JOURNAL OF FOOD QUALITY & HAZARDS CONTROL

SHAHID SADOUGHI UNIVERSITY OF MEDICAL SCIENCES & HEALTH SERVICES

Journal of Food Quality and Hazards Control 2 (2015) 90-96

Physical Characteristics of Some Native Rice Varieties Cultivated in Northern Iran

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Article type
Original article

Keywords
Oryza sativa
Food Quality
Analysis

Received: 13 Apr 2015
Revised: 26 May 2015
Accepted: 10 July 2015

Abstract

Background: Physical characteristics of crops play an important role in designing the required machinery and apparatus for planting, harvesting, transport, processing and also storing. The aim of this study was to determine physical characteristics of some native rice varieties cultivated in northern Iran, namely Gerde, Shafagh, Tarom-e-Hashemi, Shiroodi and Keshvari.
Methods: Some geometrical, gravimetrical and frictional characteristics of the five varieties were determined by standard methods at their initial wet basis moisture content ranging between 10-11% (w.b.). Data analysis was carried out by SPSS software (ver. 16.0) using one-way ANOVA.
Results: Among all the five studied rice varieties, the highest length, width and thickness values were measured as 8.06 mm, 3.59 mm and 2.87 mm, belonging to Shafagh, Gerde and Shiroodi varieties, respectively which each of them had significance difference ($p<0.05$) with the other varieties from point of view of the mentioned characteristics. Also, Shafagh and Keshvari revealed maximum and minimum values of volume, equivalent diameter and surface area, respectively. Shafagh had also the highest rate of weight of thousand grains (25.06 g). Gerde was found to be the most spherical variety and revealed the highest bulk density (0.82 kg/m^3) and angle of repose (45.57°) while having minimum true density (1.41 kg/m^3).
Conclusions: There were significant differences among the examined varieties in the case of physical properties and most of these properties were related to each other. These data could be useful for resolving some problems associated with design, development and analysis of behavior of products during post-harvest processing.

Introduction

Rice (*Oryza sativa* L.) is one of the basic food items, which is constantly in demand for more than half of the world's population. It is a considerable source of rare amino acids, mineral elements, vitamins as well as energy (Ashtiani Araghi et al., 2010). Rice is a strategic food in Iran, which is classified as the second food with high

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consumption. Therefore, a thorough knowledge about rice properties is necessary for improving quality and quantity of rice production and consequently reaching economical independence (Darvishsefat et al., 2011).

Rice quality can be considered by physicochemical properties; aromatic, nutritional, cooking and eating quality; ageing; milling quality; and degree of milling (DOM) (Bhattacharya, 2011). Determining physical properties of rice can facilitate design of machinery for planting, harvesting, storing and processing operations such as threshing, handling, cleaning and drying (Ashtiani Araghi et al., 2010; Darvishsefat et al., 2011; Ghasemlou et al., 2010). A comprehensive chart of physical properties of rice is presented in Fig. 1 (Bhattacharya, 2011).

The rice grains' axial dimensions (length, width and thickness) would be so practical for choosing sieve separators and calculating required power for rice milling process. They can also be used in determining aspect ratio, surface area and volume of grains which are essential for modeling of drying kinetics, heating, cooling and aeration. Porous mode of grain bulk allows the airflow to pass through and approach to almost all individual kernels. Its value is in relation to the power of aeration system (Navarro and Noyes, 2001). Angle of repose is another important friction parameter describing flow behavior of granular materials. Rice grain is usually measured using angle of repose as a measure of internal friction between kernels. It is one of the frictional properties that will be useful for designing angle of hoppers and conveyer systems (Ghasemlou et al., 2010; Navarro and Noyes, 2001).

In Iran, the major amount of rice cultivation occurs in Guilan and Mazandaran provinces (northern Iran) supplying 75% of all rice production in this country (Zareiforoush et al., 2009). Therefore, the aim of this study was to determine physical characteristics of some native rice varieties cultivated in northern Iran.

