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The Effect of Spinach Leaves Powder (*Spinacia oleracea*) on the Quality of Dried Noodle

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Abstract: Vegetables are nutrient-dense foods that provide great health benefits to the consumers. However, vegetables are not always being consumed. Thus, there is a need in increasing the consumption of vegetables in the society. Noodle was used as the matrix in this case as it is a famous staple food. In this study, a total of five formulations of dried noodles incorporated with various amounts (2g, 4g, 6g, 8g and 10g) of spinach leaves powder were developed. F2, made up of 4g of spinach leaves powder was chosen to be the best formulation due to its most well-accepted sensory results and satisfying textural properties. This formulation showed an increased content of ash, protein, crude fibre, moisture and total chlorophyll content and a lower content of fat and carbohydrate than the control. From the aspect of cooking quality, it exhibited significantly lower ($p<0.05$) cooking time, cooking loss and swelling index, but significantly higher cooking weight and water absorption than the control. After eight weeks of storage, the data collected showed that the product was still safe for consumption from the aspects of water activity (aw), moisture content and microbiological quality. No significant difference ($p<0.05$) was observed in the texture properties, but a significant difference in terms of colour was observed during the storage. Overall, 4g of spinach leaves powder was considered suitable to be used in developing spinach noodle without deterioration to its overall quality and this formulation has the potency to be acceptable in society as an alternative healthier choice of noodles to ordinary commercialized dried noodles.

Keywords: spinach, dried noodles, proximate compositions, noodle quality, storage study.

Introduction

Due to modernity, eating patterns are shifting unfavourably, with poor diets and a lack of physical activity posing major health hazards on a global scale (WHO, 2020). Poor eating habits associated with low consumption of vegetables and fruits are often linked to the increased risk of non-communicable diseases such as heart disease, diabetes, obesity and some cancers (Wang et al., 2019). Therefore, lifestyle and diet intake should be modified in order to prevent and reduce the risks of these diseases. Despite having a high nutritional value and health benefits, vegetables are not often consumed, especially by children and adolescents (Choong et al., 2017). It is found that the main barrier to the consumption of vegetables in the society, especially children is the unfavourable sensory elements of vegetables, including taste, colour, flavour, and texture that affect people's preferences and intake of vegetables (Kasprzak et al., 2020).

The effective strategy to the hurdle of low consumption pattern of vegetables and depleted nutrients in noodles is by developing a functional food product incorporated with vegetables (Micha et al., 2015). This can lead to the indirect ingestion of vegetables by children (Shere et al., 2020b).

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Several studies show that children enjoy eating noodles, making the development of vegetable-based noodles a feasible one (Shere et al., 2018a). Additionally, this might attract children because of the attractive green colour of spinach noodle and encourage consumer of all age groups to increase their vegetable consumption in a convenient way (Choong et al., 2017; Aune et al., 2017).

For Asians, noodle is the primary source of energy and the most economical energy-dense food in preventing hunger (Zhang & Ma, 2016). Due to their ease in preparation, transportation, minimal cooking time, palatability, low cost, storage stability and nutritional characteristics, noodles are currently viewed as a quick and easy meal. (Ramu et al., 2018; Rathod & Annapure, 2017). Till now, noodles remain as a staple food in Asian diets.

Spinach with the scientific name of *Spinacia oleracea* from the family Amaranthaceae was chosen in this study. Spinach is a highly nutritious vegetable as it provides a very good amount of dietary fiber, vitamins, minerals, phytonutrients and bioactive compounds which help to prevent chronic health problems (Salehi et al., 2019; Manzoor et al., 2020). Furthermore, the spinach leaves are turned into powder form for easier handling, storage and usability due to its volume and light weight (Ankita & Prasad, 2015a). Cabinet drying has been chosen as the drying method in this study as this drying method is more economical, easily controlled and gives similar effect as freeze drying (Hasan et al., 2019).

This study dominantly aimed to investigate the potential application of adding spinach leaves (*Spinacia oleracea*) in developing dried noodles by incorporating the spinach leaves in the form of powder into the noodles' formulations at various levels. The best-formulated sample was identified based on sensory evaluation and physicochemical properties and subsequently analyzed for its nutritional content, cooking quality and lastly, the changes of storage quality throughout the storage period. It is expected that noodles produced in this study have the potency to be a healthier alternative to the public who are getting more mindful of their food choices.

