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Effect of Sodium Substitution on Sensory and Quality Parameters in Mango Pickle

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Authors' contributions

This work was carried out in collaboration of both the authors. Author PKP designed the study, performed the statistical analysis and wrote the protocol. Author AM managed the analyses of the study, managed the literature searches and wrote the draft of the manuscript. Both authors read and approved the final manuscript.

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ABSTRACT

Aims: An intensive study was conducted so as to find out the best salt combinations when NaCl was partially replaced with KCl and $CaCl_2$ while curing mango pieces. Mango pickle contains 15-20% salt, the consumption of which cause hypertension and high blood pressure. This is due to excess sodium ion (Na^+) consumption.
Study Design: D-Optimal Quadratic Mixture Design using Response Surface Methodology was adopted with 3 mixture components to get 16 mixture combinations of salts.
Methodology: 16 runs were formulated depicting diverse salt mixtures and pickle samples were cured using these 16 different brine formulations. After pickling, the final sample were analyzed for water drawing capacity (g/100g salt), hardness of cured sample (N), water activity (a_w), sodium and potassium concentration in pickle (in ppm) and organoleptic properties based on hedonic scale.
Results: The result shows that water drawing capacity was maximum (102.692) in the 6th run and minimum (58.364) in 2nd run. Hardness of cured sample (in N) was maximum (8.470) in11th run and minimum (6.998) in 9th run. Water activity was maximum in 9th run (0.974) and minimum (0.968) in the 2nd run. Na concentration in pickle (ppm) was highest in the 14th run (408.715) and lowest in 2nd

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run (68.715). K concentration in final pickle (ppm) was maximum in 6th run (472.222) and minimum in 9th run (28.744). Organoleptic properties based on hedonic scale was evaluated, it was found that run number 14 and 12 have maximum score of 7.429 and 7.393 respectively whereas Run-1 and Run-2 showed minimum score of 6.552 and 6.616 respectively.

Conclusion: Numerical optimization revealed that formulation with 0.5 fractions NaCl and 0.5 fractions KCl is having the maximum desirability of 0.658. Another formulation with NaCl 57.1% and KCl with 42.9% is having a desirability of 0.64. This formulation can also be adopted for the purpose of commercialization.

Keywords: Commercialization; desirability; hypertension; organoleptic; sodium reduction.

1. INTRODUCTION

Pickle made from unripe mango pulp is one of the most demanding processed food products which is consumed since centuries. The origin of the term pickle is from Dutch word ‘Pekel”, meaning brine [1]. Pickles are prepared all the way through the natural fermentation of fruits and vegetables. Pickles are known to possess advantageous nutritional significance and also perform as a food accompaniments [2]. The systematic process of pickle preparation involve fermentation of the pieces which is a primal preservation technique principally used to facilitate the long-term storage of foods. Fermentation is basically a measured decomposition of organic substances induced by beneficial microorganisms that fundamentally convert carbohydrates to alcohols or organic acids [3]. When the fruits and vegetables are fermented it is known as pickling. Many approaches of fermentation are there among which lactic acid fermentation using natural microflora or lactic acid bacterial (LAB) cultures is used throughout the globe. Lactic acid (LA) fermentation of vegetables and fruits is a universal practice to sustain the quality and perk up the nutritional and sensory attributes of food commodities [4,5].

Salt is a crucial part of our food habit and cannot be left off from our diet. Salts are known to improve the taste, increase palatability and also have an enormous role in human nutrition and ionic balance. NaCl is employed mainly to introduce saltiness to food. Apart from that it is responsible for conservation of food, allowing substantial augment in storage duration by reducing total water activity. Salt is the oldest known food seasoning technique which provides one of the most imperative basic human tastes (saltiness) and preserves foods to extend the shelf life. Salt principally have Sodium (Na^+) as Cation and Chlorine (Cl^-) as Anion. Sodium (Na^+) is chiefly accountable for the saltiness taste in food. Sodium is a critical element required in minute amounts by the human body. Sodium ion is necessary for ion exchange and it also helps to administer homeostasis and nerve impulses [6]. Sodium chloride (NaCl) is a crucial in our food as it preserves the food, improves the taste and augment overall sensory quality [7]. However the extra intake of salt led to extra sodium absorption in our blood. This might lead to serious health issues such as hypertension and high blood pressure. Roughly one quarter of the world’s current population suffers from hypertension and high blood pressure [8]. High sodium intake is increasing the risk of heart attack and high blood pressure [9].

