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The Development of Moringa Oleifera Leaves Cereal using full Cream and Soy Milk as Fillers.

KARINA CITRA RANI[1]*, NANI PARFATI[1], NIKMATUL IKHROM EKA JAYANI[2], TAN SHERLY EVELINA[3] and CHERRY CHRISTIANTO[3]

[1]Department of Pharmaceutics, Faculty of Pharmacy University of Surabaya, Surabaya, Indonesia.
[2]Departement of Biology Pharmacy, Faculty of Pharmacy University of Surabaya, Surabaya, Indonesia.
[3]Faculty of Pharmacy University of Surabaya, Surabaya, Indonesia.

Abstract

Moringa oleifera leaves powder can be fortified to improve the nutritional values and health benefits of several food products including cereal. This research aimed to obtain an optimized formula for Moringa oleifera cereal which was produced through the wet granulating method. This powder was developed into four cereal formulas. F1 and F2 use full cream milk as filler combined with 1.5% and 2% xanthan gum respectively. F3 and F4 usea combination of full cream milk and soymilk as a filler with 1.5% and 2% xanthan gum concentration. The effect of xanthan gum concentration and type of milk also were evaluated to the physical granule characteristics, reconstituted physical and chemical characteristics, as well as theIndonesian national standard (SNI)01-4270-199 for the cereals, were also analyzed. The four formulas performed excellent granule flow characteristics with suitable dispersion time, pH, viscosity, and flow behavior. Xanthan gum concentration, filler type, and interaction between these components significantly influenced the cereal viscosity ($p < 0.05$). However, formulas 2 and 4 which used 2% xanthan gum exhibited higher viscosity (333,75 cps and 305 cps) and dispersion stability (F=1). These formulas were further evaluated for cereal quality requirements based on SNI 01-4270-199 for cereals. The combination of full cream-soy milk and 2% xanthan gum exhibited a positive impact on the proximate content. Therefore, from these results, it can be concluded that Formula 4 was the recommended formula. However, these components are required to be optimized in further study to meet the SNI requirements of crude fiber, water, and fat content.

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CONTACT Karina Citra Rani karinacitrarani@staff.ubaya.ac.id Department of Pharmaceutics, Faculty of Pharmacy University of Surabaya, Surabaya, Indonesia.

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Introduction

Moringa oleifera is an Indonesian plant with the potential to be developed as a food source and used for fortification.[1] This plant contains important nutritional requirements, such as amino acids, carbohydrates, minerals such as a macro (calcium, magnesium, potassium, phosphorus, and sulfur) and microelements (iron, zinc, copper, and manganese), fatty acids, omega-6, vitamins, chlorophyll, antioxidants (lutein, carotenoids, zeatin, quercetin, kaempferol), and beta-sitosterol.[2] Furthermore, *Moringa* leaves are reported to have high nutritional contents, including protein (19-29%), fiber (16-24%), fat, carbohydrates, minerals, calcium, magnesium, phosphorus, potassium, copper, iron, sulfur, oxalic acid, vitamin A, B (choline), B1 (thiamine), B2 (riboflavin), B3, C, and E[3]. Therefore, these leaves have a high potential to be utilized as an alternative food portion in overcoming malnutrition.[4]

A recent development has revealed that the powder form of *Moringa oleifera* leaves can be fortified in several food products,[5] including pudding, cake, cookies, cabbage, and grains. Furthermore, results from this fortification process also led to the rapid improvement of a population's macro and micronutrient status, especially in Africa.[6] Consequently, *Moringa oleifera* leaf powder can be developed into nutraceutical products, which are commodities from foods in the medicinal form of pills, capsules, granules, or liquids with physiological benefits to maintain health status.[7] This powder can be fortified and formulated in food products or nutraceuticals in 2%-10% concentration.[6] The development of these products such as cereals in granule form has good prospects to diversify food and meet the nutritional requirement of the Indonesian population.[5]