Materials and Methods

Materials

All ingredients used in this study were purchased from a local market in Kota Kinabalu, Sabah, Malaysia.

Preparation and analysis of noodle sample

Preparation of spinach powder

Spinach leaves were steam-blanched and dried in a cabinet dryer for 8 hours at 45°C. Dried spinach leaves were cooled and ground using a blender. Then, the spinach powder was transferred into a glass bottle and kept at 4°C (El-Sayed, 2020).

Noodle Preparation

50 g of whole egg was added into the mixture of ingredients, mixed for 5 min and followed by the addition of water to form a crumbly mass. After mixing and cohesive dough was formed, the dough was covered with plastic wrapper and left rested for 20 min. The dough then underwent repeated sheeting and lastly extruded through a die with 12 outlets of 0.8 mm in diameter. The noodles were cut into 20 cm long, steam-cooked for 5 min, followed by 5 hrs of drying at 65°C and finally inserted into polyethylene bags. The formulations of spinach noodles are listed in Table 2.1.

Table 2.1: Several formulations of spinach noodle by using different

Ingredients	F0	F1	F2	F3	F4	F5
Wheat Flour (g)	100	100	100	100	100	100
Spinach Powder (g)	-	2	4	6	8	10
Whole egg (g)	50	50	50	50	50	50
Water (g)	10	10	10	10	10	10
Salt (g)	1	1	1	1	1	1

Sensory Evaluation

All the formulations were served in soup during the sensory evaluation (Shere et al., 2018a). 9-point hedonic test was chosen and a total of 40 panelists from the Universiti Malaysia Sabah (UMS) were recruited. The attributes evaluated included colour, texture, taste, aroma, and overall acceptability.

Colour Analysis

Konica Minolta colour measurement system which was calibrated by using a white tile of barium sulphate that had 100% reflectance was used to evaluate the colour values of cooked and raw noodles. The L*, a*, and b* values were reflected. All measurements were done in triplicate.

Texture Profile Analysis

300 ml of water was used to cook 30 g of spinach noodles for 8 minutes, followed by draining and cooling in a sieve for 3 minutes. Noodle strands of not more than 75 mm length were used in texture profile analysis with the aid of Texture analyzer (TA-XT PLUS, Stable micro system limited). The test conditions used were as follows, pretest speed of 1mm/sec, test speed of 1mm/sec, post-test speed of 5mm/sec, 80% strain and 20 g trigger force (Shere et al., 2018b). The parameter evaluated included hardness, adhesiveness, springiness, cohesiveness, gumminess, and chewiness. For each formulation, the measurements were repeated 10 times.

Proximate Analysis

The proximate compositions which included moisture, ash, crude protein, crude fat, and crude fibre were analyzed by referring to AOAC (1990). The total carbohydrate content was obtained by subtracting the sum of other values from 100%.

Pigment Chlorophyll

2.5 g of sample was transferred into a 125 ml glass stoppered flask. 10 mL of 80% acetone was used to extract the chlorophyll of the 80-mesh spinach noodle for 10 minutes. This step was repeated and halted once the samples totally lost their greenness. Using a filter paper, the extract was filtered into an amber graduated flask. 80% acetone was added until the final volume became 25 ml. UV/VIS spectrophotometer was employed in measuring the chlorophyll extract's absorbance. The samples being analyzed were read at 645 nm and read again after the wavelength was reset to 663 nm. The formulae below were used to calculate the values of the total chlorophyll (T_c), chlorophyll a (C_a), and chlorophyll b (C_b)contents in the samples (Yu et al., 2019).

