Determination of production factors of dehydrated strawberries by using Taguchi method approach

I C Ardhani, R M Putri, M A F Falah* and K H Widodo

Departement of Agroindustrial Technology, Faculty of Agricultural Technology, Universitas Gadjah Mada, Jl. Flora No 1 Bulaksumur Yogyakarta, Indonesia, 55281

Corresponding author: affan_tip@ugm.ac.id

Abstract. Dehydrated fruit is important as an alternative to increase shelf-life and the value of the fresh fruit. Hence, it is important to know approach for this processing. Objective of the study was to know the optimal combination for treatments of material and process for production of dehydrated strawberries by using Taguchi method. The treatments were the combinations from orthogonal array and signal to noise ratio from Taguchi method with several control variables of processing of timing and concentration during immerse in osmotic solution (30,45,60 minutes) and (30, 40, 50 °Brix) and also drying temperature (50, 60, 70 °C) were applied in this processing. Several quality parameters of dehydrated fruits were determined such as color of skin fruit, texture, water content, vitamin C, total phenol, acidity, and total soluble solid were measured using standard method. Results showed that, optimum condition for drying temperature was 70°C, and concentration and timing during osmotic dehydration were 60 minutes and 50 °Brix, respectively. Drying temperature was highest factor that affected quality of the dehydrated fruit processing. Physical characterization of dehydrated strawberries were skin drying with softened flesh of fruit, darker red color, and chemical characterization sweet taste, low acidity, high vitamin C and total phenol.

1. Introduction

Strawberry (Fragaria x annanassa) is one of the world’s largest fruit crops and also one of the most delicate and highly perishable fruits, due to respiration, weight loss and susceptibility to fungal contamination [1]. Strawberries can be consumed in natural due to their sensitivity to fungal attack and excessive textures softening caused by the natural ripening process [2]. It can also be processed in many other forms such as juice, concentrate jam, and jelly and dried rehydrated with yoghurt and bakery products [3]. On the other side, phenolic compounds in strawberry are represented by the flavonoids (mainly anthocyanins and flavanols) and anthocyanins in strawberries are the best-known polyphenolic compounds and quantitatively the most important [4]. It is important as antioxidant activity component that beneficial for human health such as in the prevention of certain types of cancers, anti-inflammatory functions, other chronic diseases [5]. However, strawberry’s phenolic content varies with the cultivars, growing conditions, degree of ripeness, and handling after harvest, where for anthocyanin content increases with ripeness of the fruit [6].

Processing has been a crucial aspect of the fruits and vegetables production chain that associates agricultural production with the delivery of food and aimed for optimizing nutrient availability and to maintain product quality along with the reduction of losses and wastes [7]. Dehydration is the oldest method for applied processing fruit to preserve the food, and objectives of this method are to remove
water until the water activity is low enough to prevent growth of microorganisms and increase the shelf life of the product [8]. Dehydration of strawberry must consider the effect of high temperature on all factors that determine the nature of the fruit. The process should be used with special care in strawberry to avoid the chemical changes of some important functional components [9]. High temperatures on dehydration such as hot air drying can produce a harmful effect in the product instead of maintaining the qualities for which these products are especially appreciated [10]. Furthermore, for the dehydration of fruits, some pre-treatments are used to enhance the drying rate, thus allowing shorter processing times for better product quality. Due to the high moisture content of agricultural products, osmotic dehydration is often applied as a pre-treatment procedure for obtaining final products with desirable taste and long shelf life [11]. During the osmotic pre-treatment, simultaneous solids gain plays a crucial role in mass exchange, then optimal concentration of the osmotic solution assures a high effectiveness of dehydration and improves the flavor of the dried product [12].

The demand of high-quality dehydrated products in the market requires dried foods to maintain nutritional and organoleptic properties of initial fresh products at very high levels [13]. One of the methods to approach optimization technique is Taguchi Method. Taguchi method is a unique and powerful optimization discipline that allows optimization with minimum number of experiments, and this method have some advantages, such as that numerous factors can be simultaneously optimized and more quantitative information can be extracted from fewer experimental trials. The experimental design also can reduces cost, improves quality, and provides robust design solutions [14]. Furthermore, Taguchi method is used to find the impact of different factors on product properties and determine optimal conditions of factors [15] and also as an alternative to full factorial design, more straight-forward to use, faster and simultaneously precise, and reliable, saves time and reduce costs [16].