The most essential part of the development of *Moringa oleifera* leaves as a cereal product is the stability of active substances contained in the leaves. According to previous research, these active substances did not decrease significantly when heated up to 60°C.[8] Therefore, the development of these products can be conducted through a wet granulation method with a drying temperature below 60°C. The *Moringa oleifera*leaf powder was chosen as the starting material in the food fortification of cereal due to the low moisture content absent in fresh leaves,[9] which ensured the stability of the final product. Furthermore, a nutrition study revealed this powder was able to meet the daily nutritional requirement.[10] A study to develop an acceptable formula for cereal must be conducted, to provide a practical food product and maintain a healthy condition.

Moringa oleifera leaf cereal can be produced by the wet granulation method to improve the powder's physical characteristics such as flow, prevent component segregation, and increase the uniformity of content.[11] The binder is an important component in the granule formula which serves to adhere the particles and form bonds.[12] Furthermore, the hydrocolloid is another component that produces a significant impact on the structure, dispersion characteristics, microstructure, and taste of the cereal product. The use of this component is determined by its ability to increase system viscosity, water holding capacity, and hydration rate.[13] Xanthan gum is a hydrocolloid that can improve the physical and chemical characteristics of cereal products and its concentration is very essential because it affects the physical and chemical characteristics of granules before and after reconstitution in the aqueous media. This gum is easy to mix, pour, and swallow due to its low viscosity exhibited at high shear, which indicates a good suspension and coating property. In addition, a colloidal suspension was observed in an aqueous mixture of xanthan gum to have good stability.[14] The use of 1.0-2.0% gum in cereal and bread preparation increased the product viscosity, and texture, and hindered particle sedimentation.[15]

The other component in granules formulation which exhibits a persistent impact on physical and chemical characteristics is the filler, where its type and concentration influence flow characteristics and water content.[16] Furthermore, milk is a suitable filler in the cereal granule formulation because it enhances its formation and fulfills the nutrient requirement as well as provides proper energy, protein, vitamins, and minerals.[17] Full cream and soy milk can be utilized in cereal as fillers because of their nutritional contents, where Full cream contains 150 Kcal of calories, 8.15, 5.07, 0.00, 8.02, 11.37, 4.27, 214.69, 12.90, and 1.75, grams of fat, fatty acids, fiber, protein, carbohydrate, lactose, water, total solids, and ash, respectively, as well as 290.36, 0.12, and 226.92 of Ca, Fe, and P, respectively. Meanwhile, soy milk contains 79 Kcal of calories, 4.67, 0.52, 3.18, 6.73, 4.43, 0.00, 228.57,10.40, 0.66 grams of fat, fatty acids, fiber, protein, carbohydrate, lactose, water, total solids, and ash, respectively, as well as 9.80, 1.42, 120.05 milligrams of Ca, Fe, and P18. However, soy milk seems like a healthier choice because it contains a lower number of calories, carbohydrates, fat, and fatty acid, as well as the potential to be developed for a specific population allergic to cow milk protein and lactose. The *Moringa oleifera* leaves granules must fulfill the national quality requirement of cereal milk (SNI 01-4270-199), which specifies the fat content specification of 7.0%. Therefore, full cream and combinations of full cream-soy milk are utilized in this formulation.

In this research, 8% *Moringa oleifera* leaf powder was developed into four cereal formulas using several combinations of xanthan gum concentration (1.5% and 2%) and milk types as a filler (full cream and combination full cream-soy milk). This research aimed to obtain an optimized formula for*Moringa oleifera* cereal which was produced through the wet granulating method. Subsequently, the products were subjected to granule characteristics evaluation, physical and chemical characteristic analysis after reconstitution, as well as an assessment on the Indonesian National Standard(SNI) 01-4270-199 quality parameter for cereals. Xanthan gum and a combination of milk types as a filler are also intended to enhance the physicochemical characteristics of the cereal following the SNI of cereal milk. Hence the effect of this component on the dispersion time and product viscosity was also observed in this study.

