ADVANCES IN AGRICULTURAL AND FOOD RESEARCH JOURNAL

HH PUBLISHER

Original Research Article

Effect of Different Drying Processing Methods on the Physicochemical Properties of Watermelon Powder

Asnawi, Shahar[1]*, Wan Mohd Fariz, Wan Azman[1], Sharifah Hafiza, Mohd Ramli[1]

[1]Engineering Research Center, MARDI Headquarters, Persiaran MARDI-UPM, 43400, Serdang, Selangor,Malaysia.

*Corresponding author: Asnawi, S.; Engineering Research Center, MARDI Headquarters, Persiaran MARDI-UPM, 43400, Serdang, Selangor,Malaysia; asnawi@mardi.gov.my

Abstract: Watermelon is a tropical fruit popular among Malaysians due to its high essential ingredients such as lycopene. Due to high water content and water activity, watermelon fruit is susceptible to microbial and enzymatic deterioration. Thus, drying fruit juices into powder forms has been one of the common methods used to preserve the fruit. A study was conducted to analyse watermelon powders produced by spray-drying and freeze-drying techniques. Four watermelon extract samples were used on two concentrations of maltodextrin, which were 5% (w/w) and 13% (w/w) towards both drying techniques. The dried powders were analysed for water content, water activity, colour, and solubility. Results demonstrated that the water activity of watermelon powder attained from spray-drying was less than freeze-drying (0.23–0.27 and 0.44–0.47, respectively). The colour analysis showed that freeze-dried watermelon powder has higher redness (a* value), and yellowness (b* value) than spray-dried powder. The water content of the watermelon powder produced through spray-drying yielded lower water content than freeze-drying for both 5% (w/w) and 13% (w/w) of maltodextrin. The solubility of the watermelon powder showed that freeze-drying has a higher solubility time than spray-drying. The study found that the spray-drying technique is the preferred method for producing watermelon powder with a good solubility rate. However, to maintain the colour characteristic of the watermelon powder, the freeze-drying technique is more suitable.

Keywords: watermelon; powder; drying method; physicochemical properties

Received: 23rd February 2022

Received in revised form: 29th July 2022

Available Online: 5th August 2022

Published: 30th December 2022

Citation: Asnawi, S., Wan Mohd Fariz, W. A., F., Sharifah Hafizah, M. R. Effect of different drying processing method on the physicochemical properties of watermelon powder. *Adv Agri Food Res J* 2022; 3(2): a0000305. https://doi.org/10.36877/aafrj.a0000305

1. Introduction

Watermelon (*Citrullus lanatus*) is a member of the Cucurbitaceae family, which is a popular fruit to consume during hot weather and the summer season. It is made out of 90% water content that is abundant to stay hydrated and contains antioxidants such as lycopene that give free radicals towards the body and lower the risk of developing heart disease and cancer. In Malaysia, there are many watermelon cultivars which vary on their sizes, shapes, flesh and skin colours, and seed or seedless. The colour of the flesh ranges from light pink, red, or yellow to orange, while the skin's colour ranges from light to dark greenish (Sabeetha *et al*., 2017). However, in the local market, the most favoured cultivars include the red and yellow flesh watermelon cultivars, being both seeded and seedless (Sabeetha *et al*., 2017).

Watermelon juice secures the chemical-induced hepatotoxicity in rats (Altaş *et al*., 2011), rise the plasma concentrations of β-carotene in people (Edwards *et al.,* 2003), and grows the antiproliferative activity in cell lines of both liver cancer and human breast cancer (Rahmat *et al.,* 2002). However, watermelon juice is sensitive to both oxygen and heat, which may cause the juice to be off-colour due to high temperature and ruins the phenolic compound of the watermelon juice. Therefore, the analysis of watermelon powder can be compared using the spray-drying and freeze-drying techniques to determine its physicochemical properties. Watermelon powders also have the potential to be used as a colourant, flavouring, and essential ingredient, as well as in the manufacture of lycopene-rich capsules with functional and nutritional value (Shi *et al.,* 2018)

Spray-drying is an excellent common method for preserving heat and oxygen-sensitive fruits (Shi *et al.,* 2018). The method entails atomising the solution in hot air to produce a powder product in a short amount of time. Aside from preserving colour and aroma, dried powders offer significant cost savings over liquids, such as in lowering the weight, minimising packaging, and ensuring longer shelf life (Tuyen *et al.,* 2010).

