



Formulation of Low Sodium Papad by Partially Replacing Sodium Chloride with Calcium Chloride

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ABSTRACT

Background: Excessive salt intake leads to increased sodium levels in the body, which is associated with hypertension. Papad, a traditional snack food, is typically prepared using high concentrations of salt.

Methods: In present study an attempt has been made to prepare black gram papads by replacing sodium chloride with calcium chloride in different proportions and evaluate them for physiochemical, microbiological, textural and organoleptic qualities during storage at ambient temperature (25±5°C) using low-and high-density polyethylene packaging.

Result: The results showed replacing sodium chloride with calcium chloride by 75% did not alter the quality of raw papads up to 135 days and 255 days in low and high density polyethylene respectively.

Key words: Black gram, Packaging material, Papad, Salt, Snack food.

INTRODUCTION

The basic role of salt, a common table salt that is sodium chloride is to improve the taste of food products. Salt is one of the common ingredient used in food products. Along with taste it also has vital role in human nutrition. Salt is having distinctive flavour and also having the ability to enhance the flavour of other ingredients. Along with flavour profile salt also influences texture and plays role in the preservation of foods against microbes by reducing water activity (Kremer *et al.*, 2009). It mainly consist of two element sodium (40%) and chloride (60%). The major source of sodium ion in the diet is salt. All mammals, including humans, need only a little amount of sodium ions to keep the blood pressure and volume constant. It has an effect on the relative fluid volumes inside and outside of the body cells. The majority of dietary sodium comes from salt added to food. It is estimated that approximately 75% originates from processed foods, 10-15% is added by consumers during cooking or at the table and another 10-15% occurs naturally in foods (Mattes and Donnelly, 1991; Ainsworth and Plunkett, 2007).

High sodium/salt containing foods includes mainly snack foods, meat products, fast foods and others fruit, vegetable based products like pickles, soups *etc.* Since the raw material used to make snack foods is bland, flavouring is required for every snack food. Usually, they are seasoned majorly with salt and often with other flavourings. Due to its inexpensive cost, unique flavour and numerous functions salt is widely used in the snack food sector. Among snack foods papad is one of the popular snack food that has been a staple of Indian diets. They are typically prepared with dough consisting of grain, millet, pulses and edible starch flour either separately or together with ingredients such salt, spices, additives and edible oil. Traditionally, papads are prepared using black gram

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dhal, which remains the most widely sold variety in both local and national markets.

Although sodium is essential for normal human functioning, its excessive consumption has been proved to be dangerous to human health. Numerous studies have conclusively shown that consuming too much sodium, primarily in the form of table salt is harmful to individual's health. While there are a number of things that might raise blood pressure, research has indicated that salt is one of the most significant ones. Salt intake in India is estimated to be more than double the recommended maximum of 5g salt/day (2000 mg sodium) set by World Health Organization (Dhelma and Varma, 2015). Over utilization of sodium raises the risk of non-communicable diseases such as stroke, cardiovascular disease and hypertension in the general population (Ruusunen and Puolanne, 2005). He and MacGregor, (2010) mentioned that high blood pressure is thought to be the root cause of 62% of strokes and 49% of coronary heart illnesses. As per study excessive salt consumption is estimated to cause about 6 lakh deaths

each year and to be the 5th leading cause of death in India (WHO, 2006).

There are many ways to reduce sodium content in processed products like by a) lowering the amount of salt while food preparation b) replacing salt with other chloride salts c) using flavour enhancers such as monosodium glutamate, naturally brewed soya sauce d) the salt reduction through public awareness e) the using organic acids such as citric acid, lactic acid, acetic acid f) the addition of dried bonito in egg custard g) changing the form of salt and h) using some herbs and spices instead of salt. Among all those chloride salts like KCl and CaCl_2 have been tried by various researchers in variety of products like cooked sausages, smoked kikka, bread, lime pickle, lemon pickle, gizzard pickles and processed cheese (Bansal and Rani, 2014; Anandh *et al.* 2019). Thus, on consideration of today's population growing demand for low-sodium food products present research project was carried out to reduce the salt content in black gram papad by a) substituting NaCl with CaCl_2 b) using herbs like curry leaves and tamarind pulp as a natural source of acid.