Materials and Methods

Materials

The*Moringa oleifera* leaves were obtained from Bogo, Bojonegoro, in October 2019 and identified by the Development Center of Traditional Medicine at the University of Surabaya, Indonesia with no. 1412/D.T/X/2019 as the authentication number. Furthermore, the excipients which were used in the cereal formula, include xanthan gum (Neimenggu Fufeng Biotechnology, China), sucrose (Bratachem, Jakarta, Indonesia), stevia (PT. JamuIboe, Surabaya, Indonesia), full cream milk (Fonterra Co-operative Group Ltd, Tokoroa, New Zealand), and soy milk (Unisoy, Woodlands, Singapore). Others include natrium benzoate (Emerald Kalama Chemical, B.V, Rotterdam, Netherlands), creamer (PT. Almer, Philippine), maltodextrin (ZhuchengDongxiao Biotechnology Co., Ltd. China), melon flavor (KH Roberts, Singapore), and strawberry flavor (KH Roberts, Singapore). All the materials in this study were food grade and pharmaceutical grade.

Preparation of *Moringa* ***oleifera*** Leaf Powder

Fresh *Moringa oleifera* leaves were obtained from Bogo, Bojonegoro, and immediately placed into a washing tub to remove dirt and dust. Subsequently, the leaves were sorted, drained, and dried for 7 days at room temperature until a <10% moisture content was attained by measuring this parameter using a moisture content analyzer.[19] The dried *Moringa* leaves were then crushed in a blender and sieved with a mesh no. 100 to produce the powder. The dried leaves powder was then subjected to moisture content analysis.

Preparation of *Moringa oleifera* Leaf Cereal

Table 1 shows the formula of *Moringa oleifera* leaf cereal produced through the wet granulation method. In this research, four formulas were developed to optimize the concentration of xanthan gum and the filler type. Furthermore, formulas 1 and 2 used the full cream milk as a filler as well as 1.5% and 2% xanthan gum consecutively while formulas 3 and 4 used the combination of full cream-soy milk. The weight of cereal granules in each sachet was 30 g.

Xanthan gum, sucrose, stevia, vegetal creamer, milk (full cream or combination of full cream-soy milk), *Moringa* leaf, and arrowroot powder were mixed thoroughly in a dry state using a low shear mixer for 5 minutes. Subsequently, melon and strawberry flavors were added to this combination and mixed homogeneously for 5 minutes with eggs added to form a consistent granule mass. The wet granule mass from the granulation process was sieved using mesh no. 10 and dried in the oven at 50ºC for approximately 3 hours until 2-4% moisture content was attained. This dried mass was then sieved using mesh no. 16 and the granule characteristics evaluated.

Table 1: Formula of *Moringa oleifera* leaf cereal

Component	Formula 1 (%)	Formula 2 (%)	Formula 3 (%)	Formula 4 (%)
Moringa leaf powder	8	8	8	8
Aarwoot powder (*Marantaarundinacea L*)	20	20	20	20
Xanthan gum	1.5	2	1.5	2
Sucrose	20	20	20	20
Stevia	3	3	3	3
Vegetal creamer	5	5	5	5
Natrium benzoate	0.1	0.1	0.1	0.1
Egg	13	13	13	13
Strawberry flavor (powder)	5	5	5	5
Melon flavor (powder)	7	7	7	7
Full cream milk (powder)	17.4	16.9	7.4	6.9
Soy milk (powder)	-	-	10	10

Granule Characteristic Evaluation of *Moringa oleifera* Leaf Cereal

The granule characteristic evaluation of *Moringa oleifera* Leaf Cereal was performed to determine its characteristics and predict the ability to further develop in the large-scale process. This evaluation process consisted of organoleptic properties, moisture content, particle size distribution, angle of repose, Hausner ratio, and compressibility index.

