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RESEARCH PAPER

Effect of Drying and Grinding Methods on Physical and Hydration Properties of Sweet Orange Peel Powder

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ABSTRACT

During the sweet orange juice extraction process a large quantity of peel is produced which is a waste. At present, peel is used for animal feeds and as a source of dietary fibres due to their high fibre content. It could an interesting source of dietary fibre for food also. Efforts were made to investigate the effect of four drying methods (open yard sun drying, solar tunnel drying, hot air drying and dehumidified air drying) and three grinding methods (hammer mill grinding at ambient temperature, with water cooling and with liquid nitrogen cooling) on functional properties of sweet orange peel powder are reported here. Among all combinations of treatments, dehumidified air drying and hammer mill with LN_2 grinded powder showed the highest specific volume, lowest bulk density and apparent density due to good hydration properties with highest swelling capacity, water retention capacity, water holding capacity and oil holding capacity. It concluded that powder can be rich source of dietary fibres.

Keywords: Sweet orange peel powder, physical properties, hydration properties, dehumidified air drying, liquid nitrogen grinding

Peel is the main by-product obtained from sweet orange fruit juice processing which is highly perishable in nature. If not processed, the peels may become waste, spoil and thus, pollute our environment. By-product utilization of fruit waste can act as an added source of income and may also help to check environmental pollution. At present, by-product obtained from juice extraction is mainly used for animal feeds, due to their high fibre content, but can be valuable source of dietary fibre (DF) (Larrauri *et al*., 1997). Dietary fibre (DF) acts as a bulking agent, normalizing intestinal motility and preventing the diverticular disease. Coronary heart diseases can also be reduced by sufficient intake of DF. Some of the DF may also be important in reducing colonic cancer, in lowering serum cholesterol levels and in preventing hyperglycemias in diabetic patients. Thus, a search for new sources of DF is called for which can be used as food ingredients. The interest in orange by-products derived from the juice extraction and agricultural industries is mainly based on its potential use as a DF source as these are considered of higher quality due to their better balance of soluble and insoluble DF content, besides their higher water and oil holding capacities (Garau *et al.*, 2007). Since sweet orange peel has high dietary fibres, thus, could be used for treating diabetic patients. But due to high moisture and low shelf-life of fresh sweet orange peel, utilization of sweet orange peel is limited, therefore efficient conversion of sweet orange peel into stable form assumes very important role. The hydration properties *viz.*, swelling capacity, water holding capacity, water retention capacity and oil holding capacity are important because high WHC seems to relate to the intestinal regulation and it also influences the nutritional quality and behavior when it is used as food ingredients in product development (Pla *et al*., 2012).

Swelling and WRC provide a general view of fibre hydration and will provide information useful for fibre supplemented foods (Guillon and Champ, 2000). Hydration properties are related to the chemical structure of the plant polysaccharides. Therefore, the drying and grinding process may alter the physico-chemical properties of the original products, modifying their hydration properties. The objective of the present work was to evaluate physical and hydration properties of sweet orange peel powder obtained from different drying and grinding methods.

MATERIALS AND METHODS

Sample preparation

Fresh sweet oranges (*cv*. Sathgudi) were selected uniformly according to harvest, colour, size and freshness. The fruits were washed in running water to remove adhering materials on the rind surface. After washing, the fruits were weighed and peeled using knife. Then, the peels were cut into small pieces (20×10 mm) and hot water washing was carried out at 90 °C for 5 min. After that the peel surface moisture was removed, followed by four drying methods (open yard sun drying, solar tunnel drying, hot air drying at 60 °C and dehumidified air drying at 45 °C and 15% RH) and three grinding methods (hammer mill grinding at ambient temperature, hammer mill grinding with water cooling, hammer mill grinding with LN_2 cooling). After the grinding, powder was passed through 212µ sieve to get uniform particle size.

Hydration properties of sweet orange peel powder

Swelling capacity, water-holding capacity (WHC), water retention capacity (WRC) and oil holding capacity (OHC) of obtained sweet orange peel powder were determined according to Pla *et al.* (2012).

Physical properties of sweet orange peel powder

Bulk density, Specific volume and apparent density were determined according to Pla *et al.* (2012).