$$C_a \text{ (mg/L)} = 12.7D_{663} - 2.69D_{645}$$

$$C_b \text{ (mg/L)} = 22.9D_{645} - 4.68D_{663}$$

$$TC \text{ (mg/L)} = 20.21D_{645} + 8.02D_{663}$$

Cooking Quality

The cooking quality (optimum cooking time, cooking weight, cooking loss, and water absorption) were determined by referring to Method 66-50.01 from AACC. Swelling index was determined based on the method proposed by Cleary & Brennan (2006). Each attribute was then calculated using their respective formula as follows:

$$\text{Cooking weight (\%)} = \frac{\text{Weight of cooked noodles (g)}}{\text{Weight of noodles (g)}} \times 100\%$$

$$\text{Cooking loss (\%)} = \frac{\text{Dry matters in cooked water (g)}}{\text{Weight of noodles (g)}} \times 100\%$$

$$\text{Water absorption (\%)} = \frac{\text{Weight of cooked noodles (g)} - \text{Weight of noodle (g)}}{\text{Weight of noodles (g)}} \times 100\%$$

$$\text{Swelling index (\%)} = \frac{\text{Weight of cooked noodles (g)} - \text{Weight of noodles after drying}}{\text{Weight of noodles after drying (g)}} \times 100\%$$

Storage Stability

Storage stability of the best formulation noodle was determined in polyethylene bags by keeping 100 g of noodles in 8 different bags for 8 weeks. Water activity, moisture content, colour analysis, texture profile analysis, and microbial analysis were determined every week. Water activity test was carried out by using HygroLab C1 Rotronic. Microbial analysis for bacteria, yeast and mould count was performed. 9 ml of sterile water was used to homogenize 1 g of sample. Serial dilution was performed up 10^{-5} for both total plate count and yeast and mould count. Total plate count was performed on plate count agar and yeast and mould count on potato dextrose agar using pour plate technique.

Statistical Analysis

All the obtained data were subjected to statistical analysis to determine statistical significance of treatments.Data was expressed in the form of mean ± standard deviation. P value < 0.05 was considered significant. Sensory test, texture profile analysis, and storage stability test were subjected to One-Way ANOVA followed by post-hoc Tukey test. Proximate analyses, pigment chlorophyll, and cooking quality tests were subjected to Independent T Test. Data from colour analysis were subjected to Two-Way ANOVA.

Results and Discussion

Sensory Evaluation

Table 1. Sensory Evaluation of Dried Spinach Noodles

Formulation	Colour	Texture	Taste	Aroma	Overall Acceptability
F0	5.68^{a}	6.73^{a}	6.08^{a}	6.03^{a}	6.63^{ab}
F1	6.33^{a}	7.03^{a}	6.43^{a}	6.35^{a}	7.23^{bd}
F2	**8.25^{b}**	**7.98^{b}**	**7.78^{b}**	**7.70^{b}**	**8.30^{c}**
F3	7.03^{c}	6.95^{a}	6.75^{a}	6.68^{a}	7.38^{d}
F4	4.22^{d}	6.38^{a}	4.65^{c}	4.58^{c}	6.08^{a}
F5	3.63^{d}	5.48^{c}	4.60^{c}	4.45^{c}	4.72^{e}

F5 3.63^{d} 5.48^{c} 4.60^{c} 4.45 4.72

[1]Values are expressed as mean, n=40.

[2]Values denoted by various superscripts differ significantly (p<0.05).

F2 obtained the highest mean score among all the formulations for all the attributes while F5 obtained the lowest mean score for all the attributes. This highest mean score obtained by F2 can be explained by the appropriate addition of spinach powder resulting in an eye-appealing green colour in the noodle which were well accepted by most of the panelist. The fact that F5 obtained the lowest mean score can be explained by the unattractive dark green colour, soft texture, and strong vegetably taste in the noodle which was perceived as undesirable by majority of the panelists as a result of excessively high concentration of spinach powder added into the noodle. Softness of the noodle can be linked with the high fiber content in spinach powder that has great affinity for water which reduced the availability of water for the formation of for gluten network (Shere et al., 2018b). Aroma showed similar trend as taste. The overall acceptability of F2 sample was higher than the control noodle. However further increase in the concentration resulted in a reduced overall acceptability.