Organoleptic Properties

The organoleptic evaluation was conducted by assessing the granule form, color, and odor of the *Moringa oleifera* leaf cereal.[19]

Moisture Content

The determination of the granule moisture content was conducted using a moisture content analyzer instrument, where 5 grams was weighed and flattened. Subsequently, the instrument was run for 10 minutes and the value obtained was recorded in percentage units.[20]

Particle Size Distribution

The evaluation of particle size distribution was conducted using a set of standard sieves and a vibrator. Furthermore, 100 g of the granules were weighed, followed by each sieve which was arranged in mesh sizes of 20, 30, 50, 60, 80, and 100 with a pan at the bottom. The weighed granule was placed on the top sieve, covered, and tightened, then shaken with a vibrator for 20 minutes at a speed of 60 rpm. Subsequently, the weight of each sieve and pan was recorded, then the weight of the granules distributed in each sieve was calculated and the pans were collected. The particle size distribution and percent fines of the granules were also analyzed.[21]

Angle of Repose

The measurement of the repose angle was conducted to predict the flow characteristics of the granules, and then the flow velocity was determined. This evaluation was conducted using the funnel method with a funnel-shaped device opened at the bottom end of the pipe. Furthermore, 100g of the granules were inserted into the funnel with the bottom hole closed, then opened and the time for all the granules to run out was recorded. These data were calculated to obtain flow velocity. In addition, the mass piles under the funnel and the radius of the print mass pile cone base were measured. These data were used to calculate the granule angle of repose.[22]

Hausner Ratio and Compressibility Index

The bulk and tapped density of *Moringa oleifera* leaf cereals were determined to calculate the compressibility index and Hausner ratio, which is the ratio of these densities. Furthermore, the compressibility index was calculated using this equation:

Compressibility index = (Tapped density-Bulk density)/ (Tapped density) x 100%

Cereal Evaluation after Reconstitution

Each package of *Moringa oleifera* leaf cereal (30 gram) was reconstituted with 150 ml of purified water and then assessed. The evaluation of the cereal after reconstitution covered various parameters such as organoleptic test, dispersion time, pH, viscosity, flow behavior, and sedimentation volume.

Organoleptic Test

The organoleptic test of the cereal was conducted by determining the color, odor, and taste after the reconstitution process.[23]

Dispersion Time

Granules weighing 30g were measured and reconstituted with 150 ml of warm purified waterat approximately 60° C. The period required by the granules to distribute homogeneously was recorded as the dispersion time.[24]

pH Evaluation

Granules weighing ± 30 grams were reconstituted using 150 ml of warm purified water at approximately 60° C, then the dispersion pH was determined using a Scott pH meter.[25]

Viscosity and Flow Behavior Determination

Viscosity and flow behavior of reconstituted granules were evaluated using Stormer Viscometer. The amount of the samples for this evaluation was approximately 400-600 ml. Furthermore, the rheogram between the shearing stress and the rate of shear was plotted and analyzed to determine the flow behavior of these systems.[26]

Sedimentation Volume

The evaluation of the sedimentation volume was conducted using a 25 ml measuring cup. Furthermore, 25 ml of cereal granules were poured into the measuring cup and covered with aluminum foil after reconstitutionand shaken 10 times. Subsequently, this apparatus was stored and protected from shock. The initial suspension (Vo) and the final sedimentation volume (Vu) were observed at 7 observation time points, including 0, 5, 15, 30, 45, 60, and 120 minutes and the volume (F) was calculated at each point.[27]

Cereal Quality Evaluation Based on SNI 01-4270-199 for Cereals

Quality evaluation based on SNI 01-4270-199 was conducted on *Moringa oleifera* leaf cereal. The parameter of SNI applied for the evaluation include the proximate requirement of carbohydrate, fat, protein, crude fiber, water content, ash content, and heavy metal content (Pb and Cu).