Objective of the study was to know the optimal combination for determination of material and processes for production of dehydrated strawberry by using Taguchi Method approach. Combination of osmotic dehydration with convective hot air drying for production of dehydrated strawberry fruit could be optimized and resulted high quality dehydrated fruit product with longer shelf-life that acceptable in the consumer market.

2. Materials and methods

Samples of strawberry (Fragaria ananassa var. Oso grande) with maturity level of 100%, which was indicated by strawberry fruit surface with full red color. Simple greenhouse production was located in Cangkringan, Sleman. Sample of fresh strawberry was transported in packing bags to the Faculty of Agricultural Technology, Universitas Gadjah Mada. Dehydrated strawberry was made using combination of pre-treatment by osmotic dehydration with hot air convective drying method.

2.1. Dehydrated fruit strawberry production with osmotic dehydration

Fresh strawberry fruits were cleaned up using running tap water thoroughly to make the surface of the fruit more hygienic and to disappear some dirty sand or dust, then the fruit samples were put into a tray for several minutes for natural drying. The strawberries were immersed in the solution of sucrose with range of concentration between 30-50 °Brix. The solution was shaken and fresh strawberries were added using magnetic stirrer for 60 minutes with temperature of concentrate sucrose solution around 27-30 °C. Last process of osmotic dehydration was immersing the strawberry with sucrose solution for around 30-60 minutes. Fresh strawberries from osmotic dehydration process was put on the tray for 2-3 minutes before continue the process using dehydrator. Osmotic dehydration is an important intermediate step or pre-treatment technology in the preservation of fruits, it will improve the product quality by reducing the damage of heat to the flavor, color, inhibiting the browning of enzymes and decreases the energy costs [17] and osmotic dehydration of plant materials is performed in solutions, and previously, sucrose was applied for osmotic dehydration of strawberries [18].

Dehydrated strawberry drying process in this experiment was conducted using a dehydrator (MKS-FDH6, Maksindo, Malang, Indonesia) which used convective hot air drying principles. Convective
drying is still one of the most extensively used method for dehydration of food products [19]. During convective drying a drying agent consist mainly of hot air that simultaneously provides the energy necessary for water evaporation and subsequently evacuates water vapor out of the dryer. Fresh strawberries from osmotic dehydration process were laid down into tray of the dehydrator with drying temperature between 50-70°C for 6 hours, and then after the process is finished, they were moved into a desiccator for 24-48 hours to stabilize their conditions. Several parameters for production process using combination of convective hot air drying and osmotic dehydration for pre-treatment to produce the high quality of dehydrated strawberry in this study was not reached the optimum condition, and it needs to be optimized using optimizing technique. Optimizing technique for this study was used Taguchi method, and several processes to produce quality parameter of dehydrated strawberry fruit were important to be determined for receiving optimum conditions.

2.2 Physicochemical quality parameter of dehydrated of strawberry fruit
Physicochemical quality parameters of dehydrated strawberry fruit were determined using standard method. Physical content of skin color of dehydrated strawberry fruit was measured using a chromameter (Minolta, CR-400, Japan) on Lightness (L) – redness (a) – yellowness (b) values and calculated color change (ΔE) based on Mendez-Lagunas, et al. [20]. The texture of the skin was determined using a Fruit Hardness Tester (FHT200, Extech, Taiwan). The chemical content of dehydrated strawberry such as water content was analyzed using a thermo-gravimetric method, total phenolic content using Folin-Ciocalteu [21], vitamin c content was determined using indophenols titration method [22], soluble solid content (°Brix) was measured using refractometer (PAL-1, Atago Co. Ltd. Japan), and the acidity of dehydrated fruit was measured using titratable acidity approach [22].