Statistical analysis

All the experiments in the study were conducted in triplicates. Factorial completely randomised design (FCRD) was used to analyse the data. Statistical significance was examined by analysis of variance (ANOVA) for each response. The experimental design was done with the aid of the Design-Expert software version 7.7.0 (Statease Inc., Minneapolis, USA) to know the best combination among the four drying methods and three grinding methods.

RESULTS AND DISCUSSION

Effect of different drying and grinding methods on hydration properties of sweet orange peel powder

Water holding capacity (WHC)

Water holding capacity of sweet orange peel powder obtained from different drying and grinding methods (Table 1) is affected significantly ($p<0.0001$). It was revealed from the results that sweet orange peel powder obtained by dehumidified air drying and hammer mill grinding with LN_2 cooling had highest WHC (28.38 $g.g^{-1}$). Open yard sun drying and ambient temperature grinding method gave the lowest water holding capacity value (13.05 $g.g^{-1}$). The results are in agreement with the work of Pla *et al*. (2012) who reported the WHC of peach peel as 25 $g.g^{-1}$. Drying of peel increases WHC and lower sugar content results in higher WHC (Lario *et al*., 2004). Due to lower sugar

Table 1: Hydration properties of sweet orange peel powder obtained from different drying and grinding methods

Drying methods	OYSD			STD			HD			DD		
Grinding methods	AT	WC	LN	AT	WC	LN	AT	WC	LN	AT	WC	LN
Swelling capacity ($ml.g^{-1}$)	11.29	11.35	12.50	11.25	12.5	13.25	12.27	12.50	13.50	13.58	13.75	15.00
Water holding capacity ($g.g^{-1}$)	13.05	14.26	14.49	15.11	15.55	16.62	16.09	20.28	22.78	22.49	27.68	28.38
Water retention capacity ($g.g^{-1}$)	9.07	9.89	10.14	9.24	10.3	10.34	9.69	10.49	10.73	9.70	10.68	10.96
Oil holding capacity ($g.g^{-1}$)	1.35	1.36	1.41	1.35	1.38	1.44	1.55	1.55	1.59	1.59	1.61	1.63

OYSD: Open yard sun drying
STD: Solar tunnel dryer
HD: Hot air drying
DD: Dehumidified air drying

AT: Hammer mill at ambient temperature
WC: Hammer mill with water cooling
LN: Hammer mill with LN_2 cooling

content in dehumidified air dried sample, it had more WHC (28.38 $g.g^{-1}$). Processes, such as grinding, drying, heating or extrusion cooking modify the physical properties of the fibre matrix, which affect the hydration properties (Guillon and Champ, 2000), so high temperature in hot air drying might reduce the water holding capacity.

Water retention capacity (WRC)

In this case also both drying and grinding had significant effect ($p<0.0001$) as is shown in table 1. Sweet orange peel powder obtained by dehumidified air drying and hammer mill grinding with LN_2 cooling had the highest water retention capacity of 10.96 $g.g^{-1}$ compared to all other treatments. Open yard sun drying and ambient temperature grinding method gave the lowest water retention capacity (9.07 $g.g^{-1}$). This was in agreement with the work of Pla *et al*. (2012) who reported the water retention capacity of peach peel (14 $g.g^{-1}$). Guillon and Champ (2000) reported the water retention capacity of citrus peel fibre as 11 $g.g^{-1}$. Drying of peel causes structure of citrus peel to expand and puff, that result in more water retention capacity (Ghanem *et al*., 2012). Increase in water retention capacity was also observed by Garau *et al*. (2007) for hot air dried citus peel. Garau *et al*. (2007) reported that, the WRC was affected by high temperature and long drying time. Water retention capacity was however, lower at higher drying temperature; might be due to degradation of some soluble dietary fibre component during long drying period leading to the loss of ability to retain water (Chantaro *et al*., 2008). So there is less WRC in case of open yard sun drying, solar tunnel drying and hot air drying. Decrease of WRC could be explained due to cellular structure damage during drying and grinding resulting in modifications of osmotic properties of the cell as well as lower diffusion of water through the surface during rehydration, as discussed earlier also.

Swelling capacity

Both drying and grinding did not have significant effect ($p>0.5$) on swelling capacity. Sweet orange peel powder obtained by dehumidified air drying and hammer mill grinding with LN_2 cooling had the highest swelling capacity of 15.00 $ml.g^{-1}$ compared to all other treatments was clearly observed in table 1. Solar tunnel drying and ambient temperature grinding method gave the lowest swelling capacity (11.25 $ml.g^{-1}$). The similar findings were observed by Guillon and Champ (2000) who reported the swelling capacity of citrus peel fibre as 15.7 $ml.g^{-1}$. Swelling capacity value of sweet orange peel powder was less than the swelling capacity of carrot peel powder which is dried in hot air dryer according to Chantaro *et al.* (2008).