Materials and methods

Sample preparation and moisture content determination

In August 2012, five rice varieties, namely Gerde, Shiroodi, Tarom-e-Hashemi, Shafagh, and Keshvari were obtained from Iranian Rice Research Institute (Amol, Mazandaran, Iran). Gerde is a local variety originated from Guilan province (north of Iran) and others are grown in Mazandaran province (north of Iran). The rice kernels were cleaned by hand to remove dirt, straw and foreign materials and subsequently sieved to remove broken grains. The samples were packed and hermetically sealed in plastic bags. All the physical properties were assessed in initial wet basis moisture content of 10-11% (w.b.) which determined by the oven drying method.

Geometrical characteristics

In order to determine average size of the grains, 50 grains were randomly picked and their three axial dimensions, namely, length (L), width (W), and thickness (T) were measured using a vernier caliper at accuracy of 0.01 mm. Aspect ratio (R_a) was determined by the following formula:

$$R_a = \frac{L}{W} \qquad [1]$$

Equivalent diameter (D_p), volume (V), sphericity (Ø) and surface area (S) were determined using the following equations (Dursun and Dursun, 2005; Mohsenin, 1986; Zareiforoush et al., 2009), respectively.

$$D_P = (L\frac{(W+T)^2}{4})^{1/3} \qquad [2]$$

$$V = 0.25[(\frac{\pi}{6})L(W+T)^2] \qquad [3]$$

$$\phi = \frac{(LTW)^{1/3}}{L} \qquad [4]$$

$$S = \frac{\pi B L^2}{(2L-B)} \qquad [5]$$

Where L is length, W is width, T is thickness of grain (all in mm) and B is calculated by:

$$B = \sqrt{WT} \qquad [6]$$

Gravimetric characteristics

One thousand grains were taken from each sample and their weight (W_{1000}) was measured by means of a digital electronic balance with accuracy of 0.1 mg. Bulk density (ρ_b) in kg/m^3 is ratio of weight of the sample to its total volume. It was analyzed according to a previous method, in which a cylinder with volume of 50 ml was filled with rice grains to reach constant height of 15 cm (Adebowale et al., 2011). True density (ρ_t) in kg/m^3 defined as ratio of weight of the sample to its true volume (grain volume) was determined by liquid displacement method employing toluene (C_7H_8) (Garnayak et al., 2008; Mohsenin, 1986; Reddy and Chakraverty, 2004; Zareiforoush et al., 2009).

Porosity was calculated using the relationship between bulk and true densities as follow:

$$\varepsilon = (\frac{\rho_t - \rho_b}{\rho_t}) \times 100 \qquad [7]$$

Angle of repose

Angle of repose (θ) in degrees, which is angle with the horizontal axis if a granular material is placed without slumping (Reddy and Chakraverty, 2004), was determined using a device consisting of a plywood box of 140×100×35 mm and two fixed and adjustable plates. The box was filled with the samples; then, the movable plate was quickly removed. The grains were allowed to flow and assume their natural slope after making a pile. Angle of repose was calculated after understanding the slope of the heap of rice grains using the following formula (Adebowale et al., 2011):

$$Angle\ of\ repose = tan^{-1}(\frac{horizontal\ distance}{height\ of\ box}) \qquad [8]$$

Statistical analysis

All the measurements were accomplished in three replications for each variety. The obtained results were reported as mean ± standard deviation and their analysis was implemented by one-way analysis of variance at significant level of 0.05 using SPSS software (ver. 16.0). Tukey's post-hoc test was performed for pairwise comparisons.

Results

Table 1 summarizes geometrical properties of the five rice cultivars investigated in this study. As seen, the highest length (8.06 mm), width (3.59 mm) and thickness (2.87 mm) values were obtained for Shafagh, Gerde and Shiroodi, respectively, and the lowest values of 6.19, 2.87 and 2.63 mm were obtained for Gerde, Shiroodi and Keshvari, respectively. In the case of thickness, there was no significant difference among three varieties of Gerde, Shiroodi and Shafagh and also between Shiroodi and Shafagh ($p>0.05$). As a result of having higher width and lower length, aspect ratio of Gerde (0.58) was significantly higher than that of other four rice varieties ($p<0.05$).

Among the rice varieties, Shafagh and Keshvari had maximum and minimum values of volume (32.24 and 29.97 mm^3), equivalent diameter and surface area, respectively.