Colour Analysis

Table 2. Colour Values (L*, a* and b*) of Different Formulation of Raw and Cooked Spinach Noodles

Sample	L*		a*		b*	
	Raw	Cooked	Raw	Cooked	Raw	Cooked
F0	66.11 ± 0.15a	68.57 ± 0.10a	2.55 ± 0.13a	1.48 ± 0.27a	22.79 ± 0.09a	15.61 ± 0.05
F1	51.74 ± 0.14b	54.45 ± 0.37b	-4.27 ± 0.08b	-7.10 ± 0.08b	16.24 ± 0.13b	23.87 ± 0.07
F2	42.24 ± 0.16c	48.38 ± 0.04c	-3.22 ± 0.23c	-6.83 ± 0.10c	11.69 ± 0.16c	22.69 ± 0.15
F3	41.60 ± 0.31d	46.56 ± 0.19d	-2.48 ± 0.10d	-5.25 ± 0.06d	7.58 ± 0.04d	20.49 ± 0.07
F4	37.64 ± 0.08e	42.76 ± 0.05e	-1.66 ± 0.03e	4.27 ± 0.08e	4.64 ± 0.25e	16.72 ± 0.18
F5	34.80 ± 0.04f	40.32 ± 0.17f	-0.89 ± 0.03f	-3.46 ± 0.09f	2.79 ± 0.04f	14.27 ± 0.10

[1]Values are expressed as mean, n=40.

[2]Values denoted by various superscripts differ significantly (p<0.05).

There is a significant difference (p<0.05) in terms of L*, a*, and b* for all the formulations in both raw and cooked noodle. The lowest brightness achieved by F5 in both rawand cooked noodle was due to the highest concentration of spinach powder added into the noodles which resulted in the production of noodles with the darkest green colour, therefore greatly reducing the brightness of the noodle. Generally, cooked noodle showed a higher L* value as compared to raw noodle for all formulations. The result is in line with the study by Rekha et al. (2013) where cooked spinach noodle showed higher brightness values as compared to raw spinach noodle. The increase L* value indicates the colour faded when it was being cooked (Yadav et al. 2014).

F1 to F5 showed a decreasing negative a* value trend in both raw and cooked noodle. The highest negative a* value of F1 indicates that F1 has the highest green shade while the lowest negative a* value of F5 indicates that it has the lowest green shade. The result aligns with the study by Rekha et al. (2013) where cooked spinach noodle showed higher greenness values than raw spinach noodle. The lowest green shade obtained by F5 can be explained by the highest incorporation of spinach powder. The higher b* values of cooked noodle from F1 to F5 than its corresponding raw form can be explained by the swelling of the noodle and conversion of pigments resulting in an increase in yellowness during cooking (Yadav et al., 2014). On the other hand, decreasing trend of positive b* values indicate a decreasing trend in the yellowness in both cooked and uncooked spinach noodle. This means that the colour of the noodles is contributed by the natural green colour of the spinach used (Shere et al., 2018a).

Texture Profile Analysis

Table 3. Textural Quality of Different Formulation of Cooked Spinach Noodles

Sample	Hardness (kg)	Adhesiveness (kg/sec)	Springiness (mm)	Cohesiveness	Gumminess kg)	Chewines (kg/mm)
F0	5.815±0.043^{a}	-0.008±0.001^{a}	3.781±0.058^{a}	0.860±0.004^{a}	4.994±0.059^{a}	18.880±0.07
F1	4.882±0.070^{b}	-0.013±0.001^{b}	1.033±0.006^{b}	0.821±0.002^{b}	4.008±0.067^{b}	4.140±0.073
F2	4.545±0.048^{c}	-0.027±0.003^{c}	0.948±0.008^{c}	0.765±0.001^{c}	3.477±0.041^{c}	3.297±0.063
F3	3.917±0.073^{d}	-0.058±0.001^{d}	0.875±0.006^{d}	0.672±0.002^{d}	2.634±0.044^{d}	2.304±0.024
F4	3.469±0.014^{e}	-0.064±0.002^{e}	0.846±0.008^{e}	0.605±0.002^{e}	2.100±0.008^{e}	1.777±0.019
F5	2.743±0.059^{f}	-0.073±0.001^{f}	0.767±0.013^{f}	0.563±0.006^{f}	1.544±0.048^{f}	1.183±0.040

[1]Values denoted by various superscripts differ significantly (p<0.05).