Results derived from animal studies, scientific research, and human surveys for understanding relation between sodium intake and its effects on human blood pressure were found to be strongly correlated [10,11]. The bio-mechanism for the effect of salt consumption on blood pressure could be due to the ascend in plasma sodium or to the rise in extracellular fluid volume. Higher intake of sodium through our diet is also responsible for some bone disease [12]. In industrial scale common salt is traditionally been used for fermentation of cucumbers, radishes, and carrots since days immemorial [13,14,15, 16]. Pickling process is carried out in presence of elevated concentration of salt solution. The fruit and vegetable pieces are dipped to ensure an-aerobic condition and facilitate fermentation. This is why pickles contain at about 15-20% which makes it one of the high salt containing foods. The major shortcoming with pickle consumption is the presence of high concentration of sodium (Na^+) which directs to adverse effects on human health. Intake of surplus dietary salt elevates the sodium concentration in our bloodstream and further disrupts the delicate ionic balance. This also reduces the capability of our kidneys to remove the water. This can also led to a decline in food business related to pickling and fermentation. Some food products have been launched in its low salt version. Only type of salt which does not include sodium are the non-sodium alternative salts. In these salts, sodium is replaced with potassium, magnesium and calcium ion. Partial substitution of Sodium chloride (NaCl) by potassium chloride (KCl) or calcium chloride ($CaCl_2$) affords an alternative for reducing sodium content and improve ionic balance. Increased potassium consumption upto a certain extent is known to ensure proper ionic balance, reduce chance of stroke, regulates high blood pressure, ensure proper heart rhythm, prevents kidney failure and even help to prevent osteoporosis [17]. The supplementary use of KCl and $CaCl_2$ to somewhat replace NaCl could be useful in dropping sodium content [18]. It is also needed to consider that the use of KCl is not popular due to its bitter perception by some people and astringent taste [19]. A metallic after-taste was also reported by some people who consumed it and therefore the total use of KCl as a main salt in food is rarely practiced. Sole use of Calcium chloride as a salt can led to extra hardening of food and also rough after taste. Hence to overcome these issues a mixed concentration of Na, K and Ca can be tried. This research has been conducted to examine the possibility of replacing sodium chloride by calcium and potassium salts. The research is conducted optimize the salt mixture components for development of low sodium mango pickles without affecting its physiochemical, biochemical, microbiological and sensory qualities.

2. MATERIALS AND METHODS

2.1 Site of Experiment

The present study was conducted in Post Graduate Laboratory, Department of Pomology and Post-Harvest Technology, Faculty of Horticulture, Quality Control Laboratory and Central Instrumentation Centre Lab of Uttar Banga Krishi Viswavidyalaya, Pundibari, Coochbehar, West Bengal.

2.2 Source of Pickling Materials

The fruits were fresh, unripe and were free from pests, diseases and blemishes. Fazli variety was procured from local market since it is known to have high acid content. The chemical purchased were of Laboratory grade. Design for deciding the salt mixture for pickle preparation in the experiment was D-Optimal Quadratic Mixture Design using Response Surface Methodology. The Software used was Design-Expert 7.1.6, Minneapolis, US. The number of mixture component was 3.

By using the above software and considering the variable components, the Table 2 was prepared prescribing the salt combinations to be used in pickle making.

2.3 Procedure for Mango Pickle Preparation

Pickles were prepared by using the standardized procedure. The prepared pickles were stored in glass jars which were cleaned properly and were sterilized in boiling water at room temperature. During the entire storage period it was ensured that the pickle was stored in aerated, dry and hygienic conditions.

2.4 Water Drawing Capacity of Salt in the Cured Sample (g/100 g Salt Mixture)

2.4.1 Moisture content determination

Moisture content of fresh mango pieces and the final pickle was determined according to AOAC (2000) [20]. Macerated weighed sample (10 g) was taken in a clean petri dish and kept in hot air oven at 70°C till constant weight. The loss of weight was expressed as moisture fraction of initial weight.

