.85±0.16[a]	0.000[B]
D_3	5569.81±5.75[b]		13722.67±173.95[b]		9.50±0.01[b]		43.28±0.64[b]	
D_4	5688.44±179.34[b]	0.000[C]	12810.00±202.7[b]	0.000[C]	9.00±0.032[b]	0.045[C]	44.09±0.16[b]	0.000[C]
D_5	5761.75±48.61[a]		11990.00±212.13[b]		8.76±0.01[b]		42.12±0.57[a]	

Values are presented as mean±SD. Values with different lowercase superscripts within the same column are significantly different ($p<0.05$).
[A]taro flour substitution, [B]taro leaf puree substitution of taro leaf puree and taro flour, [C]interaction between A and B

variations of dry and rehydrated dry noodles had very weak antioxidant activity.

In dry noodles, the lowest antioxidant activity was found in the D_0 and the highest was in D_3. After rehydration, the lowest antioxidant activity was found in the D_0 noodle formula, and the highest is found in D_5. Compared to dry noodles, D_5 had stronger antioxidants after undergoing rehydration. Four possibilities were causing an increase in antioxidant activity after rehydration. Firstly, a large number of antioxidant components were produced due to cell wall damage during the rehydration. Secondly, the formation of strong antioxidant components were capable of capturing radicals due to chemical reactions in the rehydration. Thirdly, the oxidation capacity of antioxidants was suppressed through the thermal inactivation process of oxidative enzymes. Fourth, the formation of non-nutrient antioxidant compounds such as Maillard reaction products with antioxidant activity (Yalçın and Neslişah, 2017; Prayitno and Rahim, 2020). Furthermore, the study showed that extracts from taro leaf had high antioxidant activity. (Jyothi and Srinivas Murthy, 2019). Taro leaf and root extract had an IC_{50} value of 2.89 ppm and 74.34 ppm (Chawla *et al.*, 2020). The high antioxidant of taro leaf puree was more active after going through the boiling process. It had high phenolic content and strong antioxidant activity against DPPH radicals. Cooking processes such as boiling or steaming green vegetables increased the phenolic, flavonoids, and antioxidant activity. However, it decreased vitamin C compared to uncooked green vegetables (Adefegha and Oboh, 2011).

The rehydrated dry noodles then experienced a decrease in antioxidant activity by up to 100% compared to those before rehydration. This was caused by physical factors affecting the stability of the active compound such as heating. Antioxidant compounds had unstable properties and were damaged by the heating process. The study stated that the antioxidant activity was lower after heating for 30 mins (Shobana and Naidu, 2000). There was another study showing that the highest antioxidant activity was found in samples heated at 100°C for 20 mins. In addition, the antioxidant activity was decreased along with the heating time. The decrease in antioxidant activity occurred at 40 mins, while the lowest was at 60 mins (Gorinstein *et al.*, 2005). Furthermore, cooking processes such as roasting and boiling damaged antioxidants and reduced their activity by 20% (Hermayudha *et al.*, 2013). The taro leaf used was steamed for 15 mins before being made into a puree. The six noodle variations were steamed for 10 mins and dried for 50 mins at 100°C. It was then rehydrated by boiling for 4 mins, which was the possible cause of the very weak antioxidant activity. This was also presented in the study conducted on the antioxidant activity of wet noodles and purple sweet potato dried noodles with weak antioxidant activity (Hermayudha *et al.*, 2013).

3.5 Starch digestibility

The statistical analysis showed that Ha was accepted ($p<0.05$). There was an effect of taro flour and leaf puree substitution on the starch digestibility of dry and rehydrated noodles. Table 5 shows D_1 had the highest starch digestibility at 100%, while the lowest was found in D_5 at 87.62%. The rehydration decreased the starch digestibility of the dry noodles. Furthermore, the rehydrated D_0 dry noodle had the highest starch digestibility of 59.37%, while D_5 was 42.12%.