MATERIALS AND METHODS

Material used

The present study was conducted in the Laboratories of the Department of Food Science and Technology, Shivaji University, Kolhapur (MH) within period 2021 to 2023. The black gram dhal of variety B.D.U-1 procured from local market was cleaned and grinded to make fine flour. The black gram flour was stored in HDPE bags until further use. Sodium chloride (Tata), sodium bicarbonate (Mega), premium quality spices like cumin seed (Arjun), asafoetida (Navjeevan), black pepper and cinnamon (Satvyk), refined groundnut oil (Fortune) purchased from local market were used in this study. Fresh curry leaves and ripe tamarind were collected from local vegetable market. Food grade CaCl_2 and sodium carbonate, chemicals of analytical grade were procured from Balaji Scientific Traders, Kolhapur.

Raw material preparation

Preparation of curry leaves, cinnamon powder

Using a tray dryer, fresh curry leaves were dried at 50°C for 4 hours until they were brittle and crisp to the touch and had a moisture content of 6%. The dried leaves were grind on a lab scale and sieved through a sieve with a mesh size of 60. In the same way dried cinnamon pieces were grind and sieved.

Preparation of tamarind paste

Seeds were removed from fresh, ripe tamarind and 4 g of tamarind pulp was thoroughly homogenized in 20 ml of water. The resulting paste was strained and mixed with an additional 25 ml of water, which was then used to prepare dough using 100 g of black gram flour.

Formulations of papad

Four different formulations for each salt coded as PCa_1 , PCa_2 , PCa_3 and PCa_4 were prepared where NaCl was replaced by calcium chloride at 25, 50, 75 and 100% respectively. The sample prepared with using NaCl only was considered as control. The detailed composition are as given in Table 1.

Preparation of papad

The black gram flour was mixed with requisite quantity of other ingredients as per standard recipe given by Chansoriya and Rajput (2005) with slight modification. Before mixing of all ingredients carbonate mixture, sodium chloride and other salts were dissolved properly in to a water and then using this water the dough was prepared. This dough was divided into balls of 10 g each and rolled into thin circular disc of about 0.8-1 mm thickness using wooden rolling pin. The papads were dried in drier at 50°C up to 13-14% moisture and packed in polythene bags.

Physical analysis

All fried papad samples among CaCl_2 formulations were analysed for physical properties like weight, thickness, diameter, expansion percentage and oil absorption capacity. The weight was measured using electronic weighing balance. The thickness and diameter were determined using Vernier caliper and measuring scale respectively. The expansion percentage and oil absorption capacity in terms of increased weight percentage were calculated as per method described by Chavan *et al.* (2015). Every determination was done in triplicate and the result expressed as the average value.

Chemical analysis

All fresh raw papad samples were evaluated for their change in chemical parameters like moisture, crude protein, crude fat, ash, crude fibre, total carbohydrate, pH and ash alkalinity. The moisture, crude protein, crude fat and ash were determined as per procedure of Ranganna (2009). Total carbohydrate content was calculated by subtracting the measured values of moisture, protein, fat, crude fibre and ash from 100, as described by Ranganathan *et al.* (1937). The pH and alkalinity of ash were determined

Table 1: Different formulations for papad preparation.

Ingredients	Control	CaCl_2
Black gram flour (g)	100	100
Common salt (g)	0.6	25.50.75.100%
Cumin seed (g)	1.0	1.0
Black pepper (g)	1.0	1.0
Asafoetida (g)	1.0	1.0
Carbonate mixture (g)	1.0	1.0
Curry leaves powder (g)	1.0	1.0
Cinnamon (g)	0.5	0.5
Tamarind pulp (g)	4.0	4.0
Groundnut oil (g)	2.0	2.0
Water (ml)	45	45

by (IS 2639:1999). The raw control and selected formulation from sodium chloride replaced with calcium chloride papad samples (PCa_3) were also accessed for mineral content namely sodium and calcium by using flame photometric method with Microprocessor Flame Photometer - Model 1381. Each estimation was made three times and the average value was used to represent the outcomes.

Colour measurement

Hunter colour parameters (L^* , a^* , b^*) for control and selected formulation raw and fried papads were measured with the help of ColorFlex EZ 45/0 HunterLab Spectrophotometer (Fig 1). The average of three measurements was reported (Senthil *et al.*, 2006).

Sensory analysis

The developed papads were fried and subjected to sensory evaluation to a group of 10 semi-trained panellists where they evaluated the sensory quality in terms of colour, flavour, taste, texture and overall acceptability based on a 9 point Hedonic Scale.

Texture analysis

The texture profile analysis (TPA) of control and selected formulation raw and fried papads was conducted using the Stable Micro System TA.XT.Plus Texture Analyser Stable Micro System Ltd., London (Fig 2). The average force necessary to rupture the raw and fried papad during the respective period of time was measured in terms of hardness in gram. Five measurements were carried out and average was recorded (Senthil *et al.*, 2006).

