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EFFECT OF SELECTED MINIMAL PROCESSING TECHNIQUES IN CASSAVA TUBERS

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Key words : *Minimal processing, Quality of attributes, Storage life, Cassava tuber chips, Weight loss*

Abstract– Minimal Processing is the technique to process a fruit or vegetable commodity to a minimum level for maximum shelf life while maintaining its freshness nearly intact. The rapid perishability of fresh cassava tuber imposes a limitation in its marketing and consumption. In view of this, fresh cassava tubers of variety,' Sree Vijaya' were subjected to minimal processing techniques of steaming, dipping in hot water (98 °C), dipping in hot oil (190 °C) and microwave oven treatments. Steaming, dipping in hot water as well as the microwave oven treatments were conducted for 1,2,3,4 and 5 min time intervals using peeled cassava chips of 2,4,6,8 and 10 mm thickness. The time of treatment for dipping in hot oil, however, was resricted to 15,30 and 45 seconds. Quality factors such as crumbling, cracking, odour and surface gelatinization, were observed. The fresh sample served as the control. Shelf life studies were done for tubers packed in 28µ thick polythene bags of 21 × 15 cm size at ambient (30 °C) and refrigerated (5 °C) condition, by regular visual observations for any microbial attack. Significant difference in starch was found in case of 2,4 6 and 8 mm thick chips dipped in hot water. The weight loss parameter was statistically analysed at 5% level of significance using Anova for all the 4 techniques. Micro wave oven treatment of fresh cassava chip samples is observed to be the most effective minimal processing technique. The shelf life of the product could be enhanced to 3 days, compared to 2 days in low temperature storage for the control, and the product also has maximum resemblance with the fresh chips in its quality attributes.

INTRODUCTION

Minimal Processing is defined as to processing the Cassava tubers subjecting to different treatments such as boiling, steaming, microwave and hot oil. This minimal processing is very much useful to the processing sector since it is one way of preserving the perishable commodities and make it more ready to eat form when packed in polyethlyene bags. The cassava processed forms are chips and boiled ready to eat form. This Cassava tubers are poorman's food and nowadays gaining up market in its processed form. This cassava tuber is very cost economic in its processed form and is famous since it is nutritious in its content for all age groups and has certain medicinal value also. Most of the Cassava tuber is starch and this has many utilities when processed not only in food sector but also in non food sector such as gum, powder, starch for clothes. Starch is most cost economic and more calorie rich food and serves the high apetite people. Hence this Cassava tuber is processed to obtain more value added products. This study pertaining to know the weight loss after processing from its fresh form gains utility in the processing field. Different treatments used to control undesirable changes are physiological and physical changes that adversely afffect the quality of MP products (Gonzalez-Aguilar *et al.,* 2010). Some of the fruit and vegetables require slicing, shredding and these inturn are spoilt by microorganisms (Adams *et al.,* 1989)

MATERIALS AND METHODS

Minimal processing in Cassava tuber crop is subjecting the tuber to different types of pre treatments such as dipping in boiling water, dipping in hot water, steam treatment, subjecting to microwave heating condition and dipping in hot oil and quantifying the weight loss and starch loss due

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to these processing operations. The fresh cassava tubers were cleaned in tap water, peel removed and then sliced into different thickness of 2 mm, 4 mm, 6mm, 8 mm and 10 mm of round shape. Then 100 g of the sliced samples were dipped in boiling water for different time durations of 1,2,3,4 and 5 sec and then weight loss were determined and tabulated. Then Anova was worked out to know the significance of the experiments and the interaction effect of time and thick ness were also worked out using SPSS. The treatments of dipping in boiled water (98 °C), steaming, microwave oven and dipping in oil (190 °C) were done for peeled cassava chips (Var. Sree Vijaya) of thickness, 2,4,6,8 and 10 mm for 1, 2, 3, 4 and 5min interval. The fresh sample served as a control. To prepare minimally processed products, peeling is much essential to remove the unwanted parts (Watada and Minott, 1996). The treated tubers were packed in polyethylene covers of thickness 2.8 and size, 21 × 15 cm. The shelf life studies were done by keeping the treated samples in the covers in ambient and refrigerated (5 °C) conditions. The starch loss for the treated samples were estimated. The percent weight loss/gain due to the above treatment is given in Tables 1 and 3-5 and starch loss is given in Table 2. Shelf life studies were done at an interval of 12 h by visual observations for any microbial attack.