Therefore,

$$Moisture fraction = \frac{Weight\ of\ pieces\ before\ drying - Weight\ of\ pieces\ after\ drying}{Weight\ of\ pieces\ before\ drying}$$

2.4.2 Final water drawing capacity (g/100g salt)

$$Water\ Drawing\ Capacity = \frac{W_f \times m_f - W_c \times m_c}{Wt.\ of\ Salt\ used\ for\ curing} \times 100$$

Where,

W_f = Weight of mango pieces before curing
W_c = Weight of mango pieces after curing
m_f = Moisture fraction of mango pieces before curing
m_c = Moisture fraction of mango pieces after curing

2.5 Instrumental Texture or Hardness of Salt Cured Sample

The instrumental texture analyzer (Stable Microsystem; Model: TA.XT.Plus) in CIC laboratory, UBKV was used. A 2mm probe was used in this experiment. The pre-test speed was set at 1 mm/second, test speed at 2 mm/second, post-test speed at 5 mm/second, distance of penetration at 5mm and trigger force at 5 g. The pickle sample was kept on the tray and the probe was allowed to penetrate the sample. A graph was obtained on the screen. The force in gram (g) values corresponding to the highest peak was noted. Penetration force was presented as hardness in N (newton).

2.6 Water Activity (a_w) of Salt Cured Sample

The water activity meter (Make: Decagon Devices, Inc, Pullman, Washington, USA; Model: Aqualab series 3TE) in CIC laboratory UBKV was used for the purpose of determining water activity at 25°C with an accuracy of ± 0.003.

2.7 Na^+ and K^+ Concentration in Final Pickle Sample

2.7.1 Wet digestion using nitric acid (HNO_3) and sulphuric acid (H_2SO_4)

5 g of sample was put into the digestion flask was weighed out. 10 ml conc. H_2SO_4 and 10ml conc. HNO_3 were added. The ratio of H_2SO_4 and HNO_3 added was ensured to be 1:1. The system was subjected to sand bath. The final digestion was completed when the liquid volume comes to 5 ml and the sample is colourless. After the samples were cooled, it was passed through Whatman No. 1 filter paper into a 100ml volumetric flask. The volume was made up to 100 ml by adding distilled water.

2.7.2 Standard preparation

For analysis of Na^+ ion concentration, NaCl (A.R.)@10 ppm was prepared and was used as a standard. For analysis of K^+ ion concentration, KCl (A.R.)@10 ppm was prepared and was used as a standard.

2.7.3 Absorbance determination using the flame photometer

The flame photometer reading thus generated by feeding the digested sample of different run gave the absorbance value of that particular run. The absorbance value thus obtained was multiplied with the concentration used.

2.8 Organoleptic Property or Sensory Analysis Based on Hedonic Scale

All the 16 sample of pickle were taken in different clean pouch packets and code them arbitrarily. Since the taste perception varies from age and sex of an individual, hence it was tried to introduce a dissimilar population type for evaluation of the organoleptic properties.

2.8.1 Parameters under consideration

a. Appearance
b. Saltiness
c. Sourness
d. Sweetness
e. Softness
f. Spice quality.
g. Overall rating.

3. RESULTS AND DISCUSSION

The results for studies on sodium substitution in mango pickle are being chronologically illustrated in this very chapter. The studies have been conducted on the effect of different salt combinations that were being used for the curing purpose. Later on the different pickle samples prepared with these salt combinations were analyzed based on different responses. The responses that were studied affect the pickle properties directly or indirectly. The results are being presented in tabular fashion and are graphically explained. Suitable discussions are also drawn to support the results obtained.

3.1 Water Drawing Capacity of Cured Samples (g/100 g Salt Mixture) at Different Runs

The results for water drawing capacity in g/100 g salt mixture are shown below in Table 3. The graph shows that the water drawing capacity of cured samples (g/100g salt mixture) is maximum in Run-6 (102.692) and minimum in Run-2 (58.364). This might be due to toughening of the tissues by Calcium (Ca^{++}) ions which hinders the ex-osmosis of water from the tissues.