Storage studies

Storage stability of developed papads along with control in raw form were studied at room temperature ($25 \pm 5^\circ\text{C}$) by storing them in flexible packages of low density polyethylene (LDPE) and high density polyethylene (HDPE) for a period of 270 days. During storage the samples were checked at interval of 15 days for the parameters like moisture, peroxide value, free fatty acid (FFA), texture in terms of crispness and overall acceptability. The texture and overall acceptability were checked on deep fat frying at regular intervals using fresh refined groundnut oil every time. At intervals the samples were also analysed for microbiological quality in terms of Total Plate Count (TPC) and yeast and mould (YM) count (Andrews, 1997).

Statistical analysis

Statistical analysis of the collected data was performed using Microsoft Excel 97-2003 of windows 10 software. The standard deviation (SD) and critical difference (CD) at 5% level were provided.

RESULTS AND DISCUSSION

Effect of replacement of sodium chloride with calcium chloride on physical properties of papad

Table 2 represents physical properties of both control and PCa_3 papad formulations. The significant difference in

moisture content was observed in all raw papad samples after frying. Among all samples the papads made by replacing NaCl with CaCl_2 showed comparatively higher moisture content than others (6.24 ± 0.06 to $6.36 \pm 0.02\%$). This might be due to more affinity of calcium ion to water molecule which increases the water holding capacity. The average weight of raw samples of each formulation ranged from 3.57 ± 0.08 to 3.64 ± 0.09 g whereas after frying weight was ranged from 3.99 ± 0.13 to 4.30 ± 0.16 g. This increased weight after frying was due to oil absorption. The thickness of papads after frying also shown increase which might be due to expansion. The diameter of all raw papads was same 9.0 ± 0.0 cm whereas after frying the diameters were increased up to 10.03 ± 0.13 cm which was because of action of carbonate mixture. The expansion percentage of papads made by replacing NaCl with CaCl_2 was shown to be in range (10.78 ± 0.09 to $11.44 \pm 0.07\%$). The expansion was caused by the action of carbonate mixture. Papads with CaCl_2 showed the least oil absorption, likely due to higher water-holding capacity, resulting in lower oil uptake compared to control papads. These results are consistent with findings by Srinivasan *et al.* (2000). Fig 3 displays images of control and PCa_3 samples before and after frying.



Fig 1: Colour measurement.



Fig 2: Textural analysis.

Effect of replacement of sodium chloride with calcium chloride on sensory properties of fried papad

The result of sensory analysis of all papad samples is depicted in Table 3. It was found that among the different formulations of papads prepared by replacing NaCl the overall acceptability score of the papad made with 25% to 75% calcium chloride (PCa_1 , PCa_2 and PCa_3) had minimum differences compared with control however the overall acceptability score of 100% calcium chloride used papads declined drastically. Thus on consideration of maximum NaCl replacement percentage with product relativeness to that of control sample the PCa_3 papad formulation was selected as better. Almeida *et al.* (2016) used salt substitutes (KCl and $CaCl_2$) in addition to NaCl and successfully developed low-sodium salamis without sacrificing sensory quality.

Effect of replacement of sodium chloride with calcium chloride on chemical properties of papad

Chemical analysis results given in Table 4 showed that the moisture, protein, carbohydrate, crude fat, ash, alkalinity of ash, crude fibre content of all developed papads were in range with IS 2639 (1999) and no significant differences were found in values between control and PCa_3 samples. The pH of the papad made by replacing 75% of NaCl with $CaCl_2$ resulted in a significant reduction in pH as compared with control. There was less work reported on replacement of sodium chloride with any other salts in case of any cereal/legume based snack food, hence no literature on this aspect is available.

The mineral content given in Table 4 shows the sodium content of control and PCa_3 papad sample was about 258.91 ± 0.12 mg/100 g and 78.23 ± 0.14 mg/100 g which indicates significant reduction in the sodium content. Accordingly on the other side the level of corresponding calcium salt used increased the calcium content.