The results of bulk density, true density, weight of thousand grains, and porosity are presented in Table 2. Values of weight of thousand grains showed significant differences through the cultivars ($p<0.05$). The highest weight of thousand grains (25.06 g) was obtained for Shafagh variety and the lowest value (17.86 g) belonged to Tarom-e-Hashemi. It was also observed that Shiroodi bore the lowest amount of bulk density (775.67 kg/m^3); however, according to Table 2, there was no significant difference among the three varieties of Shiroodi, Shafagh and Keshvari in terms of bulk density ($p>0.05$). The highest bulk density was belonged to Gerde (823.03 kg/m^3) although it had minimum value of true density (1407.20 kg/m^3). Gerde and Tarom-e-Hashemi were not significantly different in terms of true density ($p>0.05$). Values of porosity ranged between 41.42% and 58.12%, which were related to Gerde and Shiroodi varieties, respectively.

The results obtained for angle of repose (a measure of internal friction between kernels) are indicated in Table 3. Angle of repose values of the five examined rice varieties in the initial moisture content of 10-11% (w.b.) ranged between 37.43-45.57°.

Table 1: Geometrical properties of the rice varieties from northern Iran

Variety	Axial dimensions (mm)			Aspect ratio	Volume (mm^3)	Equivalent diameter (mm)	Sphericity	Surface area (mm^2)
	Length	Width	Thickness					
Gerde	6.19±0.05 ^{a}	3.59±0.08 ^{c}	2.83±0.00 ^{b}	0.58±0.01 ^{b}	33.54±0.73 ^{b}	4.00±0.03 ^{b}	0.64±0.01 ^{b}	41.85±0.54 ^{b}
Shiroodi	7.61±0.12 ^{b}	2.87±0.02 ^{a}	2.87±0.02 ^{b}	0.38±0.00 ^{a}	30.64±1.07 ^{a}	3.88±0.04 ^{a}	0.51±0.00 ^{a}	40.50±1.00 ^{ab}
Tarom-e-Hashemi	7.47±0.05 ^{b}	2.90±0.01 ^{a}	2.63±0.02 ^{a}	0.39±0.00 ^{a}	29.97±0.16 ^{a}	3.85±0.06 ^{a}	0.52±0.00 ^{a}	39.80±0.15 ^{a}
Shafagh	8.06±0.09 ^{c}	3.10±0.02 ^{b}	2.84±0.03 ^{b}	0.38±0.00 ^{a}	37.24±0.71 ^{c}	4.14±0.03 ^{c}	0.51±0.00 ^{a}	46.04±0.62 ^{c}
Keshvari	7.47±0.18 ^{b}	2.94±0.02 ^{a}	2.61±0.00 ^{a}	0.39±0.01 ^{a}	30.08±0.85 ^{a}	3.86±0.04 ^{a}	0.52±0.01 ^{a}	39.86±0.83 ^{a}

- All values are mean of triplicate trials; the data were shown as mean ± standard deviation
- Mean values shown with different superscripts in a column are significantly different ($p<0.05$)

Table 2: Gravimetric properties of the rice varieties of northern Iran

Variety	Weight of thousand grains (g)	Bulk density (kg/m^3)	True density (kg/m^3)	Porosity (%)
Gerde	22.29±0.01 ^{d}	823.03±2.00 ^{c}	1407.20±66.99 ^{a}	41.42±2.73 ^{a}
Shiroodi	18.66±0.00 ^{c}	775.67±5.13 ^{a}	1852.33±11.24 ^{d}	58.12±0.52 ^{c}
Tarom-e-Hashemi	17.86±0.01^{a}	814.47±0.50 ^{b}	1458.40±5.77 ^{a}	44.15±0.20 ^{a}
Shafagh	25.06±0.05 ^{e}	781.00±2.00 ^{a}	1627.67±2.52 ^{b}	52.02±0.05 ^{b}
Keshvari	18.42±0.11^{b}	783.00±3.00 ^{a}	1733.33±17.56 ^{c}	54.82±0.29 ^{bc}

- All values are mean of triplicate trials; the data were shown as mean ± standard deviation
- Mean values shown with different superscripts in a column are significantly different (p<0.05)

Table 3: Angle of repose of the rice varieties of northern Iran

Variety	Angle of repose (°)
Gerde	45.52±2.81 ^{d}
Shiroodi	37.43±0.35 ^{a}
Tarom-e-Hashemi	41.80±0.30 ^{c}
Shafagh	42.67±0.25 ^{c}
Keshvari	40.13±0.55 ^{b}