In addition, freeze-drying is another approach well used in industry. It is about a dehydration process that removes water through ice sublimation from the frozen products. The process preserves the natural fresh fruit colour, texture, flavour, nutritional content, taste, physical characteristics, chemical compound, and biological activity with just minor alteration (Nawirska *et al.,* 2009).

Generally, different drying methods and parameters in processing watermelon fruits or fruit pulp into powder may cause changes in the physicochemical properties such as colour (Oberoi *et al.,* 2015), moisture content (Oberoi *et al.,* 2015), water activity (Goula & Adamopoulos, 2005) and also solubility (Cano-Chauca *et al*., 2005).

Therefore, the analysis of watermelon powder needs to be compared using the spray-drying and freeze-drying techniques to determine its quality and physicochemical properties. Thus, the objective of this experiment is to identify the effect of two different drying applications (spray drying and freeze-drying techniques) added with various concentrations of maltodextrin on the physicochemical characteristics of watermelon powder.

2. Materials and Methods

2.1. Material

Malaysian red flesh seedless watermelon cultivar was purchased from the local supermarket (Serdang, Selangor). The fresh watermelon data of weight raw, edible, skin, and juice were recorded using an electronic weighing balance (Model EL02HS, CAMRY, USA).

2.2. Sample Preparation

Fresh watermelon was cut, and red flesh was removed using a blender machine (Pensonic 1-speed Blender PB-3205) for juice extraction. The juice was extracted, and filtered through a 15 µm nylon mesh sheet filter. The juice was then divided into two jugs for two different drying methods; spray-drying and freeze-drying. Maltodextrin was used as a drying agent, allowing the watermelon juice mixture to become powder form easily. Maltodextrin with 5% and 13% (w/w) concentrations was used and mixed with the watermelon juice as shown in Table 1. The mixture was homogenised using a homogeniser (L5M-A, SILVERSON, USA) about 3 min to ensure the maltodextrin was fully dissolved.

Table 1. Concentration of maltodextrin used in the formulation

Ingredients	**0% (w/w) maltodextrin**		**5% (w/w) maltodextrin**		**13% (w/w) maltodextrin**	
	%	kg	%	kg	%	kg
Watermelon juice	100	1.15	95	1.10	87	1.00
Maltodextrin	0	0	5	0.05	13	0.15
Total	100	1.15	100	1.15	100	1.15

2.3. Spray-Drying

The watermelon juice was prepared with 5% (w/w) and 13% (w/w) maltodextrin for spray-drying. The spray dryer (Model B-290, BUCHI, Switzerland) were used. The drying parameters were inlet and outlet temperatures of 150 °C and 60 °C respectively, speed of 12 rpm, and 41.4 mL/min flow rate. The watermelon powders were collected in a glass bottle and further analysed.

2.4. Freeze-Drying

The homogenized juice was cooled and frozen in the freezer (Model PEN-PFZ202, Pensonic, Malaysia) at -40°C for 12 h. The frozen juice was placed in a freeze-dryer machine (Model VirTis 35EL, GENESIS, USA) and freeze-dried for three days at -48°C condenser temperature under vacuum (13.33 Pa absolute pressure).

2.5. Physicochemical Analysis

2.5.1 Analysis of moisture content

The sample was analysed based on the standard method of AOAC (2006). The sample was homogenised using a homogeniser (Model L5M-A, SILVERSON, USA) for about 3 min before the measurement was taken. Watermelon powder was weighed and dried for 24 h at 70˚C in a vacuum oven. The samples were then weighed after cooling in a desiccator. The sample was dried and weighed repeatedly until a constant final weight was achieved. Data were recorded, and analysis was done in triplicates.