Effect of replacement of NaCl with $CaCl_2$ on colour properties of papad

All fried samples had comparative higher b^* values which indicates they were more in yellowish colour after frying (Table 5). Among all the raw and fried samples PCa_3 had lower a^* value and fairly higher b^* value which resulted in higher L^* value (54.48 ± 0.00 and 64.18 ± 0.00). Boyle *et al.* (1994) reported rise in brightness value of the sausages made with calcium fortification than control. No data recorded previously regarding sodium chloride replacement in papad. However, Senthil *et al.* (2006) reported L^* , a^* and b^* values of 12 different market black gram papad samples after frying in range of 70.82 to 76.38, 2.84 to 6.89 and 30.80 to 33.62 respectively. The obtained L^* value of present research was lower (57.34 ± 0.02 to 64.18 ± 0.00), a^* was higher (6.82 ± 0.01 to 11.03 ± 0.00) and b^* was comparatively lower (31.93 ± 0.00 to 33.56 ± 0.04) which might be due to incorporation of curry leaves powder, cinnamon and tamarind pulp in papad.

Table 2: Physical parameters of papads made by replacing NaCl with $CaCl_2$.

Formulations	Raw papads			Fried papads				Expansion (%)	Increase weight(%)
	Moisture (%)	Weight (g)	Thickness (mm)	Diameter (cm)	Moisture (%)	Weight (g)	Thickness (mm)		
Control papad	12.12 ± 0.11	3.62 ± 0.09	0.81 ± 0.02	9.0 ± 0.0	5.70 ± 0.07	4.30 ± 0.16	1.42 ± 0.09	10.34 ± 0.01	18.78 ± 0.20
PCa_1	12.10 ± 0.09	3.58 ± 0.13	0.80 ± 0.01	9.0 ± 0.0	6.24 ± 0.06	3.99 ± 0.13	1.49 ± 0.07	09.97 ± 0.07	11.45 ± 0.14
PCa_2	12.11 ± 0.10	3.62 ± 0.11	0.82 ± 0.03	9.0 ± 0.0	6.27 ± 0.05	4.09 ± 0.09	1.47 ± 0.12	10.02 ± 0.10	12.98 ± 0.12
PCa_3	12.10 ± 0.07	3.64 ± 0.09	0.81 ± 0.04	9.0 ± 0.0	6.30 ± 0.03	4.17 ± 0.10	1.42 ± 0.10	10.03 ± 0.08	14.56 ± 0.08
PCa_4	12.10 ± 0.09	3.57 ± 0.08	0.83 ± 0.05	9.0 ± 0.0	6.36 ± 0.02	4.15 ± 0.14	1.41 ± 0.13	10.00 ± 0.13	16.25 ± 0.09
SD±	0.008	0.030	0.012	0.0	0.268	0.114	0.036	0.152	2.852
CD at 5%	0.014	0.047	0.018	0.0	0.427	0.181	0.057	0.241	4.535

Formulation details: Control papad- 100% NaCl, PCa_1 - 25% $CaCl_2$ +75% NaCl, PCa_2 - 50% $CaCl_2$ +50% NaCl, PCa_3 - 75% $CaCl_2$ +25%NaCl, PCa_4 - 100% $CaCl_2$ and all the values are average±SD of responses from a panel of ten semi-trained judges.

Effect of replacement of sodium chloride with calcium chloride on textural properties of papad

The developed raw and fried papads were analysed to measure the force required to break the sample to check the effect of sodium chloride replacement. Both control and PCa₃ samples showed an increase in hardness as load in 'g' following frying from 218.00±0.01 to 471.00±0.00 and 210.00±0.03 to 612.00±0.02 respectively. This notable rise in hardness after frying indicates that deep-fat frying hardened the texture. The raw papad brittle texture became crispier on frying due to starch gelatinization and physical changes in black gram proteins at the frying temperature. Among the recorded increased hardness the papads

prepared with using CaCl₂ salt had considerable higher hardness value. This increase was might be due to hygroscopic nature of CaCl₂ because during processing, hygroscopic ingredients like salt compete with starch for moisture, lowering the amount of water actually available for starch gelatinization and thus resulting in brittle nature of product. This brittle nature can be partially explained by the higher moisture retained in PCa₃ sample after frying.

Effect of replacement of sodium chloride with calcium chloride on storage life of raw papad in LDPE and HDPE

The results of storage study depicted in Table 6 and Table 7 respectively. A non-significant increase in moisture content was found in all samples throughout the storage period

Table 3: Results of sensory attributes of fried papads made by replacing NaCl with CaCl₂.