Data Analysis

The data on cereal quality parameters, granule, and cereal characteristics based on SNI 01-4270-199 were analyzed using descriptive statistics. The evaluation of granule and cereal characteristics was conducted in four replications (n=4), hence the evaluation of cereal quality parameters was conducted as single replication. These results were tabulated as mean and standard deviation. The results were compared to the requirement and then investigated to determine the promising formula for further research. The effect of xanthan gum concentration and filler type (full cream and full cream-soy milk) on the dispersion time and viscosity of cereal were analyzed statistically using a completely randomized design at the 5% level. The software for statistical analysis was IBM SPSS Statistics.[23]

Results

The Evaluation of Granule Characteristics

The formulation of *Moringa oleifera* leaf cereal was performed using the wet granulation method. Table 2 shows the results of the granule characteristics evaluation.

Figure 1 displays the physical condition of the granule, where the results indicated all the cereal formulas, including 1, 2, 3, and 4 exhibited good flow properties. The moisture content of these formulations also meets the requirement of moisture content for pharmaceutical granules.[28] Also, the particle distribution analysis showed approximately >85% of the granules had particle size >850 µm while the percentage of fines were discovered in small portions <10%.

Table 2: The Results of Granules Characteristic Evaluation

Parameters	Formula 1	Formula 2	Formula 3	Formula 4
Organoleptic	Dark green granule, sweet, and melon odor	Dark green granule, sweet, and melon odor	Dark green granule, sweet, and melon odor	Dark green granule, sweet, and melon odor
Moisture content (%)	3.14 ± 0.17	3.15 ± 0.26	2.90 ± 0.26	2.85 ± 0.23
% Fines	0.25 ± 0.50	2.50 ± 1.12	1.00 ± 1.41	1.85 ± 0.59
Compressibility Index (%)	18.36 ± 1.49	18.78 ± 1.68	13.47 ± 0.28	15.85 ± 0.74
Hausner Ratio	1.23 ± 0.02	1.24 ± 0.01	1.17 ± 0.03	1.22 ± 0.03
Flow velocity (g/s)	8.51 ± 0.37	8.48 ± 0.24	9.10 ± 0.22	8.42 ± 0.15
Angle of Repose (°)	31.12 ± 0.32	31.29 ± 0.56	32.13 ± 1.04	32.13 ± 1.04

The data are represented as mean values and standard deviation of four replications

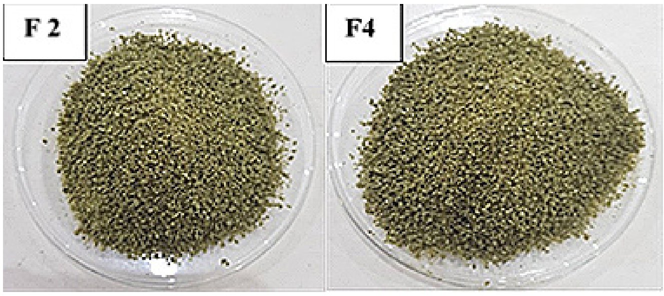

Fig. 1: Granules of Moringa oleifera leaf cereal formula 2 and 4

Evaluation of Cereal after Reconstitution

Moringa oleifera leaf cereal was also evaluated after reconstitution and various parameters of the granule, such as dispersion time, pH evaluation, viscosity, flow behavior, and sedimentation volume analyzed. The evaluation revealed that after contact with warm purified water, the granules disperse quickly and transform into a brownish-green homogenous suspension. Figure 2 displays the characteristics of the granules after reconstituted in purified water.