2.5.2 Analysis of water activity

A water activity analyser (Model AquaLab Series 3, Decagon, USA) was used to determine the water activity of the watermelon powder. The samples were analysed in triplicates, and the results were recorded.

2.5.3 Colour evaluation

A colorimeter (Model Minolta CR-410, Konica Minolta, Japan) was used to analyse the colour of the watermelon powder. Lightness (L*), redness (a*), and yellowness (b*) were recorded. Prior to sample analysis, the colorimeter was calibrated using a standard white ceramic tile. The analysis was carried out in triplicates and recorded.

2.5.4 Solubility test

The solubility test was done by weighing and filling 50 mg of sample into a small test tube (Quek *et al*., 2007). Then, the test tube was filled with 1 mL of distilled water and stirred with a vortex at half speed until the watermelon powder was fully dissolved. A timer was used to record the amount of time for the watermelon powder to dissolve completely as a practice by (Quek *et al*., 2007). The sample was done in triplicates.

2.6 Statistical Analysis

The statistical analysis was conducted using a two-way analysis of variance (ANOVA). Two factors were studied, which were the different concentrations of maltodextrin and different drying methods. The comparison between all the factors was carried out using Tukey's test method with a confidence level of 95%. Statistical analysis was carried out using Minitab Software version 19 (Minitab, LLC, USA). All analyses were conducted in triplicates.

3. Results and Discussions

3.1. Watermelon Juice's Physicochemical Properties

Based on the results, Table 2 showed the total soluble solids content (Brix), pH, moisture content, water activity, and colour of watermelon juice. The characteristics of the feed used, such as viscosity and solids concentration, are essential parameters in spray-drying (Tonon *et al*., 2009). These are to ensure an acceptable amount of yield will be obtained. The total solid content of the watermelon juice for formulations A (0% maltodextrin), B (5% maltodextrin), and C (13% maltodextrin) (w/w) were 7.67, 12.33, and 19.00, respectively. The increasing amount of maltodextrin in different formulations showed an increase in total solid content. Maltodextrin is a starch hydrolysis product that is composed primarily of D-glucose units linked by glycosidic bonds (Tonon *et al.*, 2009). Thus, the increasing percentage of maltodextrin will cause the total soluble solid content to increase. This was also proven by Oberoi *et al.* (2015), where maltodextrin increases the total solid content in the watermelon juice.

The analysis results for the moisture content of watermelon juice for formulations A, B, and C were 92.33%, 87.67% and 81.00% (wb), respectively. The moisture content of watermelon juice decreased with the addition of higher maltodextrin, implying that the increase in maltodextrin content in different formulations would also reduce the juice's moisture content. Based on formulation A with 0% maltodextrin, the moisture content of watermelon juice was similar to the previous a study, which was 92.02% (Naz *et al., 2013).*

The pH value of the watermelon juice for formulations A, B, and C were 5.21, 5.12, and 5.07, respectively. Increasing the maltodextrin content would reduce the pH value of watermelon juice. The pH value without maltodextrin addition was 5.21, which is approximate to the initial pH of fresh watermelon juice, 5.2, as done by Ishita and Athmaselvi (2017). Watermelon juice with a pH of 5.79 is susceptible to microbial growth based on the physicochemical properties of the watermelon juice used for spray-drying found by Quek *et al.* (2007).

Water activity represents the free water in a food system that is responsible for biochemical reactions, whereas the moisture content represents the water composition in a food system. High water activity suggested more free water available for biochemical reactions, which resulted in a shorter shelf life. In theory, food with a water activity of less than 0.6 is considered microbiologically stable, and if any spoilage occurs, it is caused by chemical reactions rather than by microorganisms (Quek *et al*., 2007).

