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Original Research Article

Effect of Drying Conditions on Functional Properties of Pumpkin Powder

Mohd Rashdan Rasdi, Munira Zainal Abidin, Nur Hafizah Malik*

Department of Technology and Natural Resources, Faculty of Applied Sciences and Technology, Universiti Tun Hussein Onn Malaysia, Pagoh Campus, Pagoh Higher Education Hub, KM 1, Jalan Panchor, 84600 Pagoh, Muar, Johor, Malaysia, nurhafizah@uthm.edu.my

*Corresponding author: Nur Hafizah Malik, Department of Technology and Natural Resources, Faculty of Applied Sciences and Technology, Universiti Tun Hussein Onn Malaysia, Pagoh Campus, Pagoh Higher Education Hub, KM 1, Jalan Panchor, 84600 Pagoh, Muar, Johor, Malaysia; nurhafizah@uthm.edu.my

Abstract: Preserving and processing fresh fruit in different forms are among the strategies to reduce food waste and improve food security. As a high-yield fruit, Pumpkin is known to be packed with functional ingredients that could increase its economic value upon being processed. In this context, the functional properties of pumpkin powder dried at different conditions were investigated in this study. De-seeded fresh pumpkin fruits were oven-dried at 50, 60 and 70°C for 48, 24 and 12 hours, respectively. The drying conditions significantly affected moisture content, water absorption and swelling capacities, and colour properties of pumpkin powder ($p<0.05$). An inverse relationship was observed between drying temperature and moisture content of pumpkin powder, where the values range from 6.57% to 7.44% on a wet basis. Meanwhile, increasing the drying temperature produced powder with increased water absorption, oil absorption and swelling capacities, and bulk density. Thus, it indicates the potential application as a wheat flour substitute in bakery products. However, the highest foaming capacity (0.86%) was recorded for the sample dried at 50°C for 48 hrs. Colour properties of the pumpkin powder revealed that oven drying decreased the lightness (L*) by almost 7% and increased the yellowness (b*) and redness (a*) values by 6% and 2%, respectively when compared to fresh pumpkins. However, prolonged drying at 50°C showed a slight decrement in yellowness and had the lowest L* value, indicating a browning effect and drying at 70°C for 12 hrs produced pumpkin powder with the desirable swelling, water and oil absorption capacities, which is suitable for application as a functional ingredient in various food matrices.

Keywords: Pumpkin fruit; pumpkin powder; drying; functional properties

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1. Introduction

Pumpkin is a type of squash that belongs to the Cucurbitaceae family with several species, namely *Cucucrbita pepo., Cucurbita maxima* and *Cucurbita moschata* are widely cultivated globally due to their economic significance (Hosen *et al.*, 2021; Yadav *et al.*, 2010). This yellowish-orange coloured fruit is known for its nutritional and health benefits. Pumpkin fruit is rich in bioactive compounds, especially carotenoids, phenolic acids, flavonols, zeaxanthin and lutein (Kulczyński & Gramza-Michałowska, 2019; Hashash *et al.*, 2017). Besides being a good source of macronutrients and minerals, pumpkin has been shown to have low glycemic index properties attributable to its fiber content (Kostecka-Gugała *et al.*, 2020; Slamet *et al.*, 2019). The pronounced nutritive profile of pumpkin has made it significantly explored as a functional food and ingredient in developing innovative and healthy food products. Many studies have utilized pumpkin in the form of flour to be incorporated either fully or partially in bakery products to cater for the niche of gluten-free products (Aljahani, 2022; Rismaya *et al.*, 2022; Wongsagonsup *et al.*, 2015). Moreover, pumpkin flour was also included in the formulation of crackers, cookies (Melese & Keyata, 2022), jelly (Banin *et al.*, 2022), and meat products (Unal *et al.*, 2022; Zargar *et al.*, 2014) to improve nutritional, physical and sensory properties.

