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Studies on effect of different packaging materials on the quality of wood apple fruit powder

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Abstract
The present investigation was carried out to know the effect of different packaging materials *Viz.*, 100, 200 and 300 gauge polyethylene, 25, 50 µ aluminium laminated pouches, 3 layer co-extruded film pouch and PET jars on storage behavior and quality parameters of wood apple powder under ambient storage. Significant differences with respect to moisture content, water activity, total sugars, ascorbic acid, acidity and colour values were observed among the different packaging materials used. Whereas, TSS and total carbohydrates were not influenced by the packaging materials used. Irrespective of packaging materials, the moisture content and water activity were found minimum and were within the safe limit ranging from 6.72 to 7.14 and 0.291 to 0.324 respectively, throughout the storage period. At the end of 6 MAS, the maximum retention of total sugars (10.09%), ascorbic acid (2.59 mg/100 g), acidity (7.23%) was found in powder packed in 3 layer co-extruded films. The mean organoleptic score decreased significantly from an initial value of 8.33 to 7.79 for color and appearance, 7.95 to 7.49 for flavor, 8.29 to 7.92 for taste, 8.04 to 7.94 for texture and 8.15 to 5.91 for overall acceptability with the increasing storage period. The results of the organoleptic evaluation signify that the wood apple powder stored in 3 layer co-extruded film found superiority in their acceptability compared to other treatments throughout the organoleptic study.

Keywords: Fruit powder, polyethylene, co-extruded film, aluminium laminated pouches

Introduction

Underutilized fruits should be an augment to traditional fruits and not as a supplement. Wood apple is such an underutilized fruit that can be utilized to produce numerous products and attempted to encourage its expansion. Wood apple (*Feronia limonia* Swingle) is known for its delightful pulp characters having exceptional medicinal values. It is one of the most nutritious fruit of Indian subcontinent. It contains many vitamins such as, vitamin A, Vitamin C, thiamine, riboflavin and niacin and minerals such as, calcium and phosphorus. The fruit is used in India as a liver and cardiac tonic, when unripe, as an astringent means of halting diarrhoea and dysentery (Singh, 2001) [12], effective treatment for hiccups, sore throat and diseases of the gums. Wood apple has hypoglycemic activity, antitumour, larvicidal, antimicrobial activity and hepatoprotective activity (Vidhya and Narayin 2011) [17]. It also has anti-diabetic and antioxidant potential by reducing the level of blood glucose and malondialdehyde (Patel, *et al.*, 2016) [7].

People consume the raw fruit pulp as such with or without sugar or jaggery, or as a beverage after blending it with other ingredients (cardamom, salt, ginger etc.). The pulp is also suitable for making food products such as juice, nectar, jam, jelly, fruit bar, wine, chutneys, sherbet, pulp powder *etc*. Because of its excellent flavour and nutritive value this fruit has a great potential for value addition especially in beverage industry (Gorabal *et al.*, 2020) [1]. Due to a lack of knowledge about fruit processing technologies and processing facilities, approximately 25 to 30 per cent of harvested wood apple fruits are lost before consumption (Namdev and Singh 2015) [6]. One of the best ways to prevent losses is to convert them into various products. Dried foods/ dehydrated fruits, particularly in tropical and temperate countries, have traditionally been recognized as alimentary reserves among processed foods.

Converting fruit pulp into fruit powder is a smart solution to improve shelf life, add economic value, reduce waste and support food security and export markets.

It plays a vital role in modern food processing and agro-industrial development, especially in tropical and developing countries. Global demand for fruit powders increasing day by day as consumers increasingly choose fruit powders for their natural, nutrient rich profiles; especially in functional foods and clean label products. Further, packaging plays a critical role in maintaining the quality, safety and shelf life of fruit powders. Since these powders are hygroscopic and sensitive to environmental factors, proper packaging is essential for preserving their value. Therefore, the goal of the current study was to find out the suitable packaging material for preservation of wood apple fruit powder.