Fig. 1 reveals that in absence of $CaCl_2$ in salt mixture, the water drawing capacity increases as ratio of NaCl and KCl were found to decrease. At minimum K concentration, as $CaCl_2$ fraction increases in salt mixture water drawing capacity were found to decrease quadritically to a minimum of 58.364 when it reaches the highest fraction of 0.25 in the salt mixture.. Similar decline was observed when K was added to a salt mixture having maximum Ca concentration (0.25%). When the mixture has maximum K content, addition of $CaCl_2$ would quadritically reduce the water drawing capacity.

3.2 Hardness of Salt Cured Sample (N) at Different Runs

Table 3 showsthat thehardness of salt cured Sample (N) is maximum in Run-11 (8.47) and minimum in Run-9 (6.998). This might be due to increase in the intercellular bonding due to calcium (Ca) bridge. Fig. 2 shows that at highest concentration of KCL, the effect of Ca was found to decrease initially and was increased till the highest fraction of $CaCl_2$ reaches maximum of 0.25. Similar quadratic effect was also found in salt mixtures without any KCl. In absence of $CaCl_2$ in salt mixture, the effect of increment in KCl fraction was found to increase hardness of pure sample quadritically.

3.3 Water Activity of salt Cured Pieces

Fig. 3 depicts that water activity was maximum in Run-9 (0.974) and minimum (0.968) in the Run-2. In a salt solution containing no $CaCl_{2,}$ as the KCl content was increased in the salt solution, the water activity decreases quadritically and showed a rapid decrease at maximum potassium concentration. At maximum potassium concentration in salt mixture, as calcium content is increased, the water activity shows a sharp decline. At maximum $CaCl_2$ level, as the potassium content increases in the salt mixture, the water activity declines steadily. At zero potassium level in the salt solution, as calcium chloride concentration is increased, the water activity shows a very rapid decline as well.