For colour analysis, L-value represents the sample lightness, +a* represents the red colour, and +b* represents the yellowish colour. The results showed that with increasing maltodextrin concentration, the value of 'L', 'a', and 'b' also increased (Table 2). The increase of 'a' and 'b' values indicates that the redness and yellowness of watermelon juice increased. An increase in the 'L' value indicates that the powder became lighter in colour as the concentration of maltodextrin increased. The presence of lycopene pigment in watermelon juice gives it a red colour (Oberoi *et al.*, 2015). For, the 'a' value, the result slightly fluctuated which increased to 43.88 value with 5% maltodextrin compared to without maltodextrin, however, it decreased to 40.43% with 13% of maltodextrin. This might be due to the presence of a small amount of maltodextrin, 5%, which reduced the moisture content and hence increased the redness of the juice because of the lycopene. Adding more than 5% maltodextrin decreased the 'a' value of juice due to the presence of white colour from the maltodextrin. The yellowness of the juice increased with the increasing amount of maltodextrin. Maltodextrin is currently the most widely used drying agent for spray-drying, owing to its usefulness as a carrier or encapsulating agent (Tuyen *et al.*, 2010). Moreover, the colour of foods is a significant sensory characteristic where the maltodextrin will encapsulate the colour pigment that will preserve the colour of the watermelon juice.

Table 2. Physicochemical characteristics of watermelon juice added with different maltodextrin concentrations.

Analysis	A (0%)	B (5%)	C (13%)
TSS of juice (˚Brix)	7.67±0.58[c]	12.33±0.29[b]	19.00±0.00[a]
pH	5.21±0.02[a]	5.12±0.01[ab]	5.07±0.09[b]
Moisture content	92.33 ± 0.58[a]	87.67 ± 0.29[b]	81.00± 0.00[c]
Water activity	0.96±0.01[a]	0.97±0.00[a]	0.97±0.00[a]
Colour parameters	L:45.49±1.12[b]	L:47.47±0.10[b]	L:52.81±0.95[a]
	a:28.35±1.18[c]	a:43.88±0.20[a]	a:40.43±1.48[b]
	b:9.57±0.495[b]	b:17.71±0.11[a]	b:19.02±0.88[a]

*Means within each row with different superscript letters indicate significant differences ($P<0.05$) as measured in Tukey's Multiple Comparison Test

3.2 Watermelon Powder Physicochemical Properties

The physicochemical properties of spray and freeze-dried powders were shown in Table 3. The inlet temperature, airflow rate, feed flow rate, atomiser speed, types, and carrier agent concentration influence the physicochemical properties of the spray-dried final product (Phisut, 2012). The temperature of the inlet significantly impacts the physicochemical properties of spray-dried powders (Quek *et al*., 2007). In this study, the parameters of spray-dried used are 150°C, and 60°C for inlet and outlet temperature, respectively with 12 rpm of speed. Analysis of powder for formulation A was not analysed due to 0% of maltodextrin.

3.2.1. Analysis of moisture content

Based on Table 3, the moisture content of spray-dried watermelon powder for 5% and 13% maltodextrin are 2.27% and 2.20%, respectively. According to the findings, the moisture content of the spray-dried powder decreased as the percentage of maltodextrin added increased. According to the Oberoi and Sogi (2015), the moisture content of spray-dried watermelon juice powder decreased as maltodextrin content increased from 3% to 10%. The water content of the feed has an impact on the final moisture content of the powder produced in a spray drying system (Abadio *et al.*, 2004). Maltodextrin added at the initial feeding of the spray-drying will increase the total solid content and reduce the amount of water for evaporation, hence, decreased the moisture contents of the producing powder. This meant that maltodextrin could be used to reduce the moisture content of the product. However, there is a limit of maltodextrin that can be used in producing powder. High percentages of maltodextrin will produce less quality powder because the nutrients from the watermelon juice would be diluted (Quek *et al.*, 2007). Based on Table 3, the moisture content of freeze-dried powder also reduced from 2.49 to 2.43%, with the increase in maltodextrin percentage. When comparing the two methods of the drying process, the freeze-dried powder has significantly ($p \leq 0.05$) higher moisture content than spray-dried powder. According to Oberoi and Sogi (2015), the significant difference was caused by sublimation in the freeze-drying method. Thus, spray-drying is a better drying method than freeze-drying for removing the moisture content of the Malaysian red flesh seedless watermelon cultivar.