Materials and Methods

The pulp was extracted from the fully ripe wood apple fruits. The extracted pulp was homogenized by hand crushing. It was then passed through the strainer to separate seeds and fibre. The fine pulp was pre-treated with KMS and dried at @ 60+2 °C using cabinet tray drier. The dried pulp was pulverized in a mixer. Pulverized pulp powder was sieved under 52 mesh size. The powder was packed in the different packaging materials *Viz.*, 100, 200 and 300 gauge polyethylene, 25, 50 µ aluminium laminated pouches, 3 layer co-extruded film pouch and PET jars then stored at ambient conditions for 6 months.

Result and Discussion

Moisture content (%) and water activity (a_w): The variation in moisture content and water activity of wood apple powder packed in different packaging materials during ambient storage was shown in Table 1. As the storage period proceeded, the moisture content and water activity of the samples in all of the packages marginally increased. The increase in moisture content, as well as water activity in various packaging materials during storage, could be owing to differences in their permeability, which aided in moisture gain from the atmosphere (Sagar and Islam, 2006) [9]. However, the moisture content as well as water activity found in all the packaging materials was found within the safe limit of 7 per cent for microbiological safety and also maintained the low water activity level, which checks the growth of microbes and non-enzymatic browning.

During the storage period of 6 months, the minimum gain of the moisture was recorded in T_6-3 layer co-extruded film whereas, maximum moisture gain was recorded in T_7-PET jars. Among the different gauge polyethylene (100, 200 and 300 gauge), minimum gain of moisture was noticed in 300 gauge. Whereas, among the different 25 and 50 µ aluminium laminated pouches (ALP) a narrow variation with respect to moisture gain was noticed. No significant difference was observed in 50 µ ALP and 3 layer co-extruded film. Similarly, the powder packed in 50 µ ALP and 3 layer co-extruded film recorded minimum water activity whereas, powder packed in PET jars recorded maximum water activity throughout the storage period of 6 months. ALP and 3 layer co-extruded film had a better barrier for water permeability and the wood apple powder was not high in moisture content. Similar findings were received by Wong and Lim (2016) [18], Shishir *et al.* (2017) [11] and Sornsomboonsuk *et al.* (2019) [14].

Total sugars (%), total soluble solids (°B) and total carbohydrates (g/100 g): The total soluble solid content and total carbohydrate content was not influenced by the different packaging materials however, a narrow but non-significant difference with respect to TSS and total carbohydrates was seen among the packaging materials could be due to corresponding variations in the permeability to oxygen and water vapour.

The mean values of total sugar content decreased from 10.12 to 9.99 over the storage period of 6 months. This reduction in the total sugar content during storage may be due to the utilization of sugar in non-enzymatic browning reactions that occur during storage. Among the packaging material used, the minimum decrease in the total sugars was noticed in 3 layer co-extruded film and 50 µ ALP. An almost similar trend of change in moisture content in different packaging materials has been reported by Sharma *et al.*, 2003 [10] in apple powder and Manya, 2014 [4] in sapota powder.

Ascorbic acid (mg/100 g) and titratable acidity (%): Ascorbic acid content decreased during storage in all the packaging materials used. The maximum retention of ascorbic acid content was noticed in 3 layer co-extruded pouches and the minimum retention was in PET jars. The variations in the retention of ascorbic acid content may be due to the corresponding variations in their permeability to air and moisture. Lal *et al.*, 2009 [3] reported that the decrease in ascorbic acid content might be due to oxidation process *i.e.*, the degradation of ascorbic acid molecules forming dehydro ascorbic acid in presence of oxygen. Whereas, Hymavathi and Khader (2005) [2] opinion that, the decrease in ascorbic acid content is due to an increase in moisture content of the powder during storage. Same kind of results was observed by Hymavathi and Khader 2005 [2] in mango powder and Sondarva *et al.*, 2016 [13] in custard apple powder.