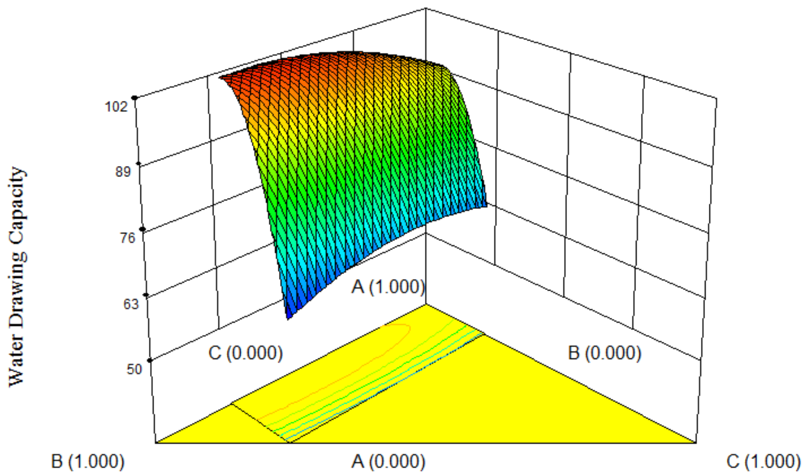

Fig. 1. Water drawing capacity of salt mixture

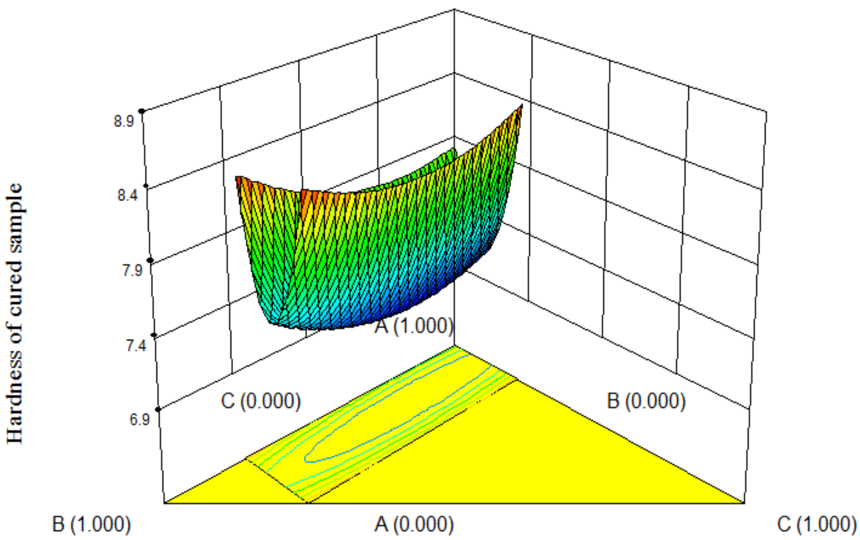

Fig. 2. Hardness of salt cured pieces

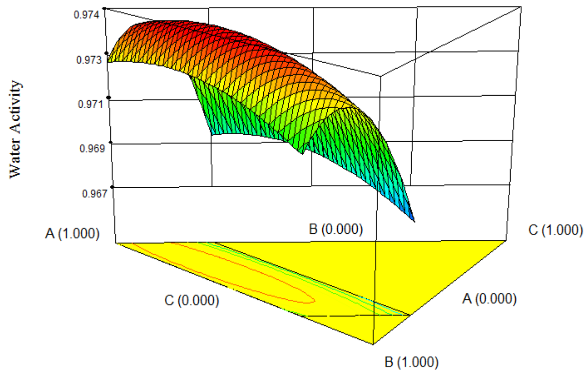

Fig. 3. Water activity of salt cured pieces

3.4 Sodium Content (ppm) of Final Pickle Samples at Different Runs

The sodium content in final pickle samples are shown in Table 1. Run-14 was having maximum sodium content (408.715 ppm) and Run-2 showed lowest sodium content in final pickle (68.715 ppm). The higher sodium content is mainly due to the higher percentage of sodium that was being used in the salt mixture during curing.

As revealed in Fig. 4, at zero Ca concentration in salt mixture, as potassium content was increased, the Na content shows a quadratic decline but shows a slight increment at maximum potassium concentration. At maximum Potassium concentration as Ca content is increased in the salt mixture, the Na content shows a slow decline. At maximum Ca content in salt mixture (0.25%), as potassium content is increased, there also is a decrease in the Na concentration in pickle sample. At zero potassium content in the salt mixture, as Ca is being added, the decline in Na content is found to be the steadiest.

Table 1. Components of salt mixtures used in experiment

Variable component	Name	Units	Low Actual	High Actual
A	NaCl	Fraction	0	1
B	KCl	Fraction	0	0.75
C	$CaCl_2$	Fraction	0	0.25

Table 2. Different ratio of salts to be used following the above maximum and minimum limits

	Component of salt mixture		
Run order	**NaCl**	**KCl**	**$CaCl_2$**
Run-1	0.000	0.750	0.250
Run-2	0.000	0.750	0.250
Run-3	0.625	0.375	0.000
Run-4	0.625	0.188	0.188
Run-5	0.250	0.750	0.000
Run-6	0.250	0.750	0.000
Run-7	0.125	0.750	0.125
Run-8	0.125	0.750	0.125
Run-9	0.875	0.000	0.125
Run-10	0.375	0.375	0.250
Run-11	0.750	0.000	0.250
Run-12	1.000	0.000	0.000
Run-13	0.750	0.000	0.250
Run-14	1.000	0.000	0.000
Run-15	0.750	0.188	0.063
Run-16	0.250	0.563	0.188

Table 3. Experimental runs with their mixture component variables and response variables