RESULTS AND DISCUSSION

Weight loss in process of dipping in boiled water

The pretreatments to the freshly cut cassava tubers were done to improve the palatability alongwith increase in shelf life of the tubers. With this the marketability of the freshly harvested tubers can be improved. The pretreatments reduces the degree of browning after the tubers are sliced and the color of the freshly cut tubers are maintained. The thickness of the tuber slices of cassava tuber were 2,4, 6, 8, 10 mm. The time of dipping in boiled water are 1,2,3,4 and 5 sec. The weight loss in dipping in boiled water in 2 mm thick tuber is minimum in 1sec and 5 sec. From 2 sec onwards the weight loss gradually increases and reaches maximum in 4 sec, 3.00±0.40. The average weight loss was 1.90g±0.40, cv is 47%. The weight loss in dipping in boiled water in 4mm thick tuber is minimum in 2.00±0.28 and maximum is 3.60±0.28.cv is 21%. in 4mm thick tuber, the weight loss was gradual from 1sec to 5 sec, 2.00±6.28 to 3.60±0.28. In 6 mm thick tuber, the weight loss average was 4.28g±0.14, the weigth loss gradually increases from 3.80±0.14 to 4.60±0.14, minimum is 3.80±0.14, maximum is 4.60 ± 0.14, cv is 7%. In 8 mm thick tuber, the weight loss average was 5.45±0.17, minimum was 5.1± 0.17, maximum was 5.98±0.17, cv is 7%, the weight loss gradually increases from 5.10±0.17 to 5.98 ±0.17. In 10 mm thick tubers, the weight loss average was 6.52±0.16, minimum is 6.10± 0.16, maximum is 7.00±0.16, cv is 6%, the weight loss increases gradually from 6.10± 0.16 to 7.00±0.16, 1 to 5sec. Factors that affect minimal processing fruits and vegetables includes improper handling and processing (Lester, 2003; Thybo *et al.*, 2006). To reduce microbial loads on surface, hot water immersion treatments, are used to reduce browning. This coincided with the earlier findings of Dea *et al.*, 2010; Campos. Vargas *et al.*, 2005 in lettuce, apple and pears. In mean comparision by Least Significant Difference, LSD, among the 5 sizes of 2,4,6,8 and 10 mm of Cassava tubers, 8 mm sized tubers has minimum weight loss and 2 mm sized tubers has maximum weight loss. In the interaction effect, dipping in oil and 5 sec duration has minimum weight loss and the combination of dipping in oil wih 1 sec duration has maximum weight loss. Weight loss in process of dipping in boiled water. (Fig. 3), Weight loss in process of dipping in boiled water (Fig. 6), weight loss in Process of dipping in boiled water. (Table 1), Anova for weight loss in Process of dipping in boiled water (Table 6), Anova for 2 mm sized cassava tuber, (Table 11) Anova for 4 mm sized cassava tuber, (Table 12), Anova for 6 mm sized cassava tuber, Table 13), Anova for 8 mm sized cassava tuber, (Table 14), Anova for 10 mm sized cassava tuber (Table 15) are shown. The weight loss of the different sizes of cassava tubers at 2 mm, 4 mm, 6 mm and 10 mm are significant at 5% level of significance in dipping in boiled water ($p \leq 0.05$)

Starch loss in dipping in hot water

Generally cassava is grown for its starch content. The starch content during pretreatment had to be estimated so that the full potential of the worth of tubers can be tapped.

Average starch loss in 2 mm thick tuber is 3.86±0.37, minimum is 2.45 ± 0.37, maximum is 5.00±0.37, cv is 21%. In 2 mm thickness, the starch loss gradually increases from 2.45±0.37 to 5.00±0.37. In 4 mm thickness, the average starch loss is 3.10±0.31, minimum is 1.78±0.31, maximum is 4.20± 0.31, cv is 22%, the weight loss in starch gradually increases from 1.78±0.31 to 4.20±0.31,1 to 5 sec. In

6mm thickness, the average starch loss is 2.05± 0.13, minimum is 1.49± 0.13, maximum is 2.40±0.13, cv is 15%. The starch loss in % in cassava tubers due to dipping in hot water is 1.49±0.13 to 2.40±0.13. in 8mm thickness, the average starch loss is 1.55± 0.18, minimum is 1.23±0.18, maximum is 1.90±0.18, cv is 26%, the starch loss gradually increases from 1.23±0.18 to 1.90±0.18. In 10 mm thickness tuber, the average starch loss is 0.94±0.18, the minimum starch is 0.88±0.18, maximum loss is 0.99 ± 0.18, cv is 42%, the starch loss gradually increases from 0.88±0.18 to 0.99±0.18, cv is 42%. In mean comparision by LSD, among the 5 sizes, 10 mm sized tuber has minimum weight loss and 2 mm size shows maximum weight loss. 1 sec duration is the best treatemnt for minimum weight loss and 5 sec. shows maximum weight loss, in combination of 1 sec duration and 10 mm sized tubers shows minimum weight loss and 2 mm sized tubers and 5 sec. duraion has maximum weight loss. weight loss in 2 mm thick cassava tuber, (Fig.1). Weight loss inprocess of dipping in hot water. (Fig. 7) starch loss in cassava tubers due to dipping in hot water (Table 2). Anova for starch loss in cassava tubers due to dipping in hot water (Table 7) are shown. The starch loss of the different sizes of cassava tubers at 2 mm, 4 mm, 6 mm and 10 mm are significant at 5% level of significance in dipping in hot water ($p \leq 0.05$)

Weight loss of Cassava tubers due to steaming

Minimal processing increases the rates of metabolic processes that cause deterioration of fresh produce. Microbial growth gets controlled in minimally processed vegetable than in freshly cut raw tubers. Hence minimal processing is highly recommended for quick cooking of vegetable and also for export markets and the tuber has to remain fresh for quiet a long time before cooking.Conditions for processing of the minimally processed cassava tubers such as peeling, slicing, pretreatments, packing and storing must be standardized to retain the freshness, texture and flavor of the product equal to that of raw material with improved shelf life.