Table 3. Comparison of physicochemical properties of spray-drying and freeze-drying watermelon powders.

Analysis	**Spray- drying**		**Freeze- drying**	
	Maltodextrin 5%	Maltodextrin 13%	Maltodextrin 5%	Maltodextrin 13%
Moisture content	2.27±0.52^{Ab}	2.20±0.44^{Ab}	2.49±1.33^{Aa}	2.43±0.08^{Aa}
Water activity	0.27±0.03^{Bb}	0.23±0.01^{Bb}	0.44±0.01^{Aa}	0.47±0.01^{Aa}
Colour	L:64.98±3.02^{Aa}	L:69.97±1.50^{Aa}	L:26.10±0.63^{Bb}	L:26.25±1.07^{Bb}
	a:16.88±1.08^{Ab}	a:16.90±0.66^{Ab}	a:18.78±1.19^{Aab}	a:21.47±2.59^{Aa}
	b:11.54±1.14^{Ab}	b:9.72±0.59^{Ab}	b:22.24±0.37^{Aa}	b:22.54±0.64^{Aa}
Solubility (s)	125.00±43.70^{Ab}	121.00±10.54^{Ab}	210.00±39.1^{Aa}	275.00±62.40^{Aa}

Data given were mean values ± standard deviation of triplicates (n=3). Capital different letters indicate a difference (p<0.05) between mean values within the concentration of maltodextrin. Small letters indicate a significant difference with (p<0.05) between mean values within the method of processing

3.2.2 Water activity, a_w

Water activity is one of the important indicators to have great shelf-life effect of the fruit powder. Theoretically, food with water activity, a_w< 0.6 is considered microbiological stable (Quek *et al.*, 2007). According to the results (Table 3), the water activities of the spray-dried powders were in the range of 0.23–0.27 with 13% maltodextrin having the lowest water activity compared to 5% maltodextrin. Thus, both maltodextrin concentrations for spray-dried powders were microbiologically stable. These findings were in line with those of other researchers (Goula & Adamopoulos, 2005; Masters, 1991). The maltodextrin encapsulates the molecules in the watermelon juice, which causes the free water in watermelon juice to be lower than the fresh watermelon juice. Meanwhile, the water activity of freeze-dried powder was significantly higher ($p \leq 0.05$) than that of spray-dried powder for 5% maltodextrin and 13% maltodextrin, respectively, at 0.44 and 0.47. However, both concentrations of freeze-dried powder also were in the range of microbiological stability. The trend between water activity and moisture content in freeze-dried products was inversely proportional due to higher hygroscopicity and amorphous sugars, thus able to absorb more free water than spray-dried powder (Carlos *et al.*, 2005). This indicates that watermelon samples that have been dried with freeze-dried techniques have more free water for biological reactions.

3.2.3 Analysis of colour

Analysis of colour is an important quality indicator for sensory attractiveness and the quality of the final product produced in the spray-drying process (Quek *et al*., 2007). From Table 3, the L* value for formulation 13% was higher than 5% due to the higher percentage of maltodextrin, and both formulations showed an increasing value of L* after the spray-drying process. This could be due to the products' moisture content being reduced, resulting in increased powder lightness in the presence of maltodextrin. When compared to samples before the spray-drying process, a* and b* values for both formulations decreased. This is because the maltodextrin and the drying process caused the colour of the watermelon juice to decrease due to the destruction of juice pigment (Oberoi & Sogi, 2015). For the spray-dried powder, adding more maltodextrin to the watermelon juice shows an increase in a* value indicating more redness. The colour of the spray-dried powder is commonly affected by the concentration of maltodextrin (Tuyen *et al.*, 2010). Lycopene contents are an indicator of nutrient preservation during the spray drying process, hence the lycopene content could affect the colour of the spray-dried powder produced (Quek *et al*., 2007). The preservation redness colour of watermelon in the 13% maltodextrin in spray dried watermelon powder indicates that the maltodextrin able to encapsulate more lycopene, hence, increase the a* value in 13% maltodextrin formulation.