From Table 3, there is a significant decrease in hardness, springiness, cohesiveness, gumminess, and chewiness. This can be attributed to the presence of fibers in spinach powder which have high affinity for water (Shere et al., 2018b). This disturbed the gluten matrix and caused dilution of gluten which weakened the structure of noodle. Decrease in firmness values were also seen in the study by Rekha et al. (2013) by the incorporation of vegetable puree in pasta. However, significant increase in adhesiveness of noodle from F1 to F5 was reported and this can be attributed to the presence of high fiber content in spinach which has strong water absorption capability that contributed to a higher adhesiveness. F5 incorporated with the highest concentration of spinach powder showed the highest adhesiveness value as compared to all the other samples but it is an undesirable property.

Proximate Composition

Table 4. Proximate Compositions of Control and Best Formulation (F2)

Composition (%W/W)	Control	F2
Moisture	6.26 ± 0.02[a]	8.21 ± 0.01[b]
Ash	1.85 ± 0.01[a]	3.33 ± 0.01[b]
Crude Protein	13.28 ± 0.02[a]	14.22 ± 0.01[b]
Crude Fat	5.62 ± 0.01[a]	5.46 ± 0.05[b]
Crude Fiber	1.38 ± 0.02[a]	8.69 ± 0.06[b]
Total Carbohydrate	71.61 ± 0.03[a]	60.09 ± 0.13[b]

[1]Values are expressed as mean, n=40.
[2]Values denoted by various superscripts differ significantly ($p<0.05$).

F2 recorded a significantly higher moisture content ($p<0.05$) than the control. The greater moisture content in F2 can be linked with the higher amount of fiber in the flour that can bind water well. Therefore, the water was bound by fiber, not lost but retained in fiber during drying (Shere et al., 2020b). The significantly higher ($p<0.05$) ash content of F2 than the control may be due to the presence of more minerals in the noodles through the incorporation of spinach powder (Shere et al., 2020b). A significantly higher protein content ($p<0.05$) was seen in F2 (14.22%) than the control (13.28%). This can be supported by the study from Waseem et al. (2021) which found that the nutritional status of the end-product was enhanced through the enrichment of nutrient-dense ingredients like vegetable powder in wheat flour. Fat content of control (5.62%) is significantly ($p<0.05$) higher than F2 (5.46%). This can be explained by the dilution of gluten caused by the spinach powder in the flour (Shere et al., 2020b).

Crude fiber content of F2 (8.69%) is significantly higher ($p<0.05$) than the control (1.38%). This can be explained by the high fiber content present in the spinach. This result matches with the finding by Shere et al. (2018a) in which spinach noodle had a higher fiber content as compared to wheat flour noodle. Other than that, F2 contained a significantly lower ($p<0.05$) carbohydrate content (60.09%) as compared to the control (71.6%). This can be explained by the increase of other nutritional compositions in F2, such as moisture, ash, protein, and crude fiber content of the noodles. Since the carbohydrate content of wheat flour is higher, hence there is a necessity to incorporate spinach powder which contains lower carbohydrate content but rich in other nutrients.

Chlorophyll Pigment Analysis

Table 5. Chlorophyll Pigment Analysis of Control Sample and Best Formulation (F2)

Chlorophyll Content	Control	F2
Chlorophyll a (mg/L)	-0.003 ± 0.001[a]	22.599 ± 0.026[b]
Chlorophyll b (mg/L)	0.549 ± 0.000[a]	2.077 ± 0.012[b]
Total Chlorophyll (mg/L)	0.546 ± 0.000[a]	24.675 ± 0.014[b]

[1]Values are expressed as mean, n=40.
[2]Values denoted by various superscripts differ significantly ($p<0.05$).

Based on the result shown in Table 5, F2 contained a much higher total chlorophyll content (24.68 mg/L) as compared to the control sample (0.55 mg/L). The trace amount of chlorophyll observed in control can be supported by residual amount of chlorophyll in wheat (16.82 mg/100g) as shown in the study from Niroula et al. (2019). The higher chlorophyll content present in F2 was because of the abundant chlorophyll pigments present in the spinach leaves. The result is in line with the study by Rekha et al. (2013) which showed that spinach noodle contained a higher chlorophyll content than its corresponding control sample. Besides, F2 contained a higher value of chlorophyll a (22.60 mg/L) than chlorophyll b (2.08 mg/L). This is because chlorophyll a is the most abundant type of pigment found in all photosynthetic plants. Chlorophyll a is the primary pigment of photosynthesis, while chlorophyll b plays a supporting role in photosynthesis.