In 2 mm thickness, the average is 44.74±1.68, minimum is 39.50±1.68, maximum is 48.70 ± 1.68, cv is 8%, the weight loss gradually increases from 39.50±1.68 (1 sec) to 48.70± 1.68 (5 secs). In 4 mm thickness the average weight loss is 39.70±3.34, minimum is 30.50±3.34, maximum is 50.00±3.34, cv is 19%, weight loss gradually increases from 1 to 5 sec., 30.50 ± 3.34 to 50 ± 3.34. In 6 mm thick tubers, the average weight loss is 38.40±2.40, minimum is 29.50± 2.40, maximum is 43.50±2.40, cv is 14%, the weight loss gradually increases from 29.50 ± 2.40 to 43.50 ±2.40. In 8 mm thick tubers, the average weight loss is 28.90 ± 2.54, minimum is 24.50 ± 2.54, maximum is 38.50±2.54, cv is 20%, the weigth loss gradually increases from 24.50±2.54 to 38.5±2.54. In 10 mm thick tubers, the average weight loss is 29.20±3.01, minimum is 19.5 ± 3.01, maximum is 37.00±3.01, cv is 23%, weight loss gradually increases from 19.50 ± 3.01 to 37.0 ± 3.01. Among the selected 5 thickness, the weight loss of cassava tubers due to steaming is maximum in 2 mm thickness and minimum in 8 mm thickness and from 10 mm thickness onwards the weight loss increases. In mean comparision by Least Significant Difference, LSD, 5 sec duration has minimum weight loss and 1 sec. duration has maximum weight loss. 2 mm sized tubers has minimum weight loss and 8 mm sized tubers has maximum weight loss and in combination of 5 sec. druation and 2 mm sized tubers shows minimum weight loss and 1sec. duration and 10 mm sized tubers has maximum weight loss. weight loss in 4 mm thick cassava tuber (Fig. 2), weight loss in steaming treatment (Fig. 8), weight loss of cassava tubers due to steaming (Table 3) Anova for weight loss of cassava tubers due to steaming (Table 8) are shown. The weight loss of the different sizes of cassava tubers at 2 mm, 4 mm, 6 mm and 10 mm are significant at 5% level of significance in steam treatment ($p \leq 0.05$)

Weight loss of Cassava tubers due to microwave treatment

Main advantage of microwave processing over thermal preservations like pasteurization is taste and flavor preservation of the product. It does not lead to change in sensory characteristics including flavor, odor and color of the product and does not produce any undesirable products. Therefore microwave technology could be used as a promising food preservation method instead of application of synthetic antimicrobial agents or thermal treatments. One of the main problems associated with minimally processed fruits and vegetables is browning that causes color change and poor appearance of products. Washing with water alone is not adequate to slow down this browning process. Microwave treatment will solve the problem of browning.

In 2 mm thick cassava tuber, average weight loss

is 32.70±6.89, minimum is 13.50 ±6.89, maximum is 49.50±6.89, cv is 47%. In 4 mm thick tuber, average weight loss is 27.90± 5.99, minimum is 11.50±5.99, maximum is 44.50±5.99, cv is 48%, the weight loss gradually increases from 11.50±5.99 to 44.50±5.93. In 6 mm thick ubers, average weight loss is 25.58± 5.11, minimum is 11.50±5.11, maximum is 36.20±5.11, cv is 45%, the weight loss gradually increases from 11.50±5.11 to 36.20±5.11. In 8 mm thick tubers, average weigth loss is 23.30±4.97, minimum is 9.50±4.97, maximum is 34.00±4.97, cv is 48%, weight loss gradually increases from 9.50± 4.97 to 34.00 ± 4.97. In 10 mm thick tubers, average weight loss is 21.30±4.74, minimum is 8.50 ± 4.74, maximum is 31.50±4.74, cv is 54%, weight loss gradually increases from 8.50 ± 4.74 to 31.5 ± 4.74. In the selected 4 thickness of tubers, the weight loss gradually increases from 32.70±6.89 to 21.30±4.74. In mean comparision by Least Significant Difference, LSD, 10 mm sized tubers has minimum weight loss and 1 mm sized tubers shows 2 mm sized tubers.1 sec has minimum weight loss and 5 sec. has maximum weight loss and in combination of 10 mm sized tubers and 1 sec. duraion has minimum of 10 mm sized ubers and 1 sec. duration has minimum weight loss and the combination of 2 mm sized tubers and 5 sec. duration has maximum weight loss. weight loss of 6 mm thick cassava tuber (Fig. 4), Weight loss in microwave treatment (Fig. 9), weight loss of cassava tubers due to microwave treatment (Table 4), Anova for weight loss of cassava tubers due to microwave treatment (Table 9) are shown. The weight loss of the different sizes of cassava tubers at 2 mm, 4 mm, 6 mm and 10 mm are significant at 5% level of significance in microwave treatment ($p \leq 0.05$)