The acidity content was decreased during storage in all the packaging materials used, the loss of acidity may be due to the utilization of acids for conversion of non reducing sugars to reducing sugars (Lal *et al.*, 2009) [3] and in non-enzymatic browning reaction. Another reason for loss of acidity may be due to loss of ascorbic acid during storage. Among the packaging material the in 3 layer co-extruded pouches packed sample had maximum retention (7.23%) acidity content while, in PET jars it was minimum (6.57%). Similar results have been reported by Sharma *et al.*, 2003 [10] in apple powder, Manya, 2014 [4] in sapota RTU powder.

Colour values (*L, *a** and *b**):** Colour is an important attribute because it is usually the first property, the consumer observes. Both packaging material, as well as storage period, had an influence on colour of the powder. The powder gradually became darker over the period. This observation was also reflected by the increasing of Hunter *a** values and *b** values, decreasing of Hunter *L** values, which was obviously due to the permeability of the packaging material to water vapour and oxygen. Moreover, residual air remaining in the package may cause oxidation that leads to colour changes during storage.

The parameter *L** indicates the lightness (0 for black, 50 for grey and 100 for white) of the sample (Vardin and Yasar, 2012) [16]. Initially, 63.83, 9.14 and 20.01 were the *L**, *a** and *b** values of wood apple powder, respectively. *L** values were found to decrease during the storage period. The maximum *L** was recorded in powder packed in 50 µ

ALP (62.17, 60.12 and 58.73) whereas, the minimum *L** value was found in powder packed in PET jars (59.17, 57.63 and 53.84) at 2, 4 and 6 months after storage, respectively.

Both *a** and *b** values were found to increase during the storage period. The maximum *a** (towards redness) and *b** value (towards yellowness) were recorded in powder packed in PET jars followed by powder packed in 100 gauge polyethylene pouches during storage. The minimum *a** value and b* value was recorded in 50 gauge ALP and in 3 layer co-extruded film. These results were in agreement with those reported in banana powder reported by Mary *et al.* (2007) [5] and Swami *et al.* (2014) [15] in jamun seed powder.

Organoleptic evaluation: The prepared wood apple powder which was stored under different packaging materials was subjected to organoleptic evaluation by the semi-trained panel to assess the quality attributes like colour and appearance, flavour, texture, taste and overall acceptability using 9 point hedonic scale.

The score for colour and appearance was decreased (8.50-7.79 at initial, 6 MAS, respectively) with the advancement of the storage period in powder packed in different packaging materials. In correlation to this, the decreasing *L** values and increasing *a** and *b** values during the storage period indicate the darkening of the product. The reduction in colour and appearance value was more in powder packed in PET jars and very less in powder packed in 3 layer co-extruded pouches and 50 µ ALP pouches. The darkening of the colour may be due to the nonenzymatic browning and was more common in many of the fruit powders (Sharma *et al.*, 2003) [10]. The retention of light brown colour in 3 layer co-extruded pouches and 50 µ ALP pouches was mainly because of variations in their permeability to light and air main reason for scoring minimum value score was noticed in PET jars may be due to the darkening the product.

The maximum score for flavour was recorded in 3 layer co-extruded pouches at 6 MAS and it was on par with 50 µ ALP pouches and 300 gauge polyethylene bags. Similarly, the maximum score for taste was recorded in 3 layer co-extruded pouches it was found on par with all the other packaging materials except PET jars and 100 gauge polyethylene bags. Potter and Hotchkiss, 1996 reported that laminated aluminium foil pouches possess better barrier properties for moisture, light and gases. Thus, minimum deteriorative changes that were noticed in 3 layer co-extruded, ALP pouches might be responsible for scoring maximum flavour and taste.