Cooking Quality

Table 6. Cooking Quality of Control Sample and Best Formulation (F2)

Cooking Quality	Control	F2
Cooking Time (min)	6.45 ± 0.08[a]	5.33 ± 0.06[b]
Cooking Weight (g)	239.32 ± 0.05[a]	246.52 ± 0.01[b]
Cooking Loss (%)	13.70 ± 0.05[a]	7.43 ± 0.13[b]
Water Absorption (%)	148.88 ± 0.04[a]	161.26 ± 0.10[b]
Swelling Index (ml/g)	1.93 ± 0.03[a]	1.85 ± 0.03[b]

[1]Values denoted by various superscripts differ significantly ($p<0.05$).

From Table 6, it is seen that a shorter cooking time was shown by F2 (5.33 min) as compared to the control (6.45 min). Therefore, this proves that cooking time is progressively reduced by the incorporation of spinach powder. Since gluten is primarily responsible in producing the starch or protein complex that dictates the structure and cooking characteristics of the noodles, the reduced cooking time can be explained by the dilution of gluten in dough by the addition of spinach powder (Rekha et al., 2013). Cooking weight and water absorption of control differed significantly ($p<0.05$) from F2, where a higher cooking weight (246.52 g) and water absorption (161.26%) were seen in F2 as compared to the control (239.32 g of cooking weight and 148.88% of water absorption). On the contrary, there is a significant difference ($p<0.05$) in terms of cooking loss between control and F2.

A lower cooking loss was seen in F2 (7.43%) as compared to the control (13.70%). Thus, this shows that the binding capacity of noodle strands cohesively can be enhanced by the addition of spinach powder in flour, which then contributed to a better binding of starch granules in gluten matrix (Rekha et al., 2013). Due to this cohesiveness, the loss of solids in cooking water was reduced (Shere et al., 2020b). Additionally, a significant difference ($p<0.05$) from the aspect of swelling index is also observed in these two formulations, where F2 showed a lower swelling index (1.85 ml/g) as compared to the control (1.93 ml/g). The starch components may have absorbed less water during the optimum cooking time, leading to reduced swelling indices, which can be explained by the rivalry between fibre and starch for water absorption. Therefore, increasing the amount of fibre led to less starch swelling, which in turn led to a lower swelling index.

Storage Stability

Water Activity and Moisture Content

Table 7. The Changes of Water Activity (A_w) and Moisture Content of the Best Formulation (F2) during Storage

Week	Water activity (A_w)	Moisture content (%)
0	0.354 ± 0.003[a]	8.094 ± 0.001[a]
1	0.355 ± 0.003[ab]	8.094 ± 0.001[a]
2	0.359 ± 0.006[abc]	8.095 ± 0.001[ab]
3	0.361 ± 0.003[abcd]	8.096 ± 0.001[abc]
4	0.366 ± 0.007[abcde]	8.097 ± 0.001[bc]
5	0.368 ± 0.004[bcde]	8.099 ± 0.001[c]
6	0.369 ± 0.004[cde]	8.101 ± 0.001[d]
7	0.374 ± 0.003[de]	8.102 ± 0.001[de]
8	0.377 ± 0.007[e]	8.104 ± 0.000[e]

[1]Values are expressed as mean, n=40.
[2]Values denoted by various superscripts differ significantly ($p<0.05$).

Water activity (A_w) is important in determining the shelf life of food products. From the result in Table 3.7, the water activity increased from 0.35 on week 0 to 0.38 on week 8. This can be explained by the hygroscopic nature of the product, permeability of packaging used and the inconsistent surrounding environmental conditions, such as temperature and relative humidity (Jalgaonkar, 2017a). According to Sandulachi (2012) dried product should contain water activity less than 0.60, therefore the water activity of F2 is still within the acceptable range, and is still safe to eat.

Referring to Table 7, the moisture content of F2 increased from 8.09% on week 0 to 8.10% on week 8. The increment in moisture content from week 0 to 3 in F2 was not significant ($p<0.05$). This slight rise in the moisture content of the samples can be caused by the penetration of water vapour into the samples from the surrounding (changes in relative humidity and temperature) since the product is of hygroscopic nature (Gull et al., 2017; Jalgaonkar et al., 2017). 10% of moisture content is the maximum allowable limit of moisture content in foods as per the codex standards. Therefore, the moisture content of F2 is still within the acceptable limit.