The freeze-dried powder showed no significant increase ($p \geq 0.05$) in the L* value by changing the maltodextrin concentration from 5% to 13%. However, the L* value was significantly lower in comparison to spray-dried powder for both formulations. Compared to the spray-dried powder, it also showed higher redness (a* value) and yellowness (b* value), indicating that the freeze-dried product has more redness and yellowness in colour. The droplet form for spray-dried products has a larger surface area, thus providing more exposure to the air, which contributed to the oxidation of lycopene faster than the freeze-dried product (Goula & Adamopoulos, 2005).

3.2.4 Solubility

The most reliable criterion for evaluating the behaviours of powder in an aqueous solution is solubility. Maltodextrin has a high-water solubility, which has made it a popular carrier agent in the spray-drying process (Cano-Chauca *et al*., 2005; Phisut, 2012). As the concentration of maltodextrin increased, less time was required to dissolve the spray-dried powders. According to the results presented in Table 3, the solubility increases as the concentration of maltodextrin increases. This result was consistent with the findings by Cano-Chauca *et al*. (2005), who found that adding maltodextrin to mango powders during spray-drying increased its solubility. Maltodextrin is a material that acts as a coating agent when a particle crust forms during spray drying, resulting in a highly soluble product (Desai & Park, 2004). Based on the findings, maltodextrin was found to be effective in increasing the solubility of spray-dried watermelon powder. Products with high moisture content and low maltodextrin have a higher tendency to agglomerate, which helps to increase powder reconstitution (Masters, 1991). Due to the high moisture content of freeze-dried powder, it takes a longer time to dissolve and has high reconstitution capacity than spray-dried powders, which have 210s and 275s for 5% and 13% maltodextrin concentration, respectively.

4. Conclusions

The purpose of this study was to identify the physicochemical properties of watermelon powder based on different methods of the drying process (spray drying and freeze-drying) added with different concentrations of maltodextrin 5% (w/w) and 13% (w/w). Both drying techniques showed greater effects on reducing moisture content. Freeze-dried watermelon powder resulted in higher water activity than spray-dried powder due to its highly hygroscopic nature, which indicates more free water for biological activities and reduces the shelf life compared to spray-dried powder. The colour analysis showed that freeze-dried watermelon powder has better quality than spray-dried powder due to low lightness (L*), high redness (a*), and yellowness (b*) values which indicate that spray-dried watermelon powder would produce low quality in terms of colour appearance. However, freeze-dried watermelon powder's solubility was much lower than spray-dried powders. For the overall study, spray-drying techniques are the best method to produce watermelon powder with a good solubility rate and shelf stability. However, freeze-dried drying techniques are preferable for producing watermelon powder that maintains the characteristics of the colour appearance as fresh watermelon fruit.

Funding: No external funding was provided for this research

Acknowledgments: The authors would like to acknowledge the financial support by MARDI, technical supports from UPM and team members whose contribution to stimulating suggestions, encouragement, and coordinate this project.

Conflicts of Interest: The authors declare no conflict of interest.

References

Abadio, F. D. B., Domingues, A. M., Borges, S. V., *et al.* (2004). Physical properties of powdered pineapple (Ananas comosus) juice-effect of maltodextrin concentration and atomization speed. *Journal of Food Engineering*, 64, 285– 287.

Association of Official Analytical Chemists. Official Methods of Analysis of the Association of Official Analytical Chemists, 18^{th} ed.; AOAC Press: Gaithersburg, MD, 2006.