- All values are mean of triplicate trials; the data were shown as mean ± standard deviation
- Mean values shown with different superscripts in a column are significantly different (p<0.05)

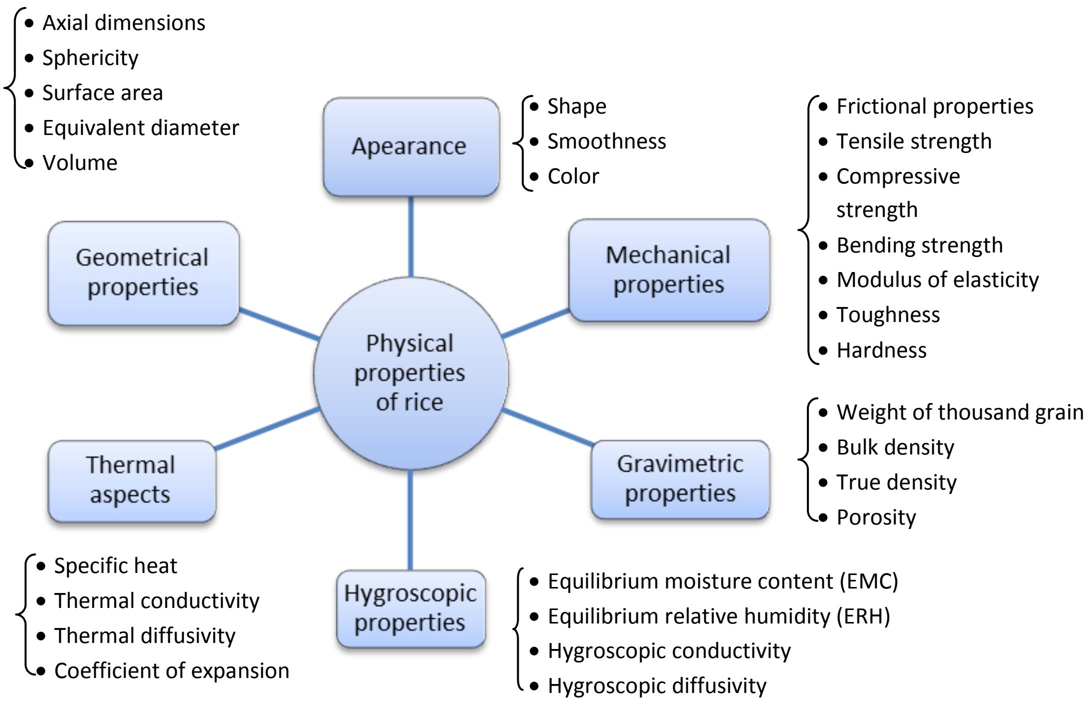

Fig. 1: A comprehensive chart of physical properties of rice (Bhattacharya, 2011)

Discussion

The knowledge of geometrical properties of grains is crucial for accurate design of the equipment for planting, harvesting, transporting, processing as well as storing (Adebowale et al., 2011; Al-Mahasneh and Rababah, 2007; Ghasemlou et al., 2010). Axial dimensions are important in determining size of apertures and mode of reciprocating motions in designing grain handling machinery (Adebowale et al., 2011; Al-Mahasneh and Rababah, 2007; Varnamkhasti et al., 2008). For instance, effective grading in terms of width using sieves with round holes occurs while the sieves vibrate vertically. When length of the grain is less than twice of width, grading would be acceptable even on sieves which vibrate horizontally (Varnamkhasti et al., 2008). Considering the latter fact and according to Table 1, grading based on horizontal vibration can be performed only for Gerde cultivar.

Several researchers have reported that some physical properties such as length and porosity have significant influences on increasing DOM in rice cultivars and consequently loss of selenium when producing white rice from brown rice. In a similar milling time, long-grain rice has revealed a higher DOM than the grains with shorter length (Liang et al., 2008; Liu et al., 2009; Prom-u-thai et al., 2007). These findings indicate that length, aspect ratio and porosity are noteworthy for optimizing milling process in order to achieve a desired DOM while retaining higher levels of selenium.