Formulations	Sensory parameters				
	Colour	Flavour	Taste	Texture	OA
Control	8.12±0.12	8.09±0.05	7.92±0.06	8.25±0.14	8.10±0.06
PCa ₁	8.13±0.08	7.88±0.10	7.63±0.09	7.72±0.05	7.84±0.05
PCa ₂	8.12±0.06	7.68±0.06	7.25±0.06	7.31±0.08	7.59±0.10
PCa ₃	8.09±0.11	7.19±0.09	6.87±0.10	6.93±0.07	7.27±0.11
PCa ₄	8.10±0.07	5.61±0.07	4.98±0.11	5.59±0.05	6.07±0.08
SD±	0.016	0.4997	1.160	1.005	0.791
CD at 5%	0.026	1.585	1.844	1.598	1.258

*Formulation details: Control papad- 100% NaCl, PCa₁- 25% CaCl₂+75% NaCl, PCa₂- 50% CaCl₂+50% NaCl, PCa₃- 75% CaCl₂+25%NaCl, PCa₄- 100% CaCl₂ and all the values are average ± SD of responses from a panel of ten semi-trained judges.

Table 4: Chemical composition of raw control and selected papad formulation made by replacing NaCl with CaCl₂.

Parameters	Formulations		SD±	CD at 5%
	Control	PCa ₃		
Moisture (%)	12.10±0.01	12.12±0.07	0.010	0.009
Crude protein (%)	25.22±0.19	25.19±0.23	0.035	0.056
Crude fat (%)	1.86±0.18	1.90±0.16	0.020	0.032
Ash (%)	3.49±0.08	3.48±0.05	0.020	0.033
Total	55.90±0.28	55.92±0.26	0.015	0.024
Carbohydrate (%)				
Crude fibre (%)	1.43±0.08	1.40±0.05	0.015	0.024
Alkalinity of ash (%)	1.91±0.14	1.82±0.11	0.049	0.038
pH	7.00±0.01	6.87±0.05	0.081	0.129
Minerals (mg/100 g)				
Sodium	258.91±0.12	78.23±0.14	92.026	146.321
Calcium	171.87±0.16	339.61±0.17	97.322	154.741
Potassium	716.45±0.13	713.22±0.10	96.167	148.135

*Control papad- 100% NaCl, PCa₃- 75% CaCl₂+25% NaCl all values are mean ± standard deviation of three determinations

Table 5: CIE colour parameters of raw and fried control and selected papad formulations made by replacing NaCl with CaCl₂.

Formulations	L* value		a* value		b* value	
	Raw	Fried	Raw	Fried	Raw	Fried
Control	53.36±0.010	61.73±0.01	5.82±0.00	7.73±0.01	23.19±0.01	31.93±0.00
PCa ₃	54.48±0.00	64.18±0.00	5.66±0.02	6.82±0.01	23.36±0.03	33.01±0.03
SD±	1.473	1.733	0.971	1.108	0.388	0.614
CD at 5%	4.685	5.510	3.087	3.522	1.233	1.952

*Control papad- 100% NaCl, PCa₃- 75% CaCl₂+25% NaCl, all values are mean±standard deviation of three determinations.

both in LDPE and HDPE packaging material. However this rise was considerably more in LDPE as compared with HDPE. This might be due to the difference between the water permeability of packaging material. Among the rise in moisture content sample PCa₃ was shown relatively higher gain which might be due to hygroscopic nature of CaCl₂. The greater rise in moisture content was observed after 150 days of storage in control while in PCa₃ after 135 days in LDPE. As a result the control papads became less crisp and developed noticeable rancid flavour after 150 days and PCa₃ was after 135 days. Wherever in HDPE pouch the control papads remained crisp throughout 270 days of storage and PCa₃ became less crisp after 255 storage days. Similar rise in moisture content during storage in LDPE and HDPE was reported by Wadhawan and Bansal, (2018) in date chakli (HDPE) and Devi *et al.* (2013) in wheat pasta (200 gauge LDPE).

The peroxide values and free fatty acid (FFA) content of all samples stored in LDPE and HDPE were found to be increased throughout storage period. According to safe acceptable limit for both parameters, the control sample packed in LDPE was found safe up to 150 days and PCa₃ sample up to 135 days storage. While in HDPE the control sample was found acceptable throughout 270 days of storage and PCa₃ was up to 255 days of storage.

The sensory score in terms of overall acceptability at intervals of all fried samples stored in LDPE shown that the overall acceptability score of control sample was declined from 8.10±0.09 to 4.88±0.15 up to 165 days of storage and PCa₃ samples from 7.66±0.08 to 4.41±0.11 up to 150 days storage. Thus as per hedonic scale prediction control and PCa₃ samples were found within acceptable quality up to 150 days and 135 days respectively. Storage study of samples packed in HDPE shown that there was comparatively less decline in the overall acceptability score throughout the storage of 270 days. The control sample had maximum overall acceptability score up to 270 days and PCa₃ sample was within acceptable quality up to 255 days. This may be because HDPE has good barrier properties than LDPE.