Nevertheless, developing pumpkin-based food products involved delicate and suitable processes for fresh pumpkin fruit before its application as functional ingredients. Due to their perishability, drying is one of the central processing techniques applied to fruits and vegetables in food product development. The dehydration process is essential in extending a product's shelf life as it helps in reducing water content enzymatic and microbiological activity (Marquez-Cardozo *et al.*, 2021). Besides, dehydrated fruits and vegetables have reduced volume and weight, enabling easy handling in further processing steps. Oven drying is commonly used in the food industry due to its simple operation, versatility and economic value (Chikpah *et al.*, 2022; Korese *et al.*, 2021; Seremet *et al.*, 2016; Sturm *et al.*, 2014). Previous studies have reported that pumpkin oven drying enables pumpkin inclusion in various food products ranging from solid, liquid and semi-solid food matrices (Banin *et al.*, 2022; Wongsagonsup *et al.*, 2015). However, the drying conditions, such as drying temperature and time, are closely related and can affect dried products' physicochemical and functional characteristics (Sturm *et al.*, 2014). Heat can change the pumpkin's colour, bulk density and bioactive compounds (Kazeem *et al.*, 2018). While pumpkin fruit is extensively utilized in the form of flour or powder, the functional properties of the processed pumpkin must be characterized. Functional properties such as the ability of pumpkin powder to interact with water and oil, its bulk density and foaming capacity greatly influence the quality of the end product.

Therefore, in this study, pumpkin fruit was oven dried at different conditions, namely at 50°C for 48 hrs, 60°C for 24 hrs and 70°C for 12 hrs before being processed into powder. The physical and functional properties of pumpkin powder obtained at different drying conditions were then evaluated to identify suitable drying conditions in the processing of powdered pumpkins.

2. Materials and Methods

2.1. Drying of Pumpkin and Preparation of Pumpkin Powder

Matured pumpkin fruits exhibiting hard rind, brown tendril and lack of firmness (Sonu & Ramana, 2013) were bought from a local market in Bukit Pasir, Muar, Johor. The fruits were washed, peeled and de-seeded before being dipped into salt solution to control browning. Then, the pulp of the fruits was thinly sliced into wedges with thickness between 0.2-0.3 inches before being dried in an air-circulated oven (Memmert UNE 400) at three different conditions (50°C for 48 hours, 60°C for 24 hours and 70°C for 12 hours) to a moisture content between 6-7% (Pereira *et al.*, 2020; Roongruangsri & Bronlund, 2016). The dried pumpkins were then milled using a mechanical grinder and sieved through a 500 µm mesh sieve. The milled pumpkin was stored in a desiccator at room temperature (25°C) for a week until further use.

2.2. Physical and Functional Properties of Pumpkin Powder

2.2.1. Moisture content

The moisture content of the fresh and dried pumpkin powder samples was analyzed using a rapid-moisture analyzer (MX-50 A&D, Japan). Measurement for each sample was repeated three times, and the readings were reported as mean ± standard deviation.

2.2.2. Bulk density

With some modification, bulk density was measured based on Famurewa *et al.* (2018). 5g of sample (W_0) was weighed in a 50 mL graduated measuring cylinder. Then, the measuring cylinder was tapped gently ten times against the palm until constant volume was obtained (W_1). Bulk density was calculated using Eq.1. The experiment was conducted in triplicate for each dried pumpkin powder sample type.

$$Bulk\ density\ \left(\frac{g}{cm^3}\right) = \frac{W_0}{W_1} \tag{1}$$

2.2.3. Water absorption capacity (WAC) measurement

The water absorption capacity of the pumpkin powder was measured according to Joy *et al.* (2021). 1g of pumpkin powder was weighed (W_0) and placed into a pre-weighed 50 mL centrifuge tube (W_1). 10 mL of distilled water was added into a pre-weighed centrifuge tube. The mixture was mixed using a vortex at the highest speed for 2 minutes. The mixture was allowed to rest at room temperature for 30 minutes before being centrifuged for 25 minutes at 3000 rpm and 20°C. Then, the clear supernatant was discarded and measured in a 10 mL measuring cylinder, and the centrifuge tube containing sediment was weighed (W_2). Water absorption capacity was calculated using Eq.2. The experiment was triplicated for each pumpkin powder sample.

$$Water\ absorption\ capacity\ \left(\frac{g}{g}\right) = \frac{W_1}{W_2} \tag{2}$$