Oil holding capacity (OHC)

Effect of different drying and grinding methods on oil holding capacity of sweet orange peel powder (table 1) showed that dehumidified air drying and hammer mill grinding with LN_2 cooling had the highest oil holding capacity of 1.63 g $oil.g^{-1}$ while open yard sun drying and ambient temperature grinding method gave the lowest oil holding capacity value of 1.35 g oil.g^{-1}. Similar findings were observed by Ghanem *et al*. (2012) who reported the oil holding capacity of citrus peel as 1.8 g oil.g^{-1}. Oil holding capacity of sweet orange peels was lower than other OHC values reported by Garau *et al*. (2007) for air dried orange peels (3.5 g oil.g^{-1}) and those presented by Lario *et al*. (2004) for air dried lemon peels 6.71±0.34 g.g^{-1}. Oil holding capacity was more affected by drying air temperature, air temperature decreases the oil holding capacity (Pla *et al*., 2012). Thus, in our study high temperature might be the reason behind the lower oil holding capacity. In case of hammer mill grinding at ambient temperature had significantly lower OHC than other combinations and similarly in case of drying in hot air drying at high temperature and prolong drying time also resulted with lower OHC.

Effect of different drying and grinding methods

Physical properties of sweet orange peel powder

Bulk density

It can be clearly observed in fig. 1 sweet orange peel powder obtained by dehumidified air drying and hammer mill grinding with LN_2 cooling had lowest bulk density of 0.271 g.cm^{-3} and.

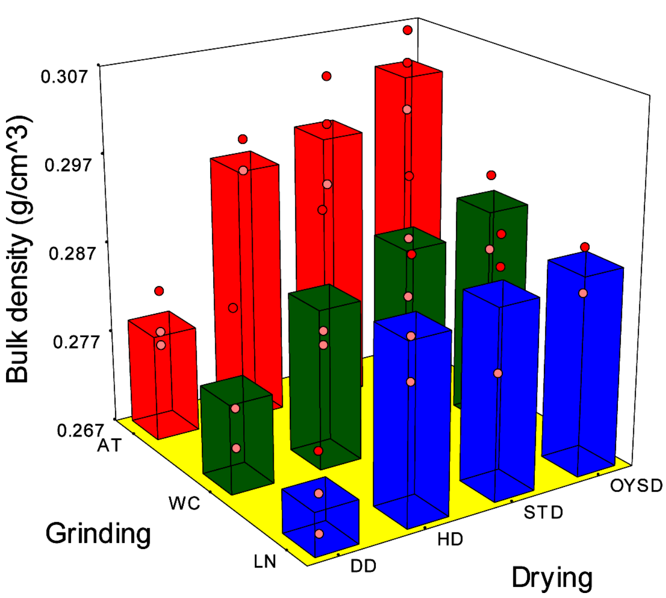

Fig. 1: The effect of different drying and grinding methods on bulk density of sweet orange peel powder

Open yard sun drying and ambient temperature grinding method gave the highest bulk density value (0.303 g.cm^{-3}). Higher temperature during grinding and drying might be the reason for higher bulk density value in case of ambient grinded samples and long time drying may also lead to high bulk density. Similar findings were observed by Pla *et al.* (2012) who reported the bulk density of peach peel powder as 0.374 g.cm^{-3}. The density is a critical parameter affecting the functional properties of the powder. The bulk density provides a perspective from the packing and arrangement of the particles and the compaction profile of a material. The drying and grinding process significantly ($p<0.0001$) influenced the bulk density of the powder. The bulk density depends on the attractive inter-particle forces, particle size and number of contact positions. The bulk density of the powder is primarily dependent on particle size which particle size distribution and particle shape, which might be the reason for the significant changes in the bulk density of powder (Mirhosseini and Amid, 2013).