Aspect ratio is related to grain's width and length. In this study, the aspect ratio term was defined as ratio of width to length (Adebowale et al., 2011; Bagheri et al., 2013; Varnamkhasti et al., 2008); whereas, in some studies, it has been considered length to width ratio (Liu et al., 2009). Anyway, its importance is in determining whether the grains will slide or roll on their flat surfaces. Higher length to width ratio or lower width to length ratio means that the grains slide more than roll on a surface (Adebowale et al., 2011; Al-Mahasneh and Rababah, 2007).

The properties of volume, equivalent diameter and surface area also depend on three linear dimensions and they are useful for modeling of drying kinetics, heating, cooling and aeration (Al-Mahasneh and Rababah, 2007). Bagheri et al. (2013) reported surface area values for Fajr (37.67 mm^2), Nemat (42.13 mm^2), Neda (38.04 mm^2), Tarom (0.24 mm^2) and Khazar (0.23 mm^2) varieties in moisture content of 13.5% (w.b.). Rate of heat transfer is a crucial factor for estimating drying time and energy requirements and significantly depends on ratio of surface area to volume. The higher the surfaces of a material per unit of volume, the better its condition for heat transfer (Varnamkhasti et al., 2008).

The result of sphericity excluded Gerde from other varieties due to having the most spherical shape. It should be noted that mean values of sphericity for all the five investigated varieties which ranged between 0.51 and 0.64 fell within the range of 0.32 to 1 for most of agricultural products (Mohsenin, 1986; Zareiforoush et al., 2009). Similar to aspect ratio, sphericity value disclose whether grains would rather slip or roll on their surface. The similar pattern of results of sphericity and aspect ratio in the present study approves the mentioned reality. As can be seen in Table 1, higher and lower amounts of sphericity belonged to the varieties with higher and lower amounts of aspect ratio, respectively. The aforementioned properties are extremely important in designing angle of hoppers, funnel-like devices through which the material is passed (Adebowale et al., 2011; Al-Mahasneh and Rababah, 2007). Dutta et al. (1988) considered that the grains with sphericity of more than 0.7 are classified as spherical grains. Therefore, according to the obtained results, none of the examined varieties except Gerde, are classified as spherical kernels.

Gravimetric properties are quite important in designing machinery related to drying, aeration, transport and storage (Ghasemlou et al., 2010). The result of having the highest and lowest amount of weight of thousand grains (Shafagh and Tarom-e-Hashemi, respectively) might be due to the fact that Shafagh variety had the highest volume and equivalent diameter compared to other varieties (Bagheri et al., 2013). Weight of thousand grains is an applicable parameter in measuring relative amount of foreign substances, shriveled and unripe kernels in a given lot of every kind of cereal grain (Reddy and Chakraverty, 2004).

True and bulk densities demonstrate density of only material substance and density of the bulk consisting of the material substance and intergranular spaces, respectively. True density is practical for designing hydrodynamic separation systems while bulk density indicates the required capacity of storage chambers and transportation equipments (Adebowale et al., 2011; Ashtiani Araghi et al., 2010; Ghasemlou et al., 2010; Reddy and Chakraverty, 2004). As a result, it could be understood that true density of an individual grain is always higher than its bulk density. Measuring densities helps in estimating breakage susceptibility and hardness amounts of cereal grains as well (Varnamkhasti et al., 2008). Some related studies have calculated bulk density of Iranian rice varieties; for instance, in dry basis moisture content of 8% (d.b.), bulk density of Alikazemi and Hashemi have been calculated as 433.56 and 381.77 kg/m^3, respectively (Zareiforoush et al., 2009); in moisture content of 13.5% (w.b.), 511.54, 535.74, 455.90, 512.99 and 596.38 kg/m^3 have been obtained for Tarom, Khazar, Fajr, Nematand and Neda varieties, respectively (Bagheri et al., 2013) and in moisture content of 10% (w.b.), 544.34 and 471.21 kg/m^3 have been reported for Sorkheh and Sazendegi varieties, respectively (Varnamkhasti et al., 2008).

Since bulk density of Shiroodi variety was less than that of other varieties in this study, it would require a larger silo with the same weight compared to others. Lower bulk density of Shiroodi and higher bulk density of Gerde were largely due to their lower and higher values of sphericity, respectively.