Run order	Component of salt mixture			Water drawing capacity (g/100 g salt mixture)	Hardness of cured sample (N)	Water activity of cured sample	Na concentration in pickle (ppm)	K concentration in pickle (ppm)	Hedonic score
	A: NaCl	B: KCl	C: $CaCl_2$						
1	0.000	0.750	0.250	60.370	8.329	0.969	76.408	469.324	6.552
2	0.000	0.750	0.250	58.364	8.429	0.968	68.715	466.425	6.616
3	0.625	0.375	0.000	96.619	7.739	0.973	157.398	170.773	7.244
4	0.625	0.188	0.188	85.531	7.440	0.973	210.485	87.193	6.952
5	0.250	0.750	0.000	100.969	8.448	0.971	114.869	475.121	7.036
6	0.250	0.750	0.000	102.692	8.129	0.971	107.177	472.222	7.131
7	0.125	0.750	0.125	90.807	7.470	0.973	99.485	449.657	6.631
8	0.125	0.750	0.125	89.143	7.237	0.972	91.792	451.063	6.619
9	0.875	0.000	0.125	85.126	6.998	0.974	330.254	28.744	7.009
10	0.375	0.375	0.250	61.353	8.071	0.970	145.638	179.469	6.818
11	0.750	0.000	0.250	60.586	8.470	0.970	276.408	54.831	7.243
12	1.000	0.000	0.000	90.415	7.796	0.973	397.946	37.440	7.393
13	0.750	0.000	0.250	65.158	8.241	0.969	269.023	46.338	7.226
14	1.000	0.000	0.000	85.419	7.952	0.972	408.715	31.643	7.429
15	0.750	0.188	0.063	96.073	7.190	0.973	237.946	80.585	7.096
16	0.250	0.563	0.188	84.455	7.450	0.973	111.254	299.034	6.631

3.5 Potassium Content of Final Pickle Samples at Different Runs

As shown in Table 1, Run-6 is having highest value of potassium in final pickle (472.222 ppm) whereas Run-8 is having lowest value for potassium content (28.744). The higher potassium content is mainly due to the higher percentage of potassium that was being used in the salt mixture during curing.

Fig. 5 show that at minimum Ca concentration in the salt solution, as KCl content in the salt solution was increased, there shows a rapid increase in the potassium content. At maximum potassium concentration, there is a quadratic increase in the K concentration in the pickle sample. At maximum Ca concentration in the salt mixture, as the potassium content was increased up to its maximum level (0.75), there is an abrupt increase in K concentration in final sample. At minimum K content is salt solution, as Ca content was increased from 0 to 0.25, there shows an increase in the K concentration in the pickle sample.

3.6 Hedonic Score of Final Pickle Sample at Different Runs

Table 1 shows hedonic score of final pickle sample at different runs. It shows that Run-14 have highest score as far hedonic scale based on organoleptic properties (7.429) and Run-1 which have a score of 6.552 showed the minimum value.