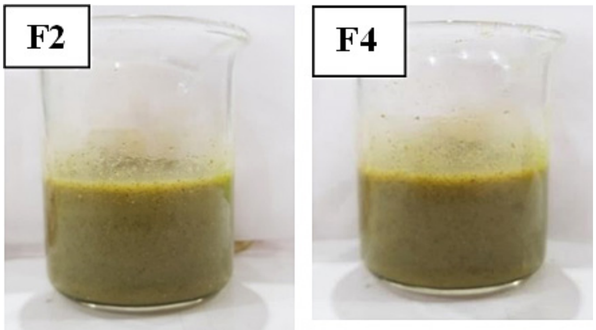

Fig. 2: *Moringa oleifera* leaf cereal after reconstitution process for formulas 2 and 4

The viscosity of the cereals was between 240-310 cps and the flow behavior after reconstitution was determined as pseudoplastic. Furthermore, the pH was observed between 6.05-6.16 while the sedimentation volume after reconstitution was 0.975-1, which indicates the dispersion stability in a specified time until 120 minutes. Table 3 shows the results of cereal characteristics after this process. The effect of xanthan gum concentration and filler type (full cream and full cream-soy milk) on the viscosity of cereal was analyzed using a completely randomized design. The results showed these factors and the interaction between them significantly affected the cereal viscosity (*p<0.05).

Table 3: The Results of Cereal Characteristics after Reconstitution

Parameters	Formula 1	Formula 2	Formula 3	Formula 4
Organoleptic	Brownies green suspension, sweet, and melon odor	Brownies green suspension, sweet, and melon odor	Brownies green suspension, sweet, and melon odor	Brownies green suspension, sweet, and melon odor
Dispersion Time (seconds)	8.89 ± 0.19	8.39 ± 0.30	9.58 ± 0.46	9.17 ± 0.10
pH	6.10 ± 0.04	6.11 ± 0.05	6.13 ± 0.02	6.11 ± 0.02
Viscosity (cps)	243.75 ± 2.50*	333.75 ± 4.79*	245 ± 5.77*	305 ± 5.77*
Flow behavior	Pseudoplastic	Pseudoplastic	Pseudoplastic	Pseudoplastic
Sedimentation Volume	0.975	1.000	0.980	1.000

The data are represented as mean values and standard deviation of four replications
(*) indicates significantly different (p<0.05)

Evaluation of Quality Requirements Based on SNI 01-4270-199 for Cereals

The evaluation of quality requirements based on SNI 01-4270-199 for cereals includes proximate analysis for carbohydrate, protein, crude fiber, fat content, heavy metal (Pb and Cu), water, and ash content. This assessment was conducted on formulas 2 and 4 which had higher viscosity and better dispersion for each filler type (full cream and combination full cream-soy milk). Table 4 shows the results which revealed the cereals meet the specification of carbohydrate, protein, ash, and heavy metal content (Pb and Cu). However, the fat content of these formulas was less than the requirement, although the water and crude fiber content were higher.

Table 4: The Results of Quality Evaluation Based on SNI 01-4270-199 for Cereals

Parameters	Formula 2	Formula 4	Requirement
Protein (%)	10.42	10.90	Minimum 5.0
Fat (%)	5.49	5.88	Minimum 7.0
Carbohydrate (%)	75.12	73.15	Minimum 60
Crude fiber (%)	1.45	1.60	Maximum 0.7
Water content (%)	4.14	5.36	Maximum 3.0
Ash content (%)	3.38	3.11	Maximum 4.0
Pb content (ppm)	Not detected	Not detected	Maximum 2.0
Cu content (ppm)	1.7 ppm	2.8 ppm	Maximum 30

Discussion

Ready-to-eat cereals are comprised of a mixture of grain or flour components and are usually fortified with vitamins and minerals.29 The previous research revealed most cereals are lacking in some essential amino acid contents, especially threonine and tryptophan.[30] Dried *Moringa oleifera* leaf contains a huge amount of protein, vitamin A, and C 31 as well as 17 amino acids of which 9 were classified as essential amino acids, including threonine, tyrosine, methionine, valine, phenylalanine, isoleucine, leucine, histidine, and lysine.[10]. These dried leaves serve as a protein source in human diets, hence, it is beneficial to fortify cereal developed in this research.