Effect of replacement of sodium chloride with calcium chloride on microbiological quality of raw papads during storage

The change in microbial quality of developed control and PCa₃ papad formulations packed in both LDPE and HDPE throughout the storage period are tabulated in Table 8. It was observed that both papad formulations were free from bacterial growth during initial period up to 30 days in LDPE and 60 days in HDPE pouches. After 30 days of storage bacteria started to grow in papads stored in LDPE. The control and PCa₃ samples shown the TPC within the permissible limit even after 150 days and 135 days of storage. Though these samples were under the safe microbial limit the papads had developed rancid, undesirable musty odour hence rendering them organoleptically unacceptable. In HDPE bacteria started to grow after 60 days storage. Both

Table 6: Effects of partial NaCl replacement and packaging material (LDPE) on physicochemical and sensory properties of raw papads during storage.

Storage days	LDPE (200 gauge)									
	Moisture (%)		PV (meq/kg)		FFA (%)		Overall acceptability		Texture	
	Control	PCa ₃	Control	PCa ₃	Control	PCa ₃	Control	PCa ₃	Ctrl	PCa ₃
0	12.12±0.05	12.13±0.09	6.31±0.19	6.34±0.16	0.33±0.09	0.34±0.10	8.10±0.09	7.66±0.08	Crisp	Crisp
15	12.27±0.06	12.33±0.07	6.40±0.12	6.73±0.11	0.47±0.10	0.47±0.13	8.00±0.11	7.52±0.06	Crisp	Crisp
30	12.49±0.09	12.57±0.06	6.78±0.11	7.00±0.13	0.49±0.09	0.53±0.09	7.92±0.10	7.41±0.10	Crisp	Crisp
45	12.62±0.10	12.69±0.07	7.02±0.10	7.56±0.12	0.58±0.08	0.60±0.08	7.71±0.19	7.22±0.13	Crisp	Crisp
60	12.83±0.06	12.90±0.05	7.49±0.15	8.16±0.13	0.64±0.02	0.69±0.10	7.61±0.07	6.97±0.12	Crisp	Crisp
75	13.02±0.05	13.29±0.06	9.12±0.16	10.11±0.14	0.79±0.09	0.89±0.09	7.53±0.08	6.76±0.11	Crisp	Crisp
90	13.37±0.04	13.56±0.10	10.66±0.14	12.23±0.13	0.90±0.07	1.00±0.08	7.44±0.09	6.64±0.09	Crisp	Crisp
105	13.65±0.04	13.93±0.11	11.34±0.13	14.54±0.17	1.02±0.11	1.19±0.13	7.21±0.11	6.52±0.07	Crisp	Crisp
120	13.92±0.03	14.26±0.10	12.79±0.15	17.24±0.19	1.13±0.13	1.37±0.12	6.94±0.16	6.48±0.13	Crisp	Crisp
135	14.19±0.07	14.56±0.09	14.14±0.16	20.01±0.14	1.34±0.14	1.48±0.14	6.60±0.16	6.13±0.14	Crisp	Crisp
150	14.48±0.09	16.06±0.07	16.52±0.16	24.60±0.16	1.51±0.11	2.15±0.13	6.42±0.13	4.41±0.11	Crisp	Less crisp
165	15.47±0.11	-	22.31±0.15	-	1.73±0.13	-	4.88±0.15	-	Less crisp	-

*LDPE- Low density polyethylene, PV- Peroxide value, FFA- Free fatty acids, Control- 100% NaCl, PCa₃- 75% CaCl₂+25% NaCl, all values are mean±standard deviation of three determinations.

Table 7: Effects of partial NaCl replacement and packaging material (HDPE) on physiochemical and sensory properties of raw papads during storage.