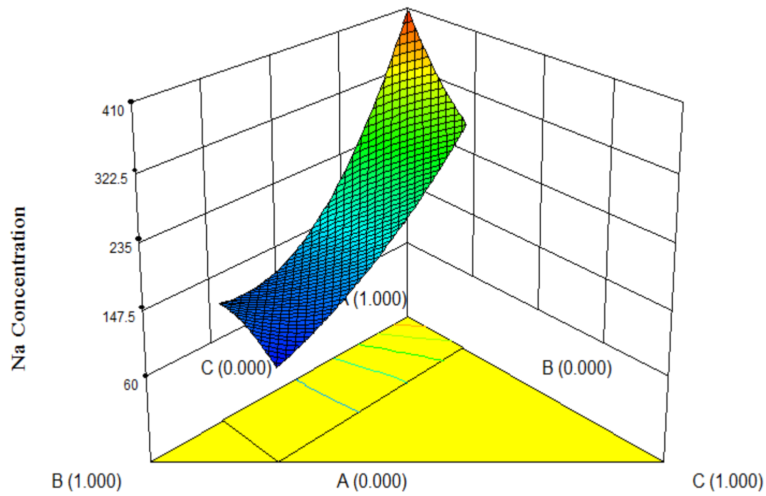

Fig. 4. Sodium concentration of final pickle sample

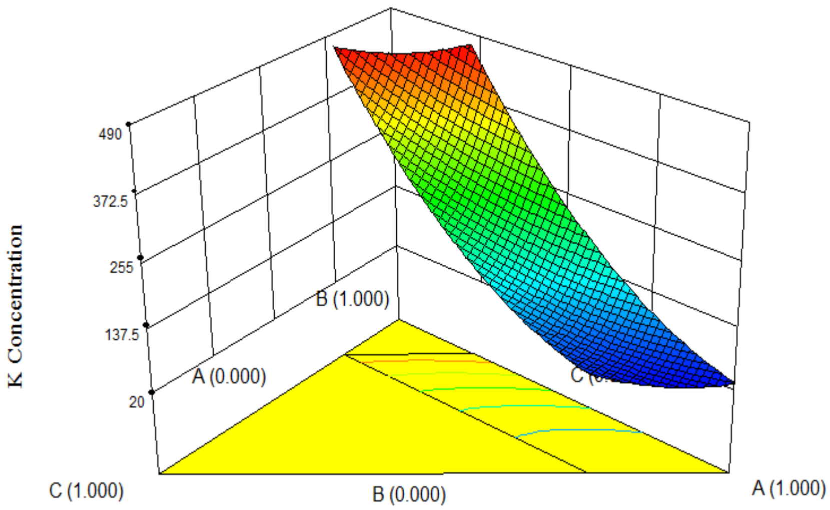

Fig. 5. Potassium concentration of final pickle sample

Fig. 6 show that at minimum Ca concentration in the salt mixture, as potassium content was increased, the Hedonic scale shows a linear decline. At maximum Potassium content in salt mixture, as $CaCl_2$ was increased, the hedonic scale shows a quadratic decline initially but shows a slight increase at maximum Ca concentration (0.25%). At maximum Ca concentration, as K content is increased in the salt mixture, there shows a decline in the hedonic score. At minimum K content in the salt mixture, as Ca content is increased from minimum (0%) to maximum (0.25%), the hedonic score shows a quadratic decline but shows a slight increase in hedonic score at the maximum Ca content level.

3.7 Numerical Optimization of Salt Mixtures

The optimum salt mixtures were obtained by following numerical optimization method using the design expert software 7.1.6. For this purpose, criteria were chosen so as to obtain a pickle with highest sensory properties and with an aim to reduce the sodium content in the salt mixture. Different constraints used are presented in Table 4.

From Table 4, it can be observed that in mixture components, the goal is to reduce NaCl such that the maximum fraction limit is 1 and minimum fraction limit is 0.5 was given an importance of 5. KCl is to be maintained in range from lower limit is 0 and upper limit is 0.75 with an importance of 3. $CaCl_2$ is to be maintained in range from lower limit 0 and upper limit is 0.25 with an importance of 3. For response variables like water drawing capacity, the goal is to maximize the value with a lower limit of 58.364 and maximize limit of 102.692 and an importance of 3. For hardness of cured sample, the goal is to minimize with a lower limit of 6.998 and upper limit of 8.471, with an importance of 3. For minimizing the water activity, the upper and lower limits are set to 0.968 and 0.974 respectively, with an importance of 3. For minimizing the sodium concentration, the upper and lower limits are set to 68.715 and 408.715 respectively, with an importance of 3. With an aim to keep the potassium concentration in range, the upper and lower limits are set to 628.744 and 475.121 respectively, with an importance of 3. For maximizing the LAB population, the upper and lower limits are set to 6.151 and 6.452 respectively, with an importance of 3. To keep the Total Plate Count in range, the upper and lower limits are set to 6.316 and 6.397 respectively, with an importance of 3. To maximize the hedonic score, the upper and lower limits are set to 6.552 and 7.428 respectively, with an importance of 3.

By considering the above constraints, an optimization of salt mixture with predicted values of response variable and desirability constant were obtained. The data thus obtained are software generated and are illustrated in the Table 5. It was observed that the formulation with 0.5 fractions NaCl and 0.5 fractions KCl was having the maximum desirability of 0.658. Another formulation with NaCl 57.1% and KCl with 42.9% is having a desirability of 0.64. This formulation can also be adopted for the purpose of commercialization.