The texture (mouth feel) was not affected by the packaging material used. At the end of the storage period, all the packaging materials retained higher score values for mouth feel except PET jars and 100 gauge polyethylene bags. The scores for all the organoleptic parameters *viz.*, colour and appearance, flavour, taste, texture and overall acceptability were found higher in 3 layer co-extruded pouches and ALP pouches as it provides a good barrier to water vapour, gases and light (Potter and Hotchkiss, 1996) [8] compare to other packaging materials used for the storage of wood apple powder. Another reason for the reduction in organoleptic quality might be due to some undesirable changes taking place in the product during storage. Light and temperature play an important role in inducing some undesirable biochemical changes in the processed products which leads to the development of off-flavor as well as discoloration and thereby masking the original color and flavor of the fruit powder. The findings of the study were in agreement with those of Sharma *et al.*, 2003 [10], in apple powder and Manya, 2014 [4] in sapota powder.

Table 1: Effect of packaging materials on moisture content, water activity, total soluble solids (TSS), total sugars and total carbohydrates of wood apple fruit pulp powder during storage

Treatments	Moisture content (%)			Water activity			TSS (ºB)			Total sugars (%)			Total carbohydrates (g/100 g)		
	Months after storage														
	2	4	6	2	4	6	2	4	6	2	4	6	2	4	6
T_1	6.93	7.23	7.61	0.316	0.329	0.343	17.33	17.31	17.27	10.01	9.93	9.88	50.12	50.09	50.11
T_2	6.79	6.88	6.92	0.302	0.311	0.323	17.32	17.33	17.29	10.04	9.95	9.91	50.12	50.10	50.13
T_3	6.81	6.83	6.83	0.298	0.308	0.312	17.33	17.30	17.30	10.09	10.06	10.01	50.11	50.11	50.15
T_4	6.77	6.81	7.03	0.305	0.313	0.315	17.32	17.27	17.27	10.10	10.07	10.03	50.13	50.10	50.11
T_5	6.80	6.82	6.88	0.294	0.298	0.304	17.33	17.27	17.28	10.12	10.10	10.09	50.16	50.12	50.11
T_6	6.77	6.81	6.84	0.298	0.302	0.307	17.31	17.32	17.31	10.12	10.11	10.09	50.15	50.12	50.13
T_7	7.17	7.53	7.83	0.325	0.347	0.361	17.30	17.24	17.23	10.03	9.93	9.91	50.09	50.10	50.08
Mean	6.86	6.99	7.14	0.305	0.315	0.324	17.32	17.29	17.28	10.07	10.02	9.99	50.13	50.11	50.12
S.Em±	0.026	0.019	0.027	0.001	0.001	0.001	0.023	0.028	0.020	0.008	0.013	0.011	0.014	0.010	0.014
C.D. @ 1%	0.108	0.081	0.112	0.006	0.006	0.006	NS	NS	NS	0.034	0.055	0.044	NS	NS	NS

Initial values: Moisture content (%) = 6.72, Water activity (a_W) = 0.291, TSS(°B) = 17.32, Total sugars(%) = 10.12 and carbohydrates (g/100 g) = 50.14

T_1-100 gauge poly ethylene bags, T_2-200 gauge poly ethylene bags, T_3-300 gauge poly ethylene bags, T_4-25 micron (100 guage) aluminium foil, T_5-50 micron (200 guage) aluminium foil, T_7-PET jars, NS: Non significant

Table 2: Effect of packaging materials on acidity, ascorbic acid, *L**, *a** and *b** values of wood apple fruit pulp powder during storage