Specific volume and apparent density

Sweet orange peel powder obtained by dehumidified air drying and hammer mill grinding with LN_2 cooling had highest specific volume and lowest apparent density of 2.400 cm^3.g^{-1} and 0.417 g.cm^{-3}, respectively. Open yard sun drying and ambient temperature grinding method gave the lowest specific volume and highest apparent density of 2.140 cm^3.g^{-1} and 0.467 g.cm^{-3} respectively. In both the cases drying and grinding methods have significant effect ($p<0.05$), faster drying and low temperature grinding lead to lower apparent density and highest specific volume as shown in fig. 2 and 3. Similar findings were observed by Pla *et al.* (2012) who reported the apparent density of peach peel powder as 0.431 g.cm^{-3}. Present result is in line with the apparent density of 0.45 g.cc^{-1} for Osmanabadi goat milk powder which was reported by Reddy *et al.* (2014). Highest value of apparent density in open yard sun dried samples indicates least porosity among all dried samples. Less apparent density value for dehumidified air dried sample indicates that the samples were more porous than the other samples. The apparent density indicates whether the material is close to a crystalline state or the proportions of a binary mixture.

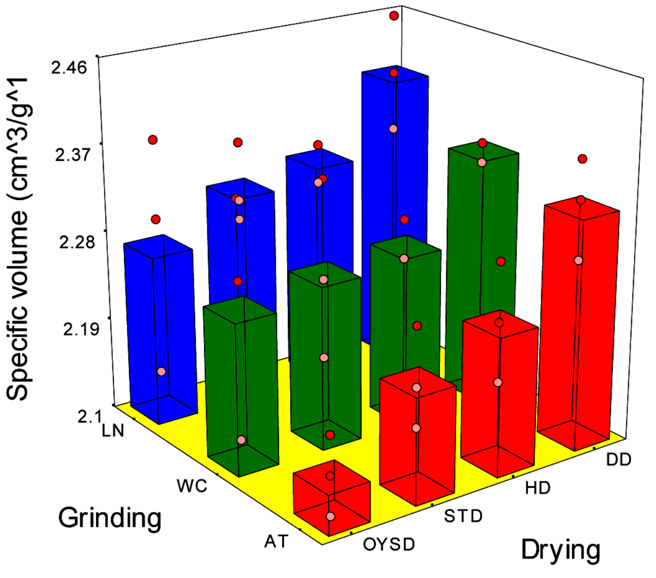

Fig. 2: The effect of different drying and grinding methods on specific volume of sweet orange peel powder

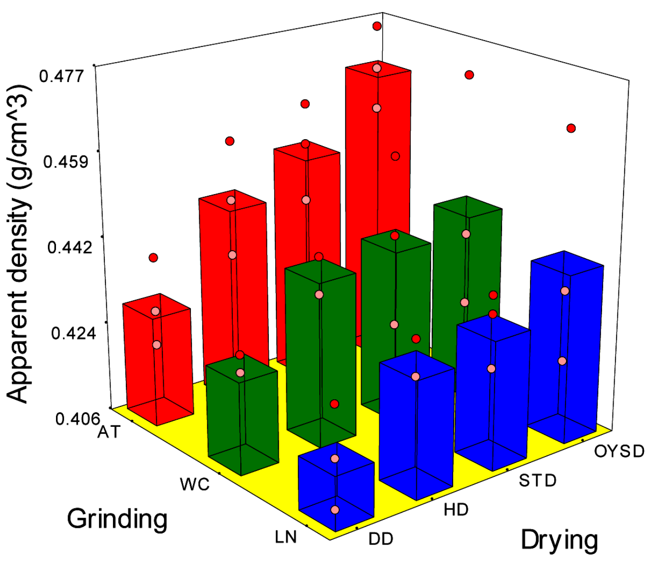

Fig. 3: The effect of different drying and grinding method on apparent density of sweet orange peel powder

Best combination (dehumidified air drying and hammer mill grinding with LN2 cooling) was selected as based on higher value of swelling capacity, oil holding capacity, water retention capacity, water holding capacity, specific volume and minimum bulk density and apparent density.

CONCLUSION

Dehumidified air dried and hammer mill grinding with LN_2 cooling method retained significantly higher hydration properties than other methods. These properties seemed to be highly influenced by both drying and grinding methods. Physical properties are found to be desirable in dehumidified air dried and hammer mill grinding with LN_2 cooling methods and these properties of sweet orange peel powder are important in storage packaging and handling/ transportation. Solar tunnel drying and hammer mill grinding at ambient temperature results in significantly poor hydration and physical properties therefore best sample can be used as source of dietary fibre.

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