Zareiforoush et al. (2009) have informed that true density of paddy grains varied from 1405.17 to 1454.93 kg/m^3 and 1328.65 to 1364.96 kg/m^3 for Alikazemi and Hashemi varieties, respectively, when moisture content increased from 8 to 21% (d.b.). Varnamkhasti et al. (2008) presented true density of Sorkheh and Sazandegi as 1269.1 and 1193.38 kg/m^3, respectively. Because of very different true density values of cereal crops and most of impurities, true density is an efficient factor for removing impurities from the grains by the aeration process (Ashtiani Araghi et al., 2010).

Porosity is defined as ratio of intergranular void space to total space occupied by bulk grain (Corrêa et al., 2007; Mohsenin, 1986; Varnamkhasti et al., 2008). The findings obtained in this experiment were to a large extent in consistence with the information revealed by Navarro and Noyes (2001), who pointed out that the porosity value of most cereal grains ranges between 35 and 55%. Differences among densities and porosity could be due to inherent characteristics of the varieties and also different amounts of the moisture content. During the drying process, higher porosity of a grain improves aeration quality and consequently increases water vaporization (Adebowale et al., 2011; Liu et al., 2009). Liu et al. (2009) demonstrated that width, thickness, sphericity and bulk density had significantly negative correlation with DOM; in contrast, length and porosity increased DOM.

Each cereal grain had its own natural angle of repose and this parameter is a useful indicator of the product's flowability. Generally, the lower the angle of repose, the easier the flowing of grain (Boumans, 1985; Varnamkhasti et al., 2008). In few investigations, angle of repose of some Iranian rice varieties have been calculated as follows: for Alikazemi and Hashemi varieties, 35.67° and 38.27° have been found in moisture content of 8% (d.b.), respectively, and 41.23° and 44.37° in moisture content of 21% (d.b.), respectively (Zareiforoush et al., 2009); in moisture content of 13.5% (w.b.), 29.47°, 30.02°, 29.94°, 29.17° and 30.69° for Tarom, Khazar, Fajr, Nemat and Neda varieties, respectively (Bagheri et al., 2013) and in moisture content of 10% (w.b.), 37.66° and 35.83° for Sorkheh and Sazendegi varieties, respectively (Varnamkhasti et al., 2008). Angle of repose could be affected by size and relatively rough surface of the product which prevents easy slide of grains on each other (Boumans, 1985). Adebowale et al. (2011), Ashtiani Araghi et al. (2010), Reddy and Chakraverty (2004) and Zareiforoush et al. (2009) have reported that moisture content can also affect angle of repose in rice cultivars since angle of repose shows a significant increase when the moisture content increases. It can be due to the surface tension of moisture surrounding the individual grains which holds the particles next to each other as an aggregate (Zareiforoush et al., 2009). There is a relationship between angle of repose and porosity; as angle of repose increases, intergranular porosity of the material also increases and vice versa (Bhattacharya, 2011).

Angle of repose is recognized by engineers as a practical property concerned with design of hoppers, seed bins and other storage equipment (Adebowale et al., 2011; Ghasemlou et al., 2010). It has been indicated that the grains with angle of repose ranging between 25-30°, 30-38°, 38-45°, 45-55° and more than 55° can be considered very free flowing, free flowing, fair flowing, cohesive or non-easy flowing and very cohesive materials, respectively (Boumans, 1985). According to the mentioned theory and the presented data in Table 3, varieties of Shiroodi and Gerde were recognized as free flowing and non-easy flowing materials, respectively, and others, namely Shafagh, Keshvari and Tarom-e-Hashemi were recognized as fair flowing materials in their initial moisture contents.

Conclusion

The most obvious finding which could be emerged from this study is that there were significant statistical differences among all the five examined Iranian rice varieties in the case of physical characteristics; most of them were related to each other.

The varieties with higher and lower values of sphericity (Gerde and Shiroodi, respectively) had the same pattern of results in the case of bulk density, aspect ratio and angle of repose while the mentioned properties and porosity seemed to be in counter current relationship. These data could be useful and effective for resolving some problems associated with design, development and analysis of behavior of products during post-harvest processing.

Conflicts of interest

The authors declare that there is no conflict of interest in this work.

Acknowledgements

We thank Iranian Rice Research Institute (Amol Station) for supplying the rice samples used in this study. Our thanks also go to National Nutrition and Food Technology Research Institute, Tehran, Iran for providing the laboratory and financial supports.

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