Altas S., Kizil G., Kizil M., *et al.* (2011). Pro-tective effect of Diyarbakir watermelon juice on carbon tetrachloride-induced toxicity in rats. Food and Chemical Toxicology, 49, 2433–2438.

Cano-Chauca, M., Stringheta, P. C., Ramos, A. M., *et al.* (2005). Effect of the carriers on the microstructure of mango powder obtained by spray drying and its functional characterization. *Innovative Food Science & Emerging Technologies*, *6*(4), 420–428.

Carlos, L. A., Resende, J. D., Cal-Vidal, J. (2005). Reduction from higroscopicidade of powders liofilizados by induction from crystallization em solutions-model of sugars constituents of fruits. *Journal of Food Technology*, 8(2), 163–173.

Desai, K. G. H., & Park H. J. (2004). Solubility studies on valde-coxib in the presence of carriers, cosolvents, and surfactants. *Drug Development Research*, 62(1), 41–48.

Edwards A. J., Vinyard B. T., Wiley E. R., *et al.* (2003). Consumption of watermelon juice increases plasma concentrations of lycopene and β-carotene in humans. *The Journal of nutrition*, 133, 1043–1050.

Goula, A. M. & Adamopoulos, K. G. (2005). Stability of lycopene during spray dryingof tomato pulp, *LWT-Food Sci. Technol*. 38 (5), 479–487.

Ishita, C. & Athmaselvi, K. A. (2017). Changes in pH and colour of watermelon juice during ohmic heating. *International Food Research Journal,* 24(2), 741–746.

Masters, K. (1991). *Spray Drying Handbook* (5th ed., pp. 365-638). Harlow: Pearson Education Limited.

Nawirska, A., Figiel, A., Kucharska, A. Z., *et al.* (2009). Drying kinetics and quality parameters of pumpkin slices dehydrated using different methods. *Journal of Food Engineering*, 94, 14–20.

Naz, A., Butt, M. S., Pasha, I., *et al.* (2013). Antioxidant indices of watermelon juice and lycopene extract. *Journal of Pakistan Nutrition*, *12*(3), 255–260.

Oberoi, D. P. S., & Sogi, D. S. (2015). Effect of drying methods and maltodextrin concentration on pigment content of watermelon juice powder. *Journal of Food Engineering*, *165*, 172–178.

Phisut, N. (2012). Spray drying technique of fruit juice powder: some factors influencing the properties of product. *International Food Research Journal*. 19(4), 1297–1306.

Quek, S. Y., Chok, N. K. & Swedlund, P. (2007). The physicochemical properties of spray dried watermelon powders. *Chemical Engineering and Processing,* 46, 386–392.

Rahmat A., Rosli R., Zain W. N. I. W. M., *et al.* (2002). Antiproliferative activity of pure lycopene com-pared to both extracted lycopene and juices from watermelon (*Citrullus vulgaris*) and papaya (*Carica papaya*) on human breast and liver cancer cell lines. *Journal of Medical Sciences*, 2, 55–58.

Santo, E., Lima, L., Torres, A., *et al.* (2013). Comparison between freeze and spray drying to obtain powder Rubrivivax gelatinosus biomass. *Food Science And Technology*, *33*(1), 47–51. doi: 10.1590/s0101-20612013005000008.

Shi Y., Wang J., Wang Y., *et al.* (2018): Inlet temperature affects spray drying quality of watermelon powder. *Czech Journal of Food Science*, 36, 321–328.

Tonon, R. V., Brabet, C., Pallet, D., *et al.* (2009). Physicochemical and morphological characterisation of açai (Euterpe oleraceae Mart.) powder produced with different carrier agents. *International Journal of Food Science & Technology*, *44*(10), 1950–1958.

Tuyen, C. K., Nguyen, M. H., & Roach, P. D. (2010). Effects of spray drying conditions on the physicochemical and antioxidant properties of the Gac (Momordica cochinchinensis) fruit aril powder. *Journal of Food Engineering*, *98*(3), 385–392.