2.2.4. Oil absorption capacity (OAC) measurement

The oil absorption capacity of the pumpkin powder was measured based on the method described by Joy *et al.* (2021). 1 g (A_0) of pumpkin powder was weighed onto a pre-weighed 50 mL centrifuge tube. The pre-weighed centrifuge tube added 10 mL of oil (A1). Then, the mixture was mixed using a vortex at the highest speed for 2 minutes. The mixture was allowed to rest at room temperature for 30 minutes before centrifuged for 20 minutes at 3000 rpm and 20°C. The supernatant was poured into a 10 mL measuring cylinder, and the volume was recorded (A_2). Oil absorption capacity was calculated using Eq.3. The analysis was conducted in triplicate for each dried pumpkin powder sample type.

$$Oil\ absorption\ capacity\ \left(\frac{ml}{g}\right) = \frac{A_1}{A_2} \tag{3}$$

2.2.5. Foaming capacity measurement

The capacity of pumpkin powder to form foam was evaluated based on Joy *et al.* (2021) with some modifications. A suspension was made with 2 g of pumpkin powder with 50 mL distilled water in a 100 mL measuring cylinder (B). The suspension was mixed using vortex at high speed in a test tube until the foam for 5 minutes. Then, it was poured into a 100 ml measuring cylinder, and the foam volume at 30 seconds after shaking (A) was recorded. Foaming capacity was expressed using Eq.4. The experiment was conducted in triplicate for each dried pumpkin powder sample type.

$$Foaming\ capacity\ (\%) = \frac{A - B}{B} \times 100 \tag{4}$$

2.2.6. Swelling capacity measurement

The method described by Aditi and Arivuchudar R. (2018) was used to determine the swelling capacity of the pumpkin powder. 3g of sample was filled into a 100 mL graduated measuring cylinder. Distilled water was added until the volume of the mixture reached 40 ml. Then, the top of the graduated measuring cylinder was tightly covered and mixed by inverting the measuring cylinder. The suspension was allowed to stand for 30 minutes. The volume occupied by the sample will be recorded after 30 minutes. Swelling capacity was calculated using Eq.5.

$$Swelling\ capacity\ (g/ml) = \frac{V_1}{V_0} \tag{5}$$

2.2.7. Color analysis

The colour properties of the pumpkin powder were analyzed based on the method described in Murzaini *et al.* (2020) using Hunter Lab Colorimeter (MiniScan EZ 4500, USA). The parameters evaluated were L*(lightness/darkness), a*(redness/greenness) and b* (blueness/yellowness) values. The measurement was carried out in triplicate for each dried pumpkin powder sample type.

2.3. Statistical Analysis

The readings obtained from triplicate for each analysis were expressed as mean ± standard deviation. One-way analysis of variance (ANOVA) was conducted using the software Minitab version 2019 to determine the significance of the data obtained. The level of significance at $P<0.05$ (95% confidence level) was used to indicate that data has significant differences.

3. Results and Discussions

Table 1. Physical and functional properties of oven-dried pumpkin powder.

Drying conditions	**Moisture content, wet basis (%)**	**Bulk density (g/cm^3)**	**Water absorption capacity (g/g)**	**Oil absorption capacity (ml/g)**	**Foaming capacity (%)**	**Swelling capacity (%)**
50°C, 48 hrs	7.44 ± 0.34^{a}	0.46 ± 0.03^{a}	4.54 ± 0.06^{c}	1.79 ± 0.25^{a}	0.86 ± 0.46^{a}	1.83 ± 0.18^{b}
60°C, 12 hrs	6.80 ± 0.22^{ab}	0.47 ± 0.03^{a}	5.16 ± 0.17^{b}	1.83 ± 0.43^{a}	0.79 ± 0.01^{b}	2.00 ± 0.04^{b}
70°C, 6 hrs	6.57 ± 0.27^{b}	0.50 ± 0.02^{a}	5.84 ± 0.13^{a}	1.92 ± 0.21^{a}	0.26 ± 0.11^{c}	2.59 ± 0.14^{a}

[1] Mean values with different letters within the same column are significantly different ($P<0.05$)