2.3 Taguchi method approach
Taguchi Method was chosen because of its excellence than the conventional statistical methods, fewer trials in experimental design, improves quality, provides robust design solutions, an alternative to full factorial design, more straight-forward to use, faster and simultaneously precise, reliable, saves time and it can reduce costs [14-16]. Taguchi method have several steps that known as design system, design parameter and design of tolerance that was shown in figure 1 mentioned below.

2.3.1 Taguchi design system. In this experiment, step one of the Taguchi method was explained as design system which consists of identification of problems, determination of research objectives and benefits, study literature, identification of the required data and choosing the methodology of design for initial step for design system. Next step of design system were identification of control factors, levels and value of factors of determination of the processing, in this experiment, three level factors were chosen, first factor was drying temperature of hot air drying (A) with three levels of 50°C, 60°C and 70°C; second factor was concentration of solution for osmotic dehydration (B) with three levels of 30°Brix, 40°Brix and 50°Brix and third factor was immersion time of strawberries during osmotic dehydration (C) with three level of 30 minutes, 45 minutes and 60 minutes. Last step in the design system was to determines the quality parameters of dehydrated strawberry and it was mentioned above in subsection 2.2 of physiochemical of quality parameter of dehydrated strawberry.

2.3.2 Taguchi design of parameters. Second step of this experiment with Taguchi method were design of parameters. The first step of design parameter was to determine of orthogonal array. To determine orthogonal array, it was decided by calculating the control and factor levels for the degree of freedom. In this experiment, three control factors and levels were used, this condition have 6 (six) minimum experiments, then orthogonal array was determined based on this condition.

In this experiment, L₀ (2⁴) was chosen based on three control factors with three different levels and larger than minimum condition for degree of freedom calculation mentioned above. Orthogonal array for the experiments can be shown in table 1.
Figure 1. Taguchi method approach using three steps of design of systems, design of parameters and design of tolerance for determining process parameter of dehydrated strawberry production

The next step was conducting the matrix experiment based on orthogonal array. The data was tabulated and calculated as the mean for each parameter using standard of Microsoft excel (Microsoft Corporation).

Table 1. Orthogonal array of Taguchi Method with L₉ experiment determining process parameter of dehydrated strawberry production

| Exp. | Drying Temp. (A) | Conc. of solution (B) | Immersion Time (C) |
|------|------------------|-----------------------|--------------------|
| 1    | 1                | 1                     | 1                  |
| 2    | 1                | 2                     | 2                  |
| 3    | 1                | 3                     | 3                  |
| 4    | 2                | 1                     | 2                  |
| 5    | 2                | 2                     | 3                  |
| 6    | 2                | 3                     | 1                  |
| 7    | 3                | 1                     | 3                  |
| 8    | 3                | 2                     | 1                  |
| 9    | 3                | 3                     | 2                  |

| Exp. | Drying Temp. (A) | Conc. of solution (B) | Immersion Time (C) |
|------|------------------|-----------------------|--------------------|
| 1    | 50°C             | 30°Brix               | 30 minutes         |
| 2    | 50°C             | 40°Brix               | 45 minutes         |
| 3    | 50°C             | 50°Brix               | 60 minutes         |
| 4    | 60°C             | 30°Brix               | 45 minutes         |
| 5    | 60°C             | 40°Brix               | 60 minutes         |
| 6    | 60°C             | 50°Brix               | 30 minutes         |
| 7    | 70°C             | 30°Brix               | 60 minutes         |
| 8    | 70°C             | 40°Brix               | 30 minutes         |
| 9    | 70°C             | 50°Brix               | 45 minutes         |
The data then was used to calculate the Signal to Noise Ratio (SNR) of each quality parameter of dehydrated strawberries based [23]. Three types of SNR, firstly smaller is better for water content and color of yellowness, secondly nominal the best for color lightness, redness, color change and Acidity and third larger is better for texture, vitamin C, total phenol and soluble solid content and then calculation of effect of SNR. The next step was statistical analysis with two ways ANOVA using SPSS ver. 23 (SPSS Inc). The last step in design parameter of Taguchi method was to calculate the multiple response characteristics and optimum condition level of multiple response characteristics; and all Taguchi method of parameter were calculated based on Taguchi et.al [23].