Colour Profile

Table 8. The changes of Colour Values (L*, a*, b*) of the Best Formulation (F2) during storage

Sample	L*		a*		b*	
	Raw	Cooked	Raw	Cooked	Raw	Cooke
0	42.26 ± 0.12[a]	48.38 ± 0.04[a]	-3.09 ± 0.07[a]	-6.83 ± 0.10[a]	11.69 ± 0.16[a]	22.69 ±
1	42.91 ± 0.18[b]	48.74 ± 0.12[b]	-3.23 ± 0.08[b]	-7.10 ± 0.08[b]	11.16 ± 0.06[b]	22.08 ±
2	43.35 ± 0.03[c]	49.05 ± 0.09[c]	-3.36 ± 0.06[c]	-7.27 ± 0.06[c]	10.69 ± 0.06[c]	21.88 ±
3	43.73 ± 0.05[d]	49.42 ± 0.06[d]	-3.46 ± 0.04[d]	-7.89 ± 0.12[d]	9.78 ± 0.07[d]	21.23 ±
4	44.16 ± 0.05[e]	49.84 ± 0.12[e]	-3.81 ± 0.06[e]	-8.12 ± 0.08[e]	9.33 ± 0.08[e]	20.64 ±
5	46.25 ± 0.08[f]	51.23 ± 0.09[f]	-4.08 ± 0.04[f]	-8.52 ± 0.04[f]	8.91 ± 0.03[f]	19.90 ±
6	47.33 ± 0.02[g]	52.36 ± 0.09[g]	-4.38 ± 0.03[g]	-8.74 ± 0.07[g]	8.38 ± 0.07[g]	18.78 ±
7	48.58 ± 0.04[h]	54.87 ± 0.07[h]	-4.48 ± 0.08[h]	-9.05 ± 0.12[h]	8.01 ± 0.08[h]	17.25 ±
8	51.34 ± 0.12[i]	56.09 ± 0.08[i]	-4.83 ± 0.03[i]	-9.35 ± 0.06[i]	7.54 ± 0.04[i]	16.72 ±

[1]Values are expressed as mean, n=40.
[2]Values denoted by various superscripts differ significantly ($p<0.05$).

From the result in Table 8, there is an increasing trend of brightness and greenness, but a decreasing trend is observed for yellowness in F2 noodle during the storage at ambient temperature for 8 weeks. The L* values of raw noodle increased from 42.26 to 51.34 while the L* values of the cooked noodle increased from 48.38 to 56.09. The a* values of both raw and cooked spinach noodle increased from week 0 to week to week 8. This can be caused by the absorption of moisture by samples during storage. Oxidation also led to the loss of surface colour in samples during storage (Srinivasan & Prabhasankar, 2018). The effect of water absorption on color seems to be variable, but higher water absorption usually led to higher L* values. Thus, the noodle become lighter (Morris et al., 2018). Besides, there is a decreasing trend in the b* value of spinach noodle, where it decreased from week 0 (11.69) to week 8 (7.54) and the b* value of cooked spinach noodle decreased from week 0 (22.69) to week 8 (16.72). This can be explained by the degradation of chlorophyll b and carotenoids.