Sto-age days	HDPE (200 gauge)									
	Moisture (%)		PV (meq/kg)		FFA (%)		Overall acceptability		Texture	
	Control	PCa ₃	Control	PCa ₃	Control	PCa ₃	Control	PCa ₃	Control	PCa ₃
0	12.12±0.05	12.13±0.09	6.31±0.19	6.34±0.16	0.33±0.09	0.34±0.10	8.10±0.09	7.66±0.08	Crisp	Crisp
15	12.12±0.09	12.18±0.09	6.33±0.17	6.64±0.15	0.34±0.11	0.38±0.11	8.10±0.10	7.64±0.10	Crisp	Crisp
30	12.15±0.10	12.25±0.08	6.62±0.16	6.92±0.14	0.37±0.12	0.41±0.13	8.09±0.13	7.61±0.12	Crisp	Crisp
45	12.20±0.13	12.32±0.10	6.81±0.15	7.24±0.13	0.42±0.09	0.49±0.16	8.00±0.16	7.52±0.13	Crisp	Crisp
60	12.27±0.12	12.38±0.11	7.09±0.12	7.55±0.14	0.48±0.10	0.57±0.11	7.94±0.15	7.47±0.11	Crisp	Crisp
75	12.38±0.08	12.48±0.13	7.43±0.12	7.91±0.15	0.54±0.13	0.62±0.09	7.87±0.14	7.41±0.12	Crisp	Crisp
90	12.43±0.06	12.59±0.11	7.92±0.11	8.23±0.16	0.61±0.12	0.68±0.09	7.82±0.13	7.38±0.11	Crisp	Crisp
105	12.50±0.09	12.70±0.09	8.27±0.10	8.54±0.14	0.67±0.09	0.72±0.10	7.75±0.13	7.31±0.10	Crisp	Crisp
120	12.61±0.10	12.79±0.11	8.68±0.10	8.86±0.13	0.75±0.10	0.80±0.11	7.70±0.12	7.26±0.09	Crisp	Crisp
135	12.76±0.10	12.90±0.13	8.92±0.13	9.77±0.14	0.81±0.12	0.86±0.13	7.62±0.11	7.19±0.07	Crisp	Crisp
150	12.89±0.08	13.02±0.11	9.23±0.14	10.64±0.16	0.88±0.13	0.94±0.12	7.55±0.13	7.11±0.13	Crisp	Crisp
165	13.00±0.12	13.14±0.13	9.45±0.15	11.93±0.17	0.94±0.14	0.98±0.12	7.46±0.11	7.07±0.14	Crisp	Crisp
180	13.12±0.13	13.39±0.12	10.00±0.16	13.08±0.18	1.03±0.07	1.09±0.13	7.35±0.10	6.89±0.13	Crisp	Crisp
195	13.23±0.16	13.66±0.09	10.62±0.12	13.99±0.19	1.11±0.09	1.17±0.14	7.21±0.16	6.77±0.09	Crisp	Crisp
210	13.32±0.08	13.89±0.09	11.19±0.11	15.12±0.21	1.19±0.11	1.25±0.12	7.03±0.15	6.69±0.08	Crisp	Crisp
225	13.42±0.12	14.28±0.10	11.70±0.10	16.76±0.18	1.27±0.13	1.34±0.11	6.83±0.12	6.59±0.09	Crisp	Crisp
240	13.53±0.13	14.58±0.11	12.32±0.13	18.04±0.16	1.34±0.14	1.39±0.13	6.59±0.11	6.50±0.08	Crisp	Crisp
255	13.79±0.11	15.00±0.08	13.05±0.12	19.87±0.17	1.40±0.16	1.48±0.15	6.32±0.10	6.42±0.13	Crisp	Crisp
270	13.90±0.11	15.82±0.08	17.09±0.11	23.65±0.14	1.49±0.12	1.99±0.17	6.24±0.13	4.61±0.12	Crisp	Less crisp

*HDPE- High density polyethylene, PV- Peroxide value, FFA- Free fatty acids, Control- 100% NaCl, PCa₃- 75% CaCl₂+25% NaCl, all values are mean ± standard deviation of three determinations.