Moringa oleifera leaf was developed as a natural ready-to-eat cereal in granule form to provide nutritional and flavor requirements. Furthermore, several attempts had been made to develop these products including the use of the granulation process,[29] which is a size enlargement procedure where small particles are transformed into larger and physically stronger agglomerates with primary particles still being distinguishable. The wet granulation process is widely used in pharmaceutical and food development because this method provided several advantages such as better powder flow, preventing aggregation of each component, and improvement in content uniformity.[29] In the research, this method was conducted by mixing all the granule components and adding an egg as a binder. This process was performed using low shear granulator because it produced granules in a less spherical shape that are more friable.[32] Also, this characteristic is beneficial for cereal development due to its easy dispersion in the medium.

The moisture content of granules is a crucial parameter to be determined in pharmaceutical or food granules with a critical limit of 5% because water acts as plasticizers above this value. Furthermore, the flowability of the granules has an indirect relationship with moisture content, where cohesion from stronger interparticle liquid bridges increases with moisture and leads to poorly flowing powders.[33] In this research, all the cereal granule formulas fulfilled the specification, with moisture content between 2.85%-3.15%.

The flowability of granules is an essential property influencing manufacturing steps such as the mixing and filling processes. This factor is determined by several physical properties, such as particle size, shape, and interaction with airflow, as well as environmental humidity.[34] The particle size is a specific parameter to investigate because the gravitational force of bigger particles is greater than the interparticle adhesive force which causes an easier flow. Furthermore, the results showed the size of 85% of the granules was >850 μm while the percentage of the fines in each formula was below 10%, indicating the requirement of fines proportion in pharmaceutical granules was fulfilled. The smaller fines percentage produced the better flowability of the granules as particles below 100 μm, usually stated as fines are cohesive and prone to problems with this factor.[34] A small quantity of these particles in the high portion of larger particles influenced good powder flowability due to its lubricating capacity.[35] The results of compressibility index and Hausner ratio calculation implied the good flow character for all the formulas, where the angle of repose and flow velocity test, which are markers also revealed the same characteristics. The *Moringa oleifera*leaf cereal exhibited good flowability, hence, acceptable filling performance, small weight variation, and homogenous content uniformity of the granules were achieved.

The granular cereal form characteristics after the reconstitution process were also observed to have good results in this research. Furthermore, reconstitution of food powder or granule generally consists of four steps including wetting of powder particles, sinking, dispersing, and partial or completely dissolving in solution.[36] The dispersion time is a crucial parameter to describe the reconstitution behavior of *Moringa oleifera* granules as this determines whether the food granules can be classified as instant where they perform good dispersibility, wettability, and optimal agglomeration.[36] Wettability time decreases in granules with larger, agglomerate particles, and lower free fat content. The results showed all the granule formulas performed acceptable dispersion time for the instant product which ranged between 8.39–9.58 seconds to produce a homogenous suspension. Also, the results of statistical analysis using a completely randomized design revealed the filler type (full cream and a combination of full cream-soy milk) and xanthan gum concentration significantly influenced the granule dispersion time ($p < 0.05$). Wettability was the essential parameter that predominantly affected the dispersion time. Wettability described the time taken for a given amount of powder to sink beneath the surface of 200 ml of water. The combination of full cream and soy milk exhibited a longer period due to high surface free fat which produces a less wettability system.[37] However, the increase of xanthan gum concentration reduced the dispersion time because of its ability to bind water molecules.[15] The higher ability of a suspending agent to bind water molecules, the faster dispersion time of the granules will be observed.