2.3.3 The Taguchi design of tolerance. The last step of Taguchi method was to conduct the design of tolerance, with confirmation attempt of the results from the experiment. This design of tolerance were to make sure that a similar mean quality parameter of product can be reproduced using significance level of 90% or 95% for statistics using SPSS ver. 23 (SPSS Inc).

3. Results and discussion
Dehydrated strawberries were produced using set of processing with osmotic dehydration as pre-treatment with hot air convective drying using dehydrator; and Taguchi method was used to optimize this combination process as with three factors and three levels that mentioned above. Data of responses in Taguchi method that known as quality characterization of dehydrated strawberries were analyzed using optimization technique based on the step of Taguchi method using orthogonal array L9, and it were described in detailed below.

3.1 Effects of mean and SNR responses to quality characterization of dehydrated strawberry

Table 2. Mean value responses of quality characterization of dehydrated strawberry

| Exp. | (L) | (a) | (b) | Color change (AE) | Texture (N) | Water content (%) | Vitamin C (mg/100g) | Total Phenol (%) | SSC (%) | Acidity (%) |
|------|-----|-----|-----|------------------|-------------|------------------|---------------------|-----------------|---------|------------|
| 1    | 34.94 | 30.94 | 16.80 | 65.56 | 12.78 | 38.60 | 185.64 | 0.58 | 3.51 | 2.34 |
| 2    | 32.55 | 27.75 | 19.68 | 67.40 | 11.35 | 44.69 | 132.89 | 0.36 | 3.04 | 1.13 |
| 3    | 33.09 | 26.79 | 16.99 | 65.75 | 9.78 | 38.13 | 258.82 | 0.65 | 3.97 | 3.30 |
| 4    | 34.43 | 25.03 | 16.49 | 63.79 | 12.68 | 43.82 | 204.98 | 0.52 | 3.42 | 2.46 |
| 5    | 33.28 | 25.03 | 19.57 | 65.74 | 10.55 | 37.31 | 183.84 | 0.57 | 2.86 | 2.21 |
| 6    | 36.95 | 27.20 | 16.29 | 62.22 | 12.15 | 46.58 | 183.84 | 0.67 | 3.09 | 2.21 |
| 7    | 29.62 | 23.80 | 15.74 | 65.93 | 13.50 | 39.48 | 197.66 | 0.54 | 3.46 | 2.68 |
| 8    | 31.62 | 24.66 | 12.93 | 67.22 | 14.83 | 35.18 | 233.42 | 0.69 | 3.82 | 1.93 |
| 9    | 29.82 | 23.36 | 14.80 | 66.14 | 12.03 | 32.62 | 225.39 | 0.59 | 3.93 | 2.43 |

Table 3. Calculation of SNR responses to quality characterization of dehydrated strawberry

| Exp. | (L) | (a) | (b) | Color change (AE) | Texture (N) | Water content (%) | Vitamin C (mg/100g) | Total Phenol (%) | SSC (%) | Acidity (%) |
|------|-----|-----|-----|------------------|-------------|------------------|---------------------|-----------------|---------|------------|
| 1    | 30.87 | 29.71 | 24.50 | 36.33 | 22.11 | -31.73 | 45.36 | -4.73 | 10.91 | 7.35 |
| 2    | 30.24 | 28.84 | 25.46 | 36.57 | 21.09 | -33.00 | 42.46 | -8.95 | 9.67 | 1.01 |
| 3    | 30.37 | 28.53 | 24.57 | 36.35 | 19.59 | -31.62 | 48.24 | -3.79 | 11.97 | 10.20 |
| 4    | 30.73 | 27.97 | 24.34 | 36.09 | 22.06 | -32.83 | 46.22 | -5.77 | 10.66 | 7.82 |
| 5    | 30.44 | 27.96 | 25.82 | 36.35 | 20.46 | -31.43 | 45.22 | -4.83 | 9.12 | 6.89 |
| 6    | 31.34 | 28.68 | 24.24 | 35.87 | 21.68 | -33.36 | 45.28 | -3.52 | 9.80 | 6.89 |
| 7    | 29.43 | 27.52 | 23.93 | 36.38 | 22.60 | -31.92 | 45.90 | -5.30 | 10.76 | 8.33 |
| 8    | 29.99 | 27.64 | 22.22 | 36.59 | 23.42 | -30.95 | 47.35 | -3.29 | 11.63 | 5.67 |
| 9    | 29.49 | 27.35 | 23.41 | 36.40 | 21.60 | -30.27 | 47.04 | -4.66 | 11.87 | 7.68 |