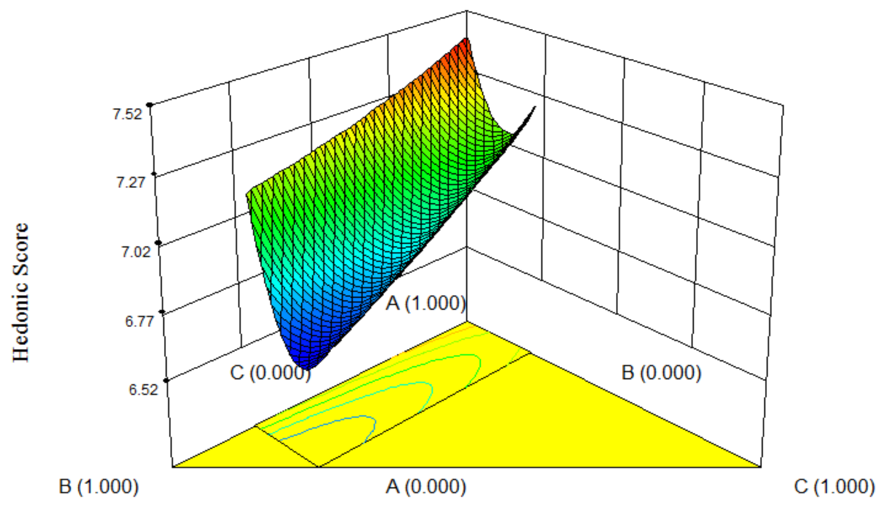

Fig. 6. Organoleptic property of final pickle sample

Table 4. Constraints for numerical optimization of salt mixture

	Name	Goal	Lower limit	Upper limit	Lower weight	Upper weight	Importance
Mixture components	NaCl	Minimize	0.5	1	1	1	5
	KCl	In range	0	0.75	1	1	3
	$CaCl_2$	Minimize	0	0.25	1	1	3
Response variables	Water Drawing Capacity	Maximize	58.364	102.692	1	1	3
	Hardness of cured sample	Minimize	6.998	8.471	1	1	3
	Water Activity	Minimize	0.968	0.974	1	1	3
	Na Concentration	Minimize	68.715	408.715	1	1	3
	K Concentration	In range	28.744	475.121	1	1	3
	LAB Population	Maximize	6.151	6.452	1	1	3
	Total Plate Count	In range	6.316	6.397	1	1	3
	Hedonic Score	Maximize	6.552	7.428	1	1	3

Table 5. Optimization of salt mixture with predicted values of response variable and desirability constant

Si. No.	NaCl	KCl	$CaCl_2$	Water Drawing Capacity	Hardness of cured sample	Water Activity	Na Concentration	K Concentration	LAB Population	Total Plate count	Hedonic Score	Desirability
1.	0.500	0.500	0.000	100.249	7.919	0.972	121.404	257.237	6.289	6.386	7.176	0.658 (selected)
2.	0.571	0.429	0.000	99.363	7.856	0.973	140.762	208.679	6.304	6.386	7.203	0.640
3.	0.500	0.314	0.186	82.565	7.303	0.973	166.063	137.329	6.304	6.346	6.826	0.496
4.	0.624	0.188	0.188	81.193	7.349	0.973	210.842	83.984	6.331	6.346	6.927	0.482
5.	0.815	0.000	0.185	78.538	7.466	0.972	297.311	35.917	6.371	6.348	7.084	0.425

4. CONCLUSION

Results revealed that Water Drawing Capacity (g/100g salt mixture) was of maximum value of 102.692 in the 6^{th} run. Hardness of cured sample (in N) was found to be maximum in Run-11 (8.470). Water activity was found to be minimum in the Run-2 (0.968). Na concentration in final pickle sample (in ppm) was found to be lowest in Run-2 (68.715). K concentration in final pickle sample (ppm) was found maximum in Run-6 (472.222). Run-14 and Run-12 have high organoleptic score of 7.429 and 7.393 respectively whereas Run-1 and Run-2 have low score of 6.552 and 6.616 respectively. Through numerical optimization, it is concluded that a salt mixture having 50% NaCl and 50% KCl can be used as salt mixture for curing mango pickle with a desirability constant of 0.658. However a salt mixture of 51.7% NaCl and 42.9% KCl can also be used as a salt mixture for curing mango pickle with a reasonably comparable desirability constant of 0.64.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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