The viscosity of *Moringa oleifera* leaf cereal ranged between 243.75–333.75 cps and increased with the xanthan gum concentration in the formula. Furthermore, the xanthan gum concentration, filler type, and interaction between these components significantly influenced the cereal viscosity ($p < 0.05$). This gum is a hydrocolloid widely used in food and pharmaceutical products to increase consistency, enhance textural properties, and produce a homogeneous system. The desired functionality of this component is provided at a concentration of about 2% or less 15, where a higher concentration in the formula leads to the increase of cereal viscosity and consistency. This phenomenon is believed to be due to the particle swelling upon contact with the aqueous medium, which displayed a rheological behavior similar to gel-like macromolecular dispersion and exhibited pseudoplastic characteristics in dispersed systems.[38] Also, the protein content serves as a significant factor to influence product viscosity, where an increase in its content and type lead to a more voluminous dispersed phase, producing higher thickness.[37] The interaction between hydrocolloid concentration and filler complexity (skim and whole milk powder) was also studied in previous research about beverage development, where the results indicated some interaction between these two parameters in beverage product viscosity.[39]

The other parameter to predict the physical stability of the suspension was sedimentation volume which increases with a highly agglomerated system and has been used to measure the degree of flocculation.[40] Furthermore, formulas 2 and 4 which used 2% xanthan gum showed maximum sedimentation volume (F=1), hence indicating the cereal products remained homogenous after reconstitution. This ensures that the consumer obtains the same content in every part of the food. All the formulas exhibited a controlled flocculated system with no sign of caking. Also, the addition of xanthan gum as a suspending agent improved the dispersion of non-soluble particles in the suspending medium for a specified time during consumption.[41]

The pH values of the products ranged from 6.11-6.13, while that of *Moringa oleifera* leaves cereal was between the pH stability of antioxidant component which was between 4.0-9.0.[42] Therefore, the cereals in this research can maintain the antioxidant activity of *Moringa oleifera* leaves. The major phytochemical compounds responsible for antioxidant activity are phenolics which provide health benefits associated with prevention, protection against degenerative disease, and reduction of heart disease prevalence in the daily diet.[43] Furthermore, higher pH values of the cereals played a pivotal role in balancing consumer body pH, because ingesting a low portion of acidic foods can lead to heart disease, obesity, cancer, fatigue, and allergies.[30] Based on cereal characteristics evaluation, the *Moringa oleifera* leaves cereal provided the desired characteristics while the xanthan gum concentration and filler type (full cream or combination full cream-soy milk) influenced cereal viscosity and dispersion time. These formulas were promising and were further developed as health-beneficial cereals.

The proximate chemical analysis of cereal products had been accommodated in the quality requirement evaluation based on SNI 01-4270-199 for cereals. Furthermore, formulas 2 and 4 were further studied since they exhibited better physical stability than the other formulas. The data in Table 4 shows *Moringa oleifera* leaves cereal provided adequate content of carbohydrate and protein, while fat was still below the requirement. Formula 4 was observed as a promising formula to be developed in the future. The combination of full cream and soymilk increased the fat content compared to the formula which used only full cream milk as filler, although this substance still requires enhancement in further development. The results of crude fiber and water content were higher than the requirement.

Reduction of particle size and optimization of formula components that contributed to the crude fiber content must be conducted in further research. Also, several components such as xanthan gum, arrowroot powder (*Marantaarundinacea L*), and *Moringa oleifera* leaves are to be optimized in the concentration and production process parameters. The pre-drying of each component is predicted as the solution to decrease the water content in the formula. In addition, the results of ash content and heavy metal content (Pb and Cu) met the specification of cereal (SNI 01-4270-199).

Conclusion

The development of *Moringa oleifera* leaves cereal as a nutraceutical product promises to provide health benefits and improve nutritional value. Based on the results, xanthan gum concentration and filler type influenced the dispersion time and viscosity of cereal. Also, the combination of full cream-soy milk and a 2% xanthan gum exhibited a positive impact on the proximate content.Formula 4 was observed as a promising formula to be developed in the future. However, these components are optimized in further research to meet the crude fiber, water, and fat content regarding SNI requirements (SNI 01-4270-199).

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Conflict of Interest

The author(s) declare no conflict of interest.

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