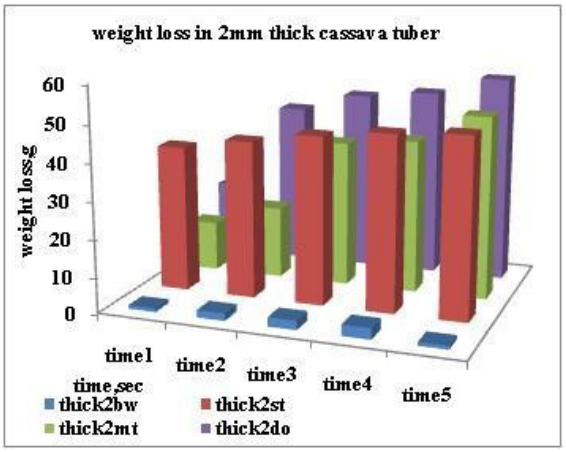

Fig. 1. Weight loss in 2 mm thick cassava tuber

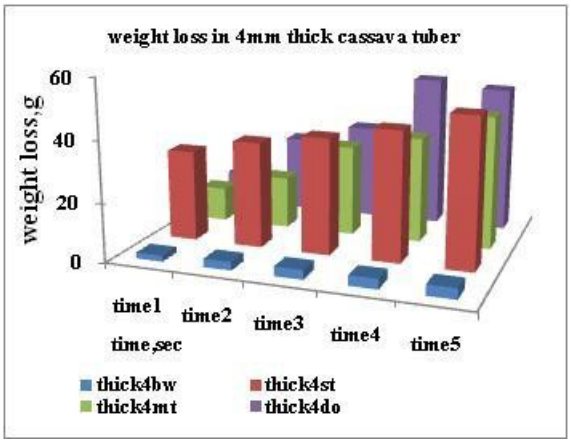

Fig. 2. Weight loss in 4 mm thick cassava tuber

Weight loss of Cassava tubers due to dipping in oil

In green and purple cauliflower, boiling for 15 min reduced total glucosinolats by about 70% (Kap usta Duch *et al.*, 2016). In fava beans, antioxidants were reduced by 10 times during soaking and boiling, but were retained during roasting. (Grain Research and

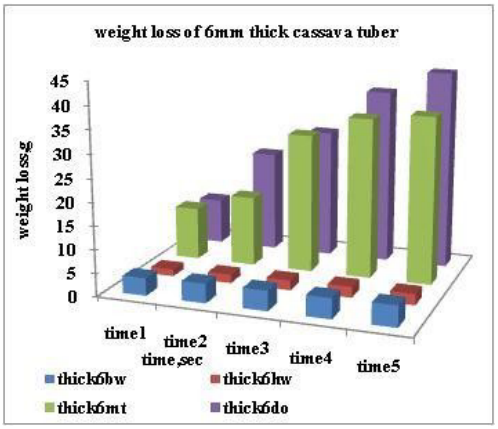

Fig. 3. Weight loss of 6 mm thick cassava tuber

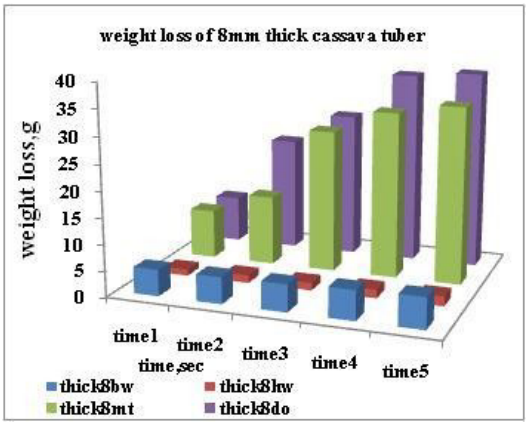

Fig. 4. Weight loss of 8 mm cassava tuber

Develpment Corporation 2007).

In white sweet potato, steaming was the best method to retain antioxidants; in purple and yellow sweet potato roasting was the best. (Sengkhamparn, 2015). In purple fletched potato, steaming and micro-waving was the best. (Svetlana Rodgers, 2016). Minimally processed fruits and vegetables,that are raw products that are simply trimmed, peeled, sliced, shredded,washed and are disinfected ,are generally considered safe to be eaten by consumers, since their surface have micro organisms that are not of human health significance. The loss in moisture results in a reduction of fresh weight accompanied by the loss of freshness, appearance and texture. In 2 mm thick tubers, the average weight loss is 44.00±6.30, minimum is 20.00 ± 6.30, maximum is 56.00±6.30, cv is 32%, the weight loss gradually increases from 20 g to 56 g. In 4 mm thick tuber, the average weight loss is 33.80± 7.45, minimum is 11.00±7.45, maximum is 51.00± 7.45, cv is 49%, weight loss gradually increases from 11.00±7.45 to 49.00±7.45,1 to 5 sec. In 6 mm thick tubers, the average weight loss is 28.20±5.85, minimum is 10.00±5.85, maximum is 43±5.85, cv is

