Standardization of different value added products from Jackfruit grown in Terai region of West Bengal and evaluation of its storage stability

Thesis submitted to

Uttar Banga Krishi Viswavidyalaya

In partial fulfillment of the requirements for the Degree of

Master of Science (Horticulture)

in

Pomology and Postharvest Technology

By

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PUNDIBARI, COOCHBEHAR, WEST BENGAL

JUNE 2016

DEDICATION

The whole hearted effort is dedicated to my parents and to the sweet dream of those who wants to carry on research

Acknowledgement

It is my proud privilege to express my deepest sense of gratitude and genuine obligation to my venerable and beloved Chairman of the Advisory Committee, Prof. (Dr.) S. K. Ghosh, Department of Pomology and Postharvest Technology, Uttar Banga Krishi Viswavidyalaya, for selection of the thesis subject, judicious and affectionate guidance, needful help, constructive criticism and unending benevolence during the entire course of the present investigation and finalization of this manuscript. His close view, selfless smile and encouragement made the work complete with perfection. I am too much beholder to him.

I emphatically express my indebtedness to Mr. Nilesh Bhowmick, Assistant Professor, Department of Pomology and Postharvest Technology, Uttar Banga Krishi Viswavidyalaya, for his keen interest, precious suggestions and inspiration in different stages of my study.

With profound glee, I extend my gratefulness to Dr. S. Dutta , Associate Professor and Department of Vegetables and Spice crops, Uttar Banga Krishi Viswavidyalaya, for providing expertise and benevolent co-operations.

A plethora of thanks to Dr. S. Khalko, Associate Professor; Department of Plant Pathology, Uttar Banga Krishi Viswavidyalaya , for his precious suggestions and affectionate behavior during the course of my study.

I extend my gratefulness to Dr. P. K. Paul, Associate Professor; Head, Department of Pomology and Postharvest Technology, Uttar Banga Krishi Viswavidyalaya, for providing his precious suggestions, benevolent co-operations and needful help in different stages of my study.

I emphatically express my indebtedness to Soumitra Sankar Das, P.hd scholar, Department of Agricultural statistics, Uttar Banga Krishi Viswavidyalaya for his needful help in statistical analysis of the data in different stages of my study.

It is a pleasure on my part to acknowledge the debt I owe to the Dean, Faculty of Horticulture, U.B.K.V., for his help and suggestive cooperation during the course of my study.

I am grateful to Dr. M. Preema Devi, Assistant Professor and Dr. Aditi Chakraborty, Assistant Professor, Department of Pomology and Post Harvest Technology, Uttar Banga Krishi Viswavidyalaya, for their large helping hands, valuable suggestion and constructive criticism

With a profound and unfading sense of indebtedness, the author avails the opportunity to express heartfelt thanks to Mr. Biswajit Mazumder, Technical Assistant, Central Instrumentation Center, Uttar Banga Krishi Viswavidyalaya, Pundibari, Cooch Behar for his selfless help, keen interest and affectionate behavior during different instrumentational analysis within C.I.C laboratory.

Sincere thanks are extended to Sujoy da, Gopobondhu da, Dibyendu da, Ananda da, Nitish sir, and all the non-teaching staff of the Department of Pomology and Post-harvest technology, U.B.K.V., and library staffs of the university.

I offer my special thanks to my seniors Gobindo da, Piyali di, Rocky da, Swarnajit da, Aditya da, Sachin da, my yearmates Sukanya, Subhrojoyti, Nawang, Bijay, Bikash, my juniors Abid, Arghya and other friends and well-wisher whose names are not mentioned here individually, for the help extended to me by them.

I owe a great deal of love to my parents and sister (Priyata) for their patience, inspiration, sacrifices, and consistent moral support during my study at U.B.K.V.

Last but not the least I like to thank God for giving enormous energy and patience to complete my thesis work.

Place: UBKV, Pundibari.

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CERTIFICATE

This is to certify that the work recorded in the thesis entitled "**Standardization of different value added products from Jackfruit grown in Terai region of West Bengal and evaluation of its storage stability**" submitted by **Mr. Priyam Chattopadhyay** in partial fulfillment of the requirements for the degree of Master of Science (Horticulture) in Pomology and Post-Harvest Technology of Uttar Banga Krishi Viswavidyalaya, is a faithful record of *bona-fide* research work carried out under my supervision and guidance. Results of the thesis have not been submitted for any other degree or diploma. Assistance and help received during the course of investigation have been duly acknowledged.

Place: U.B.K.V. Pundibari. **Prof. S. K. Ghosh**

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ABSTRACT

Worldwide there is a heavy reliance of population on rice, wheat and maize to meet our food requirement of the mankind. These three crops altogether meet more than 50% of the total dietary energy requirements across the globe. There are many other crops which can be grow in marginal soil with low inputs. Jackfruit is one of them (Singh *et.al*, 2015). India accounts for an area of 102 thousand ha, with an annual production of 1436 thousand ton and 11.40 t/ha productivity. India is the second largest producer of fruits and vegetables after China, but 70% of fruit and vegetable output is wasted, accounting for 40 % of the total cost. Jackfruit is a very nutritious fruit and is rich in vitamin A, B complex and iron. Apart from the above 100g of jackfruit pulp contain- 77.2% moisture, 18g carbohydrate, 1.9g protein, 0.1g fat, 540IU Vitamin A. Due to presence of high moisture content, the fruit is very perishable in nature. Preservation by means of dehydration helps to reduce water by immersion of concentrated aqueous solution of sugar/salt (Suttar and Suttar, 2013). Jackfruit is a very heavy and bulky fruit and hence the transportation is not very easy and is costly