Starch digestibility is the ability of starch-breaking enzymes to hydrolyze starch into smaller parts or simpler sugars. The higher it is, the more starch will be hydrolyzed in a certain time and will have a high glycaemic index value as well (Gorinstein *et al.*, 2005; Hermayudha *et al.*, 2013). Therefore, it is concluded that the higher the starch digestibility, the greater the spike in body blood glucose after the food is digested and metabolized (Eleazu *et al.*, 2018). The starch digestion process was affected by intrinsic and extrinsic factors. The intrinsic factors were related to the nature of starch, its presence in the food matrix, the size of granules, and the number and size of pores on the starch surface. Meanwhile, the extrinsic factors included the length of digestion time in the stomach (transit time), amylase activity in the intestine, the amount of starch, and the presence of other food components such as anti-nutritional substances (Eleazu *et al*., 2018). Taro tuber is known to have high levels of starch at 70-80% with a small granule size (1-5 m). The taro plant was easily digested due to the small size of the starch granules (Aboubakar *et al*., 2008).

The lower value of starch digestibility in rehydrated dry noodles was due to the formation of type 3 resistant starch and the fibre in taro flour with leaf puree substitution. After rehydration, amylose was reduced, but not significant. As a component of resistant starch, it has many health benefits, one of which is inhibiting blood sugar spikes (Eleazu *et al*., 2018).

3.6 Best determination result

The best formula was determined using the product effectiveness test with the De Garmo method, and this was performed based on all parameters tested such as the nutritional content. This was based on the preference level of the panellists in the organoleptic quality test. From the calculation, Table 6 shows D_2 was selected with the addition of 40% taro flour and 100% taro leaf puree.

The nutritional content of the selected formula was the basis for determining the serving size of noodles with taro flour and leaf puree substitution. The dose was calculated from the number of noodles to meet energy needs. The D_2 formula contained energy as much as 71.10 kcal/100 g, carbohydrates 14.56 g/100 g, protein 2.80 g/100 g, fat 0.34 g/100 g, and dietary fibre 6.72 g/100 g. The acceptance score of colour, aroma, taste, and texture were 2.40, 2.23, 2.34, and 3.37 respectively.

4. Conclusion

Dry noodle with taro flour and leaf puree substitution affected the ash, water, energy, carbohydrates, fat, and total fibre content. Protein content and organoleptic quality (taste, aroma, colour, and texture) decreased with the addition of taro flour or leaf puree. The noodle formula selected, which was close to the quality requirements according to SNI (Indonesian National Standard) was D_2 with 40% taro flour and 100% taro leaf puree substitution.

The statistical analysis showed that there was an effect of taro leaf puree on the glycaemic load of dry noodles. However, there was no effect of taro flour and leaf puree substitution on the glycaemic index. The substitution could be an alternative food for people with diabetes mellitus because of its effect on the noodle's antioxidant activity and starch digestibility. Nutrient testing was conducted on rehydrated and dry noodles. The recommendations for the best rehydration process could be determined without affecting the nutritional content.

Conflict of interest

The authors declare no conflict of interest.

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Table 6. Analysis of the best formula in dry noodles with taro flour and leaf puree substitution

Formula Yield Value	D_0	D_1	D_2	D_3	D_4	D_5
Carbohydrate	0.040	0.152	0.192	0.064	0.074	0.00
Total dietary fibre	0.00	0.054	0.060	0.064	0.168	0.173
Energy	0.069	0.122	0.154	0.039	0.041	0.00
Protein	0.135	0.065	0.081	0.004	0.00	0.019
Fat	0.115	0.097	0.100	0.004	0.00	0.037
Water content	0.096	0.030	0.00	0.085	0.044	0.074
Ash content	0.00	0.003	0.014	0.033	0.051	0.077
Organoleptic Quality	0.058	0.039	0.018	0.005	0.00	0.052
*Total Yield Value (Nh)	0.513	0.569	0.619	0.304	0.377	0.431

*The yield value (Nh) is obtained from the calculation of the DeGarmo effectiveness index

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