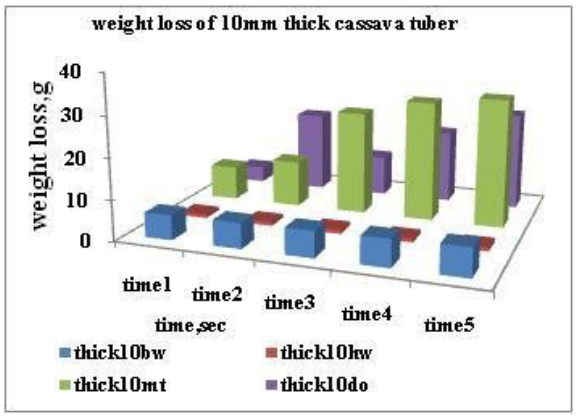

Fig. 5. Weight loss of 10mm cassava tuber

Table 1. Weight loss in Process of dipping in boiled water treatment

Treatment	Thickness of the tuber slices (mm)				
Time (min)	2	4	6	8	10
1	1.00	2.00	3.80	5.10	6.10
2	2.00	2.80	4.20	5.15	6.25
3	2.50	3.20	4.35	5.28	6.50
4	3.00	3.40	4.44	5.75	6.75
5	1.00	3.60	4.60	5.98	7.00
Aver.	1.92	3.17	4.57	5.88	7.10
Min.	1.00	2.00	3.80	5.10	6.10
Max.	3.00	4.00	6.00	8.00	10.0
Sd	0.89	0.63	0.30	0.39	0.37
Sem	0.40	0.28	0.14	0.17	0.16
Cv	47	20	7	7	5
S /ns	s	s	s	s	s

Table 2. Starch loss in cassava tubers due to dipping in hot water treatment

Treatment	Tthickness of the tuber slices(mm)				
Time (min)	2	4	6	8	10
1	2.45	1.78	1.49	1.23	0.88
2	3.65	2.20	1.85	1.48	0.92
3	3.95	3.55	2.15	1.48	0.94
4	4.25	3.75	2.35	1.68	0.97
5	5.00	4.20	2.40	1.90	0.99
Aver.	3.55	3.25	2.71	2.63	2.45
Min.	2.00	1.78	1.49	1.23	0.88
Max.	5.00	4.20	6.00	8.00	10.00
Sd	0.82	0.69	0.30	0.40	0.40
Sem	0.37	0.31	0.13	0.18	0.18
Cv	23	21	11	15	16
S/Ns	s	s	s	s	s

Table 3. Weight loss of cassava tubers due to steaming treatment

Treatment	Thickness of the tuber slices(mm)				
Time (min)	2	4	6	8	10
1	39.50	30.50	29.50	24.50	19.50
2	42.50	35.50	38.50	26.50	26.50
3	45.50	39.00	39.00	25.50	29.50
4	47.50	43.50	41.50	29.50	33.50
5	48.70	50.00	43.50	38.50	37.00
Aver	37.62	33.75	33.00	25.42	26.00
Min.	2.00	4.00	6.00	8.00	10.00
Max.	48.70	50.00	43.50	38.50	37.00
Sd	3.75	7.47	5.37	5.68	6.72
Sem	1.68	3.34	2.40	2.54	3.01
Cv	10	22	16	22	26
S/ns	s	s	s	s	s

Table 4. Weight loss of cassava tubers due to micro - wave treatment

Treatment	Thickness of the tuber slices(mm)				
Time (min)	2	4	6	8	10
1	13.50	11.50	11.50	9.50	8.50
2	19.50	17.50	15.25	13.50	11.50
3	39.50	30.50	30.20	27.50	25.50
4	41.50	35.50	34.75	32.00	29.50
5	49.50	44.50	36.20	34.00	31.50
Aver	27.58	23.92	22.32	20.75	19.42
Min.	2.00	4.00	6.00	8.00	8.50
Max.	49.50	44.50	36.20	34.00	31.50
Sd	15.40	13.39	11.44	11.12	10.59
Sem	6.89	5.99	5.11	4.97	4.74
Cv	56	56	51	54	55
S/ns	s	s	s	s	s

Table 5. Weight loss of cassava tubers due to dipping in oil treatment

Treatment	Thickness of the tuber slices(mm)				
Time (min)	2	4	6	8	10
1	20.00	11.00	10.00	9.00	4.00
2	44.00	26.00	22.00	22.00	20.00
3	49.00	32.00	28.00	28.00	10.00
4	51.00	51.00	38.00	37.00	18.00
5	56.00	49.00	43.00	38.00	24.00
aver	37.00	28.83	24.50	23.67	14.33
min.	2.00	4.00	6.00	8.00	4.00
max.	56.00	51.00	43.00	38.00	24.00
sd	14.09	16.66	13.08	11.95	8.07
sem	6.30	7.45	5.85	5.34	3.61
cv	38	58	53	50	56
s/ns	s	s	s	s	s

Table 6. Anova for weight loss in Process of dipping in boiled water treatment

Source	df	SS	MS	F	PROB
TOT	49	146.55	2.99	890.09	
Rep	1	0.01	0.01	3.25	
Trt	24	146.46	6.10	1816.13	0.00 **s
Err	24	0.08	0.003	1.00	
b	4	6.59	1.64	490.55	0.00 **s
t	4	133.95	33.48	9965.85	0.00 **s
bt	16	5.91	0.36	110.10	0.00 **s
Err	24	0.08	0.003	1.00	

CV = 1.48%

SED	CD(0.05)	CD(0.01)
b	0.02	0.05	0.07
t	0.02	0.05	0.07
bt	0.05	0.11	0.16

46%, weight loss gradually increases from 10.00±5.85 to 43.00±5.85. In 8 mm thick tubers, the average weight loss is 26.80± 5.34, minimum is 9.00±5.34, maximum is 38.00± 5.34, cv is 45%, weight loss gradually increases from 9.00±5.34 to 38.00±5.34 from 1 to 5 sec. In 10 mm thick tubers the average weight loss is 15.20±3.61, minimum is 4.00± 3.61, maximum is 24 ±3.61, cv is 53%, weight loss gradually increases from 4.00± 3.61 to 24.00 ±3.61