Mean and SNR values of quality characterization of dehydrated strawberries which were produced using nine experiments based on orthogonal array of Taguchi method using factors and levels were shown Table 2 and Table 3. Each quality response from factors were identified based on the
characterization of dehydrated strawberries [2, 10, 13], and then the responses were calculated using SNR. These steps are important to determine the next analyses of each factors on the response.

Table 4. Optimal combination for factor means on response using Taguchi method

| Factor | Level | L* | a* | b* | Color Change | Texture (N) | Water content (%) | Vit. C (mg/100g) | Total Phenol (%) | Acidity (%) | SSC (%) | TOTAL |
|--------|-------|----|----|----|--------------|-------------|-------------------|------------------|-----------------|-------------|--------|-------|
| A      | 1     | 2  | 1  | 1  | 2            | 1           | 2                 | 1                | 1               | 2           | 3      | 15    |
|        | 2     | 1  | 3  | 2  | 3            | 2           | 1                 | 2                | 1               | 2           | 1      | 18    |
|        | 3     | 3  | 2  | 3  | 1            | 3           | 3                 | 3                | 3               | 3           | 3      | 27    |
| B      | 1     | 1  | 1  | 1  | 1            | 3           | 2                 | 2                | 2               | 2           | 2      | 16    |
|        | 2     | 2  | 3  | 2  | 2            | 3           | 1                 | 1                | 1               | 1           | 1      | 18    |
|        | 3     | 3  | 2  | 3  | 3            | 1           | 2                 | 3                | 3               | 3           | 3      | 26    |
| C      | 1     | 1  | 3  | 1  | 3            | 1           | 3                 | 3                | 2               | 3           | 3      | 21    |
|        | 2     | 2  | 2  | 3  | 2            | 2           | 2                 | 3                | 3               | 1           | 2      | 17    |
|        | 3     | 1  | 3  | 3  | 1            | 3           | 3                 | 3                | 3               | 1           | 2      | 21    |

Next step was identifying the effects of factors (A, B, C) mean analyses on responses of quality based on the three types of SNR, smaller the better for water content and yellowness; nominal the best for lightness, redness, color change and Acidity; and larger is better for texture, vitamin C, total phenol and soluble solid content. Each response was ranked based on the mean value of each factor and level; then it was summed up as total, and showed in the Table 4 and Table 5. Based on these table, for factor mean analyses, highest value for each level from each factor was identified; and A3, B3 and C1 were selected; for SNR analyses there were A3, B1/B3 and C1. Then, these optimal combination were calculated again for multiple responses of the factors and levels using statistical data with two ways ANOVA to find out the factor which was significantly affecting the response of quality of dehydrated strawberries.

Table 5. Optimal combination of factors SNR analyses on responses using Taguchi method