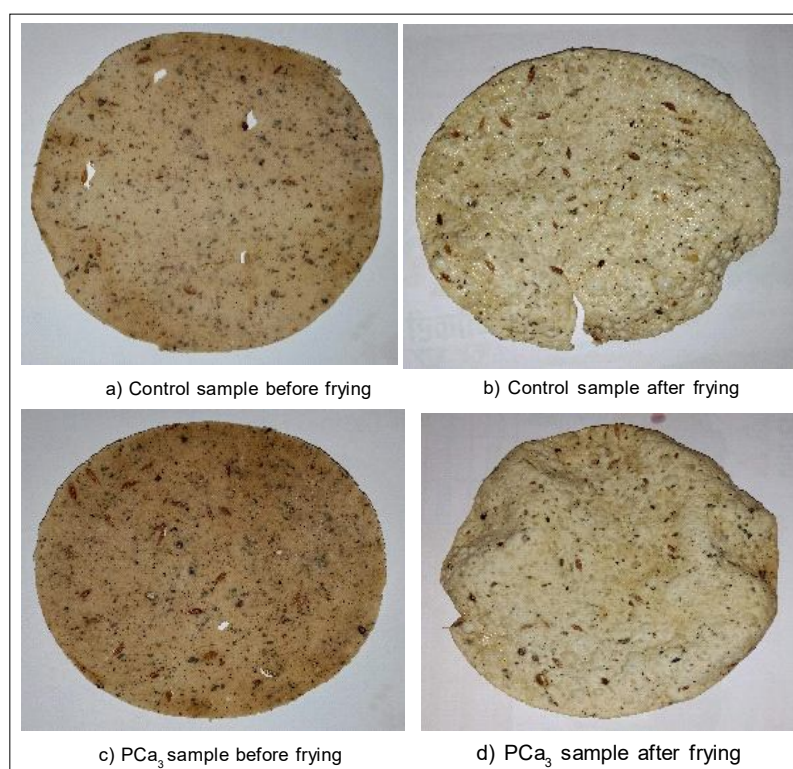


Fig 3: Photographic images of control and selected NaCl replaced papad formulations before and after frying.

Table 8: Effects of partial NaCl replacement and packaging material (LDPE and HDPE) on microbial properties of raw papads during storage.

Storage days	LDPE				HDPE			
	Control		PCa ₃		Control		PCa ₃	
	TPC (log cfu/g)	YM (log cfu/g)	TPC (log cfu/g)	YM (log cfu/g)	TPC (log cfu/g)	YM (log cfu/g)	TPC (log cfu/g)	YM (log cfu/g)
0	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
15	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
30	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
45	3.699	Nil	3.778	Nil	Nil	Nil	Nil	Nil
60	3.924	Nil	4.079	Nil	Nil	Nil	Nil	Nil
75	4.079	Nil	4.279	Nil	2.978	Nil	3.114	Nil
90	4.491	Nil	4.591	Nil	3.134	Nil	3.279	Nil
105	4.643	Nil	4.716	Nil	3.326	Nil	3.431	Nil
120	4.732	Nil	4.813	Nil	3.643	Nil	3.773	Nil
135	4.839	Nil	4.881	Nil	3.929	Nil	3.996	Nil
150	4.914	Nil	4.991	Nil	4.009	Nil	4.111	Nil
165	4.944	-	-	-	4.196	Nil	4.299	Nil
180	-	-	-	-	4.225	Nil	4.340	Nil
195	-	-	-	-	4.303	Nil	4.398	Nil
210	-	-	-	-	4.380	Nil	4.471	Nil
225	-	-	-	-	4.438	Nil	4.491	Nil
240	-	-	-	-	4.480	Nil	4.538	Nil
255	-	-	-	-	4.505	Nil	4.556	Nil
270	-	-	-	-	4.547	Nil	4.591	Nil

*LDPE- Low density polyethylene, HDPE- High density polyethylene, TPC- Total plate count, YM- Yeast and mould count, Control- 100% NaCl, PCa₃- 75% CaCl₂+25% NaCl, Nil - absent in sample, all values are mean $\pm$ standard deviation of three determinations and '-' sample discarded.

control and PCa_3 papads microbial load was within the safe permissible limit up to 270 days but because of occurrence of rancid, undesirable odour and loss of texture PCa_3 papads were rejected organoleptically after 255 days storage.

CONCLUSION

This study aimed to develop low-sodium black gram papads by partially replacing common salt with calcium chloride and to evaluate their shelf life in two different packaging materials. The formulations PCa_3 containing 75% calcium chloride replacement was selected based on optimal organoleptic, physicochemical, textural and colour properties. These formulations reduced sodium content from 258.91 mg/100 g to 78.23 mg/100 g (PCa_3). Raw papads stored in HDPE remained stable for 255 days. Therefore, the low-sodium raw PCa_3 papads can be stored at room temperature in HDPE packaging for up to 255 days without significant quality deterioration.

Disclaimers

The views and conclusions expressed in this article are solely those of the authors and do not necessarily represent the views of their affiliated institutions. The authors are responsible for the accuracy and completeness of the information provided, but do not accept any liability for any direct or indirect losses resulting from the use of this content.

Informed consent

No any animal procedures for experiments were used.

Conflict of interest

The authors declare that there are no conflicts of interest regarding the publication of this article. No funding or sponsorship influenced the design of the study, data collection, analysis, decision to publish, or preparation of the manuscript.

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