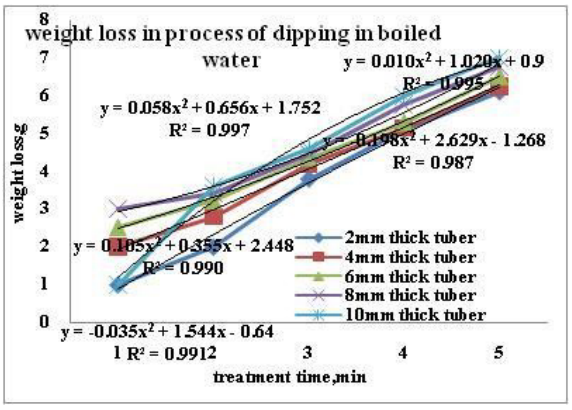

Fig. 6. Weight loss in process of dipping in boiled water treatment

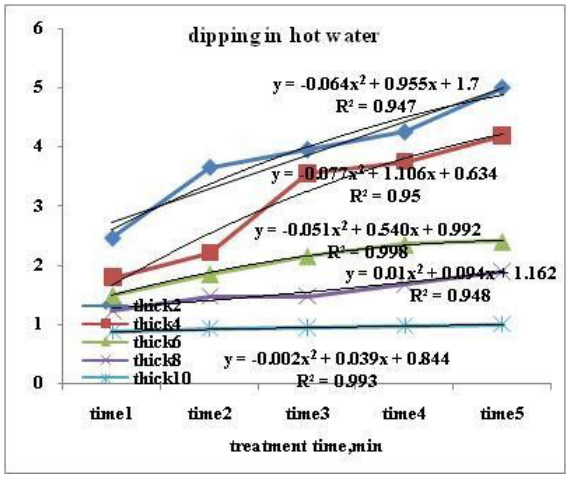

Fig. 7. Weight loss in process of dipping in hot water treatment

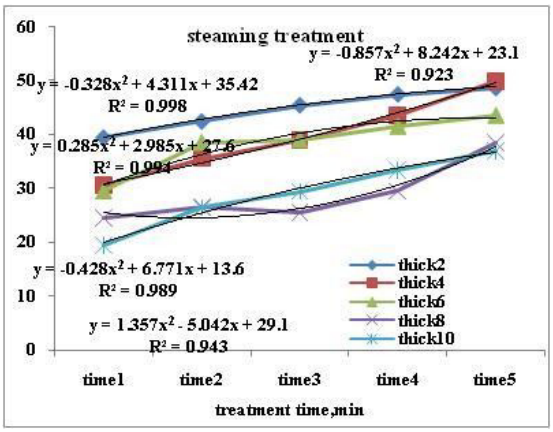

Fig. 8. Weight loss in steaming treatment

Table 7. Anova for starch loss in cassava tubers due to dipping in hot water treatment

Source	df	SS	MS	F	PROB
TOT	49	70.80	1.44	492.51	
Rep	1	0.02	0.02	8.70	
Trt	24	70.70	2.94	1004.18	0.00 **s
Err	24	0.07	0.002	1.00	
s	4	10.44	2.61	889.91	0.00 **s
t	4	53.97	13.49	4599.63	0.00 **s
st	16	6.28	0.39	133.89	0.00 **s
Err	24	0.07	0.002	1.00	

CV =	2.28%SED	CD(0.05)	CD(0.01)
s	0.02	0.04	0.06
t	0.02	0.04	0.06
st	0.05	0.11	0.15

from 1 to 5 sec. Among all the above 4 treatments, dip in hot water with 2mm thick tubers is 44.74±1.68 and minimum weight loss is dip in boiling water with 2 mm thick tubers, 1.90±0.40 followed by microwave treatment, 32.70±6.89, then dip in oil, 44.00±6.30 and then dip in hot waer, 44.74 ± 1.68. In 4mm thick tubers, the weight loss was maximum in dipping in hot water, 39.70±3.34 followed by dipping in hot oil, 33.80±3.34, then microwave treat ment, 27.90±5.99 and then in boiling waer, 3.00±0.28. In 6mm thick tuber, the weight loss was maximum in 38.40±2.40 followed by dipping in oil, 28.20±5.85,