| Factor | Level | L* | a* | b* | Color Change | Texture (N) | Water content (%) | Vit. C (mg/100g) | Total Phenol (%) | Acidity (%) | SSC (%) | TOTAL |
|--------|-------|----|----|----|--------------|-------------|-------------------|------------------|-----------------|-------------|--------|-------|
| A      | 1     | 2  | 1  | 1  | 1            | 1           | 2                 | 1                | 1               | 1           | 2      | 13    |
|        | 2     | 1  | 2  | 2  | 3            | 2           | 2                 | 2                | 3               | 1           | 1      | 21    |
|        | 3     | 3  | 3  | 3  | 3            | 3           | 3                 | 3                | 3               | 2           | 3      | 26    |
| B      | 1     | 1  | 3  | 1  | 2            | 3           | 3                 | 2                | 2               | 2           | 2      | 21    |
|        | 2     | 2  | 1  | 2  | 3            | 2           | 2                 | 1                | 1               | 3           | 1      | 18    |
|        | 3     | 3  | 2  | 3  | 3            | 1           | 1                 | 3                | 3               | 1           | 3      | 21    |
| C      | 1     | 3  | 1  | 2  | 2            | 2           | 3                 | 2                | 3               | 3           | 3      | 24    |
|        | 2     | 1  | 3  | 3  | 1            | 2           | 3                 | 1                | 1               | 2           | 2      | 19    |
|        | 3     | 2  | 2  | 1  | 3            | 1           | 3                 | 2                | 1               | 1           | 1      | 17    |

3.2 Two way ANOVA and Multiple Responses Characteristics Analyses

Two ways ANOVA is used to identify each factor’s (A, B and C) significant contribution with three different levels that affected the processing and quality of dehydrated strawberries based on the calculation that resulted from Table 4 and Table 5. The level of confidence of 90% was used with F-value (0.10;2,6) compare with F-table = 3.46, this indicated that if F-value > F table, the factor has significant effect on significant contribution responses that was measured before. If value was not significant, then each factor will be calculated again using pooled for significant of value and all calculation of two ways ANOVA were based on equation of the Taguchi method [23].

L and ΔE of responses were affected by A with 71.02% and 44.78% and B with 23.18% and 24.54% respectively, and a and b of responses was affected significantly by A only with 69.72% and 56.37%. Texture and vitamin C of responses affected by all factors of A, B or C with 39.44%, 20.13%
and 30.19% for texture and 2.62%, 21.77%, 75.61% for vitamin C. Water content and soluble solid content was affected significantly only by A with 64.90% and 51.77%, and then total phenol and acidity were affected significantly by B and C with 19.089% and 52.43% for total phenol, and with 55.19% and 33.48% for acidity. Furthermore, multiple response of the quality from production factors level of the treatments were calculated with each response must be weighted and normalized to calculate total loss function based on the quality of the dehydrated strawberry [9][10][13], and then the result were best combination for all factors from SNR and the difference between the factors can be received. Multiple response of SNR were resulted A3, B3 and C3/C1 as a best combination with A was the highest factor for the response with contribution 93.7%, then B and C with 5.82% and 0.48%, respectively using anova test.

3.3. Conformity test of the factors level and response of Taguchi method
Dehydrated strawberries that resulted from the Taguchi method was important to be produced with similar quality; and it must be conducted using conformity test. In this experiment it was conducted with two result factors combination of A3, B3 and C3/C1 using similar responses for each quality dehydrated strawberries, it was shown in the Table 6. The confidence interval at 95% level significance were calculated with resulted value of 0.170 < $\mu_{predicted.1}$ < 0.588 at -0.143 < $\mu_{confirmed.1}$ < 0.443 in the experiment 1, and 0.350 < $\mu_{predicted.2}$ < 0.738 at -0.123 < $\mu_{confirmed.2}$ < 0.463 in the experiment 2, both of predicted data from experiment were overlap with confirmed data; this indicated that both experiments were confirmed. Furthermore, experiment 2 (A3, B3 and C3) were selected because of their texture were higher, lower water content and higher vitamin C, based on [9, 10, 13, 20].

| Exp. (L) | (a) | (b) | Color change (ΔE) | Texture (N) | Water content (%) | Vitamin C (mg/100g) | Total Phenol (%) | SSC (%) | Acidity (%) |
|----------|-----|-----|------------------|-------------|-------------------|---------------------|-----------------|---------|-------------|
| 1*       | 43.63 | 30.84 | 27.87           | 55.96       | 6.34              | 28.70              | 226.90         | 0.76    | 4.67        | 2.39        |
| 2**      | 35.97 | 31.48 | 20.03           | 66.75       | 13.66             | 24.67              | 242.43         | 0.76    | 4.23        | 2.59        |

*1. A3, B3 dan C1; 2** A3, B3 dan C3

4. Conclusion
The optimal combination for treatments of material and process for production dehydrated strawberries based on Taguchi methods were A3, drying temperature of 70°C; B3, juice concentration of solution with 50°Brix and C3, immersion time of solution for 60 minutes. Drying temperature was the highest factor that affected to response of quality of dehydrated strawberries.