Treatments	Acidity (%)			Ascorbic acid (mg/100 g)			*L**			*a**			*b**		
	Months after storage														
	2	4	6	2	4	6	2	4	6	2	4	6	2	4	6
T_1	8.04	7.53	6.68	3.08	2.52	1.98	60.89	58.60	54.18	12.16	13.07	13.48	22.47	22.68	23.57
T_2	7.98	7.47	6.97	3.11	2.68	2.26	61.09	58.10	55.08	12.11	12.98	13.09	22.19	22.86	22.94
T_3	8.06	7.43	6.88	3.28	2.83	2.41	60.56	58.36	55.19	10.68	11.13	12.14	21.93	22.27	22.89
T_4	8.23	7.68	7.13	3.13	2.71	2.17	61.55	59.88	58.39	9.57	9.82	10.13	20.84	21.08	21.93
T_5	8.17	7.53	7.19	3.16	2.83	2.39	62.17	60.12	58.73	9.24	9.51	9.62	20.08	20.74	20.94
T_6	8.38	7.68	7.23	3.31	2.95	2.59	61.93	59.89	58.44	9.66	9.82	9.54	20.56	20.83	20.72
T_7	7.85	7.03	6.57	3.17	2.49	1.88	59.17	57.63	53.84	13.08	13.54	13.64	23.13	23.68	23.96
Mean	8.10	7.48	6.95	3.18	2.72	2.24	61.05	58.94	56.26	10.93	11.41	11.66	21.60	22.02	22.42
S.Em±	0.030	0.021	0.021	0.009	0.014	0.013	0.020	0.017	0.018	0.014	0.023	0.024	0.048	0.031	0.029
C.D. @ 1%	0.128	0.090	0.089	0.039	0.057	0.056	0.084	0.072	0.075	0.060	0.095	0.100	0.202	0.130	0.123

Initial values: Titratable acidity (%) = 8.93, Ascorbic acid (mg/100 g) = 3.67, *L** = 63.83, *a** = 9.14 and *b** = 20.01

T_1-100 gauge poly ethylene bags, T_2-200 gauge poly ethylene bags, T_3-300 gauge poly ethylene bags, T_4-25 micron (100 guage) aluminium foil, T_5-50 micron (200 guage) aluminium foil, T_7-PET jars.

Table 3: Effect of packaging materials on colour and appearance, flavor, texture, taste and overall acceptability of wood apple fruit pulp powder during storage

Treatments	Colour and appearance			Flavour			Texture			Taste			Overall acceptability		
	Months after storage														
	2	4	6	2	4	6	2	4	6	2	4	6	2	4	6
T_1	8.17	7.33	7.00	7.83	7.17	6.42	8.00	7.92	7.83	8.17	8.00	7.67	8.04	7.60	5.63
T_2	8.33	8.17	8.00	8.00	8.00	7.83	8.00	8.00	8.00	8.33	8.17	8.00	8.17	8.08	6.00
T_3	8.33	8.17	8.17	8.00	8.00	8.00	8.08	8.00	8.00	8.33	8.17	8.00	8.19	8.08	6.04
T_4	8.33	8.17	8.00	8.00	7.83	7.83	8.00	8.00	8.00	8.33	8.17	8.00	8.17	8.04	6.00
T_5	8.50	8.33	8.33	8.00	8.00	8.00	8.08	8.00	8.00	8.33	8.17	8.08	8.23	8.13	6.10
T_6	8.50	8.50	8.33	8.00	8.00	8.00	8.08	8.00	8.00	8.33	8.17	8.17	8.23	8.17	6.13
T_7	8.17	7.33	6.67	7.83	7.08	6.33	8.00	7.83	7.75	8.17	7.83	7.50	8.04	7.52	5.48
Mean	8.33	8.00	7.79	7.95	7.73	7.49	8.04	7.96	7.94	8.29	8.10	7.92	8.15	7.95	5.91
S.Em±	0.141	0.154	0.114	0.089	0.094	0.114	0.055	0.070	0.063	0.167	0.154	0.094	0.053	0.070	0.039
C.D. @ 1%	NS	0.650	0.478	NS	0.398	0.478	NS	NS	NS	NS	NS	0.398	NS	0.293	0.162

Initial values: Colour and appearance = 8.50, Flavour = 8.00, Texture = 8.08 Taste = 8.33 and Overall acceptability = 8.23

T_1-100 gauge poly ethylene bags, T_2-200 gauge poly ethylene bags, T_3-300 gauge poly ethylene bags, T_4-25 micron (100 guage) aluminium foil, T_5-50 micron (200 guage) aluminium foil, T_7-PET jars, NS: Non significant

Conclusion

Wood apple powder packed in 3 layer co-extruded film can be safely stored under ambient conditions up to six months with very minimum deterioration in quality *i.e.* physico-chemical characters and organoleptic qualities.

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