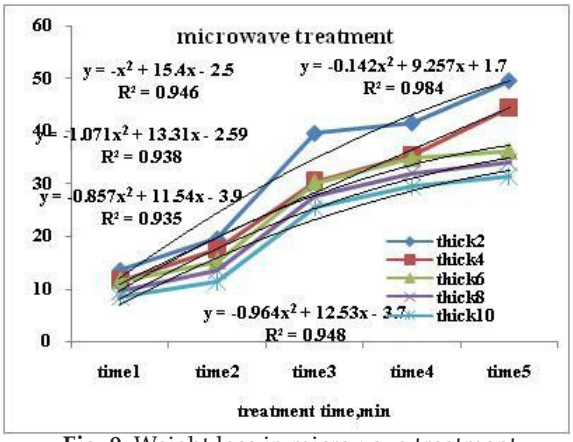

Fig. 9. Weight loss in microwave treatment

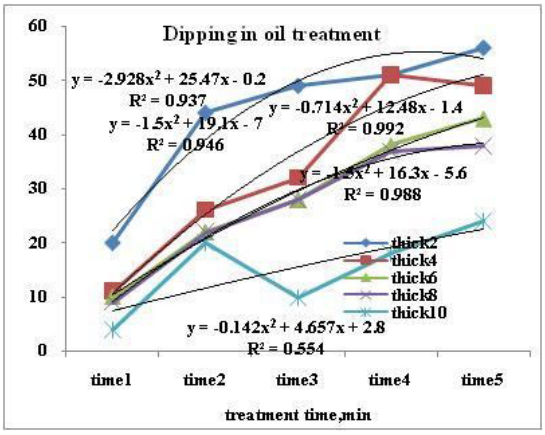

Fig. 10. Weight loss in dipping in oil treatment water

Table 8. Anova for weight loss of cassava tubers due to steaming treatment

Source	df	SS	MS	F	PROB
TOT	49	3340.35	68.17	769.77	
Rep	1	0.19	0.19	2.19	
Trt	24	3338.03	139.08	1570.53	0.00 **s
Err	24	2.12	0.08	1.00	
T	4	1275.04	318.76	3599.42	0.00 **s
S	4	1887.39	471.84	5328.06	0.00 **s
Ts	16	175.59	10.97	123.92	0.00 **s
Err	24	2.12	0.08	1.00	
CV =t	84%				
	SED	CD (0.05)	CD (0.01)		
S	0.13	0.27	0.37		
T	0.13	0.27	0.37		
Ts	0.29	0.61	0.83		

Table 9. Anova for weight loss of cassava tubers due to microwave treatment

Source	df	SS	MS	F	PROB
TOT	49	7044.96	143.77	1740.87	
Rep	1	0.03	0.03	0.46	
Trt	24	7042.94	293.45	3553.26	0.00 **s
Err	24	1.98	0.08	1.00	
S	4	6102.23	1525.55	18471.94	0.00 **s
T	4	749.96	187.49	2270.19	0.00 **s
St	16	190.75	11.92	144.35	0.00 **s
Err	24	1.98	0.08	1.00	
CV =	1.14%				
	SED	CD(0.05)	CD(0.01)		
S	0.12	0.26	0.36		
T	0.12	0.26	0.36		
St	0.28	0.59	0.80		

Table 10. Anova for weight loss of cassava tubers due to dipping in oil treatment

Source	df	SS	MS	F	PROB
TOT	49	11128.27	227.10	2351.46	
Rep	1	0.01	0.01	0.13	
Trt	24	11125.94	463.58	4799.90	0.00 **s
Err	24	2.31	0.09	1.00	
S	4	5957.08	1489.27	15419.87	0.00 **s
T	4	4369.26	1092.31	11309.79	0.00 **s
St	16	799.598	49.97	517.43	0.00 **s
Err	24	2.312	0.09	1.00	
CV =	1.07%SED	CD(0.05)	CD(0.01)		
S	0.13	0.28	0.39		
T	0.13	0.28	0.39		
St	0.31	0.64	0.87		

Table 11. ANOVA FOR : 2mm sized cassava tuber

Source	df	SS	MS	F	PROB
TOT	49	21385.69	436.44	6834.51	
Rep	1	0.52	0.52	8.27	
Trt	24	21383.63	890.98	13952.44	0.00 **s
Err	24	1.53	0.06	1.00	
T	4	1796.80	449.20	7034.28	0.00 **s
S	4	17755.00	4438.75	69508.99	0.00 **s
Ts	16	1831.82	114.48	1792.84	0.00 **s
Err	24	1.53	0.06	1.00	
CV = 9.8%					

Table 12. ANOVA FOR : 4mm sized cassava tuber

Source	df	SS	MS	F	PROB
TOT	49	12599.07	257.12	6878.55	
Rep	1	0.15	0.15	4.13	
Trt	24	12598.02	524.91	14042.55	0.00 **s
Err	24	0.89	0.03	1.00	
T	4	1413.27	353.31	9451.95	0.00 **s
S	4	9983.56	2495.89	66769.85	0.00 **s
Ts	16	1201.18	75.07	2008.37	0.00 **s
Err	24	0.89	0.03	1.00	
CV = 1.02%					

Table 13. ANOVA FOR : 6mm sized cassava tuber

Source	df	SS	MS	F	PROB
TOT	49	16196.95	330.55	4438.77	
Rep	1	0.02	0.02	0.30	
Trt	24	16195.14	674.79	9061.47	0.00 **s
Err	24	1.78	0.07	1.00	
T	4	2406.04	601.51	8077.35	0.00 **s
S	4	12059.39	3014.84	40484.72	0.00 **s
Ts	16	1729.70	108.10	1451.69	0.00 **s
Err	24	1.78	0.07	1.00	
CV = 1.24%					

Table 14. ANOVA FOR : 8mm sized cassava tuber

Source	df	SS	MS	F	PROB
TOT	49	8900.30	181.63	2874.85	
Rep	1	0.04	0.04	0.75	
Trt	24	8898.74	370.78	5868.45	0.00 **s
Err	24	1.51	0.06	1.00	
T	4	1225.08	306.27	4847.45	0.00 **s
S	4	6532.30	1633.07	25847.17	0.00 **s
Ts	16	1141.35	71.33	1129.03	0.00 **s
Err	24	1.516	0.06	1.00	
CV = 1.46%					