3.1. Physical Properties

Results of physical properties of pumpkin powder obtained through different drying conditions are presented in Table 1. It can be seen that the different drying conditions applied significantly affect ($p<0.05$) the moisture content, water absorption, foaming and swelling capacities of pumpkin powder. The significant difference is more prominent between pumpkin dried at the lowest (50°C) and highest (70°C) temperatures for the longest and shortest duration, respectively, than sample dried overnight at 60°C. The range of moisture content recorded was within the standard limits of wheat, which was set to a maximum of 15.5% moisture (Joy *et al.*, 2021). Besides, drying at 60°C for 24 hrs showed almost 3% lower moisture content than that obtained by Aziah and Komathi (2009). Meanwhile, the moisture content of pumpkin powder reported by Umuhozariho *et al.* (2020) obtained through drying at 65°C for 8 hours was slightly higher (7.62%) than the values obtained in this current study. The lower moisture content can inhibit microbial contamination and improve the powder's quality and shelf life (Amin *et al.*, 2019).

Meanwhile, the difference in drying conditions did not significantly affect bulk density (p>0.05). Although it appeared that average bulk density increased with drying temperatures, it was statistically insignificant. A similar trend has been observed by Roongruangsri & Bronlund (2016), where the highest value of bulk density was recorded for pumpkin powder dried at 70°C (0.91 g/ml) followed by 60°C (0.86 g/ml) and 50°C (0.62 g/ml). However, the reported bulk density values were lower by around 0.40g/ml than the previous report. The lower bulk density might be due to the higher value of initial moisture content, producing a larger powder particle size, which creates a more open structure (Lim *et al.*, 2021). Meanwhile, Tarwaca *et al.* (2021) reported slightly lower bulk density (0.36 g/ml) for pumpkin dried at 60°C. Drying draws out water that may also affect macromolecule interaction within the fruit, leading to large pore formation and reducing particle density (Kumar *et al.*, 2020). The lower bulk density also indicates that a more considerable packaging material might be needed to achieve a constant weight (Chen, 2016).

3.2. Functional Properties

3.2.1. Water absorption capacity (WAC)

Table 1 depicts that the water absorption capacity (WAC) of pumpkin powders was significantly affected (p< 0.05) by the drying conditions. Increasing the drying temperature seemed to increase the WAC of pumpkin powder. The WAC values were comparable with those reported by Márquez-Cardozo *et al.*, (2021) which also showed a similar trend with drying temperature. Meanwhile, greater WAC (8.3 g/ml) was obtained for breadfruit flour prepared by drying at 60°C for 24 hours than pumpkin powder prepared at similar drying conditions. The extraordinary ability of food powder to absorb water is essential to improve the consistency and texture of the end product (Chen, 2016).

3.2.2. Oil absorption capacity (OAC)

Different drying conditions showed no significant difference (p > 0.05) in the oil absorption capacity (OAC) of pumpkin powder. The result of OAC follows a similar trend observed for bulk density and WAC, where low drying temperature produced the lowest OAC. On the other hand, greater OAC and opposite trends have been reported by Roongruangsri & and Bronlund (2016). In the previous study, the OAC of air-dried pumpkin powder reduced as the drying temperatures increased, ranging from 3.87 g/g to 4.42 g/g. Nevertheless, a lower OAC, ranging from 1.21-1.28 g/g, was obtained by Márquez-Cardozo *et al.* (2021) for pumpkin powder samples dried at 60°C and 70°C. The higher oil absorption is typically thought to be a property of protein, which depends on its lipophobic and lipophilic amino acid composition (Chen, 2016). Ingredients with high oil binding capacity help stabilize high-fat food and improve the viscosity and texture of formulated foods (Aydin & Gocmen, 2015).