Aknowledgements
Authors offers gratitude to Universitas Gadjah Mada for their financial support with contract number: 2488/UN1.P.III/DIT-LIT/PT/2020; and also for Faculty of Agricultural Technology Universitas Gadjah Mada for the support of research during Pandemic Covid-19.

References
[1] FAO 2005 Food and Agriculture Organization, Statistical Database, Available: http://www.fao.org
[2] Cordenunsi B R, Genovese M I, do Nascimento J R O, Hassimotto N M A, dos Santos R J and Lajolo F M 2005 Food Chemistry 91 113
[3] Harris L J 2007 Agriculture and Natural Resources 7 15
[4] Giampieri F, Tulipani S, Alvarez-Suarez J M, Quiles J L, Mezzetti B and Battino M 2012 Nutrition 28 9
[5] Crecente-Campo J, Nunes-Damaceno M, Romero-Rodriguez M A and Vázquez-Odériz M L 2012 J. Food Composition and Analysis 28 23
[6] Hannum S M 2004 Critical Reviews in Food Science and Nutrition 44 1
[7] Van der Goot A J, Pelgrom P J M, Berghout J A M, Geerts M E J, Jankowiak L, Hardt N A,
Keijer J, Schutyser M A I, Nikiforidis C V and Boom R M 2016 *Journal of Food Engineering* **168** 42

[8] Grabowski, S and Marcotte M 2003 *Pre-treatment efficiency in osmotic dehydration of cranberries. In Transport Phenomena in Food Processing*; Welti-Chanes, W., Velez-Ruiz, F., Barbosa-Canoivas, G.V. Eds. (New York: CRC Press) pp 83–94

[9] Ioannou I and Ghoul M 2012 *Advances in Applied Biotechnology* **5** 101

[10] Hung P V and Duy T L 2012 *International Food Research Journal* **19** 327

[11] Nowicka P, Wojdylo A, Lech K and Figiel A 2014 *Food Bioprocess Technology* **8** 824

[12] Lazarides H N, Katsanidis E and Nicolaidis A 1995 *Journal of Food Engineering* **25** 151

[13] Mayor L and Sereno A M 2004 *Journal of Food Engineering* **61** 373

[14] Pundir R, Chary G H V C and Dastidar M G 2018 *Water Resources and Industry* **20** 83

[15] Dawson E A and Barnes P A 1992 *Applied Catalysis A* **90** 217

[16] Assadpour E and Jafari S M 2017 *Drying Technology* **35** 1152

[17] Torres J D, Talens Pand EscricheI A, 2006 *Journal of Food Engineering* **74** 240

[18] Piotrowski D, Lenart A and Wardzynski A 2004 *Journal Food Engineering* **65** 519

[19] Soysal Y, Ayhan Z., Estürk O and Arıkan M F 2009 *Biosystem Engineering* **103** 455

[20] Mendez-Lagunas L, Rodriguez-Ramirez J, Cruz-Gracida M, Sandoval-Torres S and Barriada-Bernal G 2017 *Journal of Food Chemistry* **230** 174.

[21] Coklar H and Akbulut M, 2017 *South African Journal for Enology and Viticulture* **38** 264

[22] A.O.A.C 1995 *Official methods of analysis* (Maryland, USA: Association of Official Analytical Chemists International)

[23] Taguchi G, Chowdury S and Wu Y 2005 *Taguchi’s Quality Engineering Handbook*, (New Jersey, USA: John Wiley and Sons) p 1804