Table 15. ANOVA FOR : 10 mm sized cassava tuber

Source	df	SS	MS	F	PROB
TOT	49	6922.97	141.28	9117.62	
Rep	1	0.001	0.001	0.08	
Trt	24	6922.60	288.44	8614.15	0.00 **s
Err	24	0.37	0.01	1.00	
t	4	897.15	224.28	14474.14	0.00 **s
s	4	5138.32	1284.58	82898.44	0.00 **s
ts	16	887.12	55.44	3578.08	0.00 **s
Err	24	0.37	0.01	1.00	
CV = 88%					

microwave treatment, 25.58± 5.85, dipping in boiling water, 4.28±0.14. In 8 mm thick tuber, the weight loss was maximum in 28.90±2.54 followed by dipping in oil, 26.80±5.34, microwave treatment, 23.30±5.34, dipping in boiling water, 5.45± 0.17. In 10 mm thick tuber, the weight loss was maximum in dipping in hot water, 29.20±3.01, followed by microwave treatment, 21.30± 4.74, dipping in oil, 15.20±3.6, 6.52±0.16 and dipping in boiled water. In mean comparision by LSD, 10 mm sized tubers shows minimum weight loss and 2 mm sized tubers shows maximum weight loss in time duration, 1 sec. dipping in oil shows minimum weight loss and 5 sec. dipping in oil shows maximum weight loss. The role of reducing sugars in the color of fried potatoes is described by Smith and Davi, 1975; Mazza, 1983. A high concentration of reducing sugars disqualifies potatoes from being used for processing because they have an adverse effect on the color and taste of cooked products.

In combination of time and size, the combination of 10 mm sized tubers and 1 sec. duration shows minimum weight loss and the combination of 2 mm sized tubers and 5 sec. duration shows maximum weight loss. Weight loss of 8 mm cassava tuber and Weight loss of 10 mm cassava tuber (Fig. 4 & 5), Weight loss in dipping in oil treatment. (Fig. 10), weight loss of cassava tubers due to dipping in oil, (Table 5) Anova for weight loss of cassava tubers due to dipping in oil. (Table 10) are shown. The weight loss of the different sizes of cassava tubers at 2 mm, 4 mm, 6 mm and 10 mm are significant at 5% level of significance in dipping in oil treatment ($p \leq 0.05$).

In mean comparision by Least Significant Difference, 5 sec duration of dipping in boiled water, 2 mm sized tuber is the best treatment for minimum weight loss and 1 sec duration of dipping shows maximum weight loss. Among 5 treatments, steaming treatment is the best treatement for minimum weight loss and dipping in hot water shows maximum weight loss of the cassava tuber. The other treatment of dipping in hot oil followed by microwave treatment, then dipping in ot water shows better results in the said order, In the interaction effect of time and 2mm size, the combination of 5sec duration and dipping in hot oil shows minimum weight loss and the combination of 1sec duration and dipping in boiling water shows more weight loss.

In mean comparision by Least Significant Difference, LSD in 4 mm sized tuber, the indivual effect of time, 5sec duration is the best for all 5 selected treatments and among the treatments, steaming is the best and dipping in hot water shows very high weight loss. In the interaction effect, 5 sec duration and steaming treatment has the best result and very high weight loss is in dipping in hot water and 1 sec duration. In mean comparision by Least Significant Difference, LSD in 6 mm sized tubers, the steaming treatment is the best of minimum weight loss and the treatments of boiling water and hot water dipping has maximum weight loss. The combination of dipping in hot oil treatment and 4 sec duration has minimum weight loss. In mean comparision by Least Significant Difference, LSD in 8 mm sized tubers, the steaming treatment and in time, 5 sec duration and in combination of 5 sec duration and steaming treatment are minimum weight loss. In mean comparision by Least Significant Difference, LSD in 10 mm sized tubers, 5 sec duration steaming treatment and in combination 5 sec duration and steaming treatment shows minimum weight loss.

CONCLUSION

Surface gelatinization was seen in all the above heat treatments, more in 2 mm sized sample and very less in 10 mm sized samples. Leathery texture with crispness at the ends were observed for 2 mm and 5 min for oven treated samples. Complete frying for dipping in oil was observed. The treated samples were translucent with soft texture and partial cooking. The shelf life of the control sample of all sizes was 1 day in ambient condition and 2 days in low temperature storage. In hot water dipping treatment, the shelf life of all the treated samples was 12 h in ambient condition and 1 day in low temperature storage. In steaming treatment, the shelf life of the samples was 1 day in ambient storage and 2 days in low temperature storage. In microwave oven treatment, the shelf life of 2 mm

sized treated samples was 3 days in ambient condition and 4 days in low temperature storage. In dipping in hot coconut oil treatment 12 h was the shelf life for all the treated samples in ambient condition and in low temperature storage it was 2 days. For samples, dipping in hot water and steamed ambient storage condition was 30 °C but for microwave oven treated samples the strorage temperature was 32 °C and for dipping in oil it was 33 °C as the experiments were done at different days. Among all the treatments, the microwave oven treated samples at the frequency of 2450 MHZ is considered to be the most effective minimal processing technique since it resembles more of the fresh sample in its quality attributes.

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