3.2.3. Foaming capacity

Table 1 shows that the foaming capacity of pumpkin powder dried at different conditions significantly ($p < 0.05$). Foaming capacity exhibited an inverse relationship with drying temperature. The sample dried at 50°C for 48 hours and 70°C for 12 hours recorded the highest and lowest foaming capacity, respectively. Despite this trend, the ability of the pumpkin powder to produce foams was lower than the foaming capacity reported for powder of other carbohydrate-rich fruits such as breadfruit (8%) (Arinola & Akingbala, 2018), potato (6.84%) (Mamat *et al*., 2020) and banana (10.85%) (Hasmadi *et al*., 2021). Besides, the result of foaming capacity corresponds to the low protein content (3-10%) for pumpkin as this functional characteristic reflects the presence of surface-active proteins (Adebayo *et al*., 2013; Amin *et al*., 2019; Mamat *et al*., 2020). As for the effect of drying temperature, the decreased foaming capacity at high drying temperatures is likely to be affected by protein denaturation. Nevertheless, the foaming capacity of non-wheat flours or powder has been suggested to be improved through germination and blending with different types of flour, which is helpful in aerated foods and can improve the texture, consistency, and appearance of the products (Arinola & Akingbala, 2018; Mamat *et al.*, 2020).

3.2.4. Swelling capacity

Table 1 shows that swelling capacity is significantly affected by the drying conditions applied. Drying fresh pumpkin at 50°C for 48 hours and 70°C for 12 hours each produced powder with the lowest and highest ability to swell. A much higher (almost 75%) swelling capacity has been reported for pumpkin powder dried at room temperature for seven days (Kuchtová *et al.*, 2016). The ability of powder to swell reflects the ability of starch to hold and swell on water absorption (Kaur *et al.*, 2010). High starch content can increase the swelling capacity, especially from starch-containing more branched amylopectin (Godswill *et al.*, 2019). Changes in swelling capacity also might depend on particle size, type of varieties and powder processing method (Chandra *et al.*, 2015).

3.3. Color Properties

The colour properties of pumpkin powder dried in different conditions are presented in Table 2. Based on this table, drying at 50 and 60°C for 48 and 24 hours, respectively, significantly (*p*< 0.05) affected the L* (lightness), a* (redness) and b* (yellowness) values of pumpkin powders. Meanwhile, the pumpkin powder sample dried at 70℃ for 12 hours showed no significant difference in fresh pumpkin's L* and b* values. This powder sample exhibited the lightest colour compared to samples dried at 60°C for 24 hours and 50°C for 48 hours. For a* value indicating redness or greenness, the sample dried at 50℃ for 48 hours has the lowest value, showing it has the least redness intensity compared to other samples. Meanwhile, b* values representing blueness or yellowness were the highest for the sample dried overnight at 60 °C. The highest value of b* indicates that the dried pumpkin powder is less yellow.

The result from this study was consistent with previous data, which dried pumpkin powder sample at 70°C has the highest L* (lightness) value, about 51.63 compared to the sample dried at 60°C (49.64) (Márquez-Cardozo *et al.*, 2021). Browning reaction and longer drying time might affect low lightness, which can cause thermal degradation (Lim *et al.*, 2021). Furthermore, drying conditions such as high temperatures, light, and oxygen exposure can alter food surface characteristics, resulting in colour change and carotenoid degradation (Workneh *et al.*, 2012).

Table 2. Colour properties of oven-dried pumpkin powder.

Drying conditions	**L* (lightness/darkness)**	**a* (redness/greenness)**	**b* (blueness/ (yellowness)**
Fresh pumpkin	62.42± 0.30^a	20.13 ± 0.07^c	49.24 ± 0.05^b
50 °C, 48 hrs	55.19± 0.05^c	23.66 ± 0.22^b	47.71 ± 0.14^c
60 °C, 24 hrs	56.00 ± 0.20^b	27.54 ± 0.85^a	53.03 ± 3.41^a
70 °C, 12 hrs	57.55± 0.40^a	24.60 ± 1.27^b	50.82 ± 4.58^b

[1] Mean values with different letters within the same column are significantly different (*P*<0.05)

4. Conclusions

In general, the functional properties of pumpkin powder depend on the processing parameters applied during the dehydration of fresh pumpkin. Drying at high temperatures for a shorter time (70°C, 12 hours) exhibited the most promising functional properties, especially for bulk density, water absorption capacity, oil absorption capacity, and colour properties. This finding indicates the potential of drying at higher temperatures with a suitable duration to produce quality pumpkin powder, which can help maximise pumpkin powder used in various food formulations.

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