Texture Profile

Table 9. Textural Changes of the Best Formulation (F2) during Storage

Sample	Hardness (kg)	Adhesiveness (kg/sec)	Springiness (mm)	Cohesiveness	Gumminess kg)	Chewines s (kg/mm)
0	4.545±0.048[a]	-0.027±0.003[b]	0.948±0.008[c]	0.765±0.001[d]	3.477±0.041[e]	3.297±0.062[f]
1	4.545±0.004[a]	-0.026±0.001[b]	0.948±0.006[c]	0.765±0.014[d]	3.475±0.065[e]	3.293±0.066[f]
2	4.546±0.007[a]	-0.026±0.000[b]	0.948±0.003[c]	0.764±0.009[d]	3.472±0.039[e]	3.302±0.042[f]
3	4.547±0.005[a]	-0.027±0.001[b]	0.947±0.006[c]	0.763±0.006[d]	3.469±0.028[e]	3.287±0.046[f]
4	4.548±0.001[a]	-0.029±0.002[b]	0.946±0.010[c]	0.765±0.003[d]	3.481±0.014[e]	3.293±0.046[f]
5	4.549±0.007[a]	-0.028±0.000[b]	0.945±0.007[c]	0.763±0.006[d]	3.469±0.023[e]	3.280±0.040[f]
6	4.550±0.005[a]	-0.028±0.001[b]	0.945±0.007[c]	0.763±0.003[d]	3.476±0.023[e]	3.279±0.041[f]
7	4.551±0.002[a]	0.028±0.003[b]	0.944±0.002[c]	0.762±0.004[d]	3.473±0.023[e]	3.277±0.033[f]
8	4.551±0.003[a]	-0.027±0.002[b]	0.944±0.003[c]	0.761±0.005[d]	3.471±0.023[e]	3.276±0.041[f]

[1]Values denoted by various superscripts differ significantly ($p<0.05$).

From the result shown in Table 9, the hardness, adhesiveness, springiness, cohesiveness, gumminess, and chewiness of the spinach noodle are not significantly influenced ($p>0.05$) during storage period. Study from Jalgaonkar et al. (2017) and Gull et al. (2017) also showed that no significant difference was seen in the textural qualities of the noodles during storage period. Similar result was obtained by Yadav et al. (2014) which reported nonsignificant difference in hardness among vegetable-incorporated pasta.

Microbiological Quality

Table 10. Effect of Storage on the Microbiological Quality of the Spinach Noodles

Week	Total plate count (CFU/g)	Yeast and Mold Count (CFU/g)
0	2.0 x 10^1	1.0 x 10^1
1	4.0 x 10^1	2.0 x 10^1
2	8.0 x 10^1	3.0 x 10^1
3	2.2 x 10^2	4.0 x 10^1
4	2.9 x 10^2	4.0 x 10^1
5	3.6 x 10^2	5.0 x 10^1
6	5. 2 x 10^2	7.0 x 10^1
7	7.5 x 10^2	7.0 x 10^1
8	1.1 x 10^3	9.0 x 10^1

The total plate count increased from 2.0 x 10^1 CFU/g to 1.1 x 10^3 CFU/g over the storage period of 8 weeks. As the moisture content increased during the storage period, the total plate count of spinach noodles increased. However, the growth of yeast and mould count increased slightly from week 0 (1.0 x 10^1 CFU/g) to week 8 (9.0 x 10^1 CFU/g). According to FDA (2013), the permissible colony count for total plate count is 1.0 × 10^3 CFU/g while the permissible colony count for yeast and mold count is 1.0 × 10^5 CFU/g. According to Malaysian Food Law 1983 dan Food Regulation 1985, the allowable total plate count and yeast and mold count are not more than 10^6. Therefore, the product was regarded safe to consume even after eight weeks of storage as the data did not surpass the maximum permissible limit. The slow growth of yeast and mold as compared to the bacteria may be explained by the suitable water activity level for the growth of yeast and mould is about 0.70 to 0.88.

Conclusions

The potential of incorporating spinach leaves powder into noodles was studied. F2 which contained 4 g of spinach leaves powder was the most acceptable formulation by the panelists and it obtained satisfying textural properties. As such, it was picked as the best formulation. Such addition resulted in an increased ash, protein, crude fibre, moisture and total chlorophyll content and a lower content of fat and carbohydrate. Thus, it has the potency to be an alternative noodle to the consumers. In terms of cooking tests, F2 recorded a lower cooking time, cooking loss, swelling index, but a higher cooking weight and water absorption in comparison to the control. F2, being stored for 8 weeks was still regarded as safe for consumption from the aspects of moisture content, water activity and microbiological quality since all the data were within the safety range. There was no significant difference for all the parameters in the textural profile of F2. However, higher brightness, greenness, and lower yellowness were observed in the samples throughout the 8-week storage. Further study can be done to determine the antioxidant capacity and digestibility of noodles incorporated with spinach leaves powder. Also, potential of using spinach leaves in the other food products, such as bakery, confectionery and snack products can be explored, too. It is also suggested to include hydrocolloid in the formulations of noodles which can improve the cooking and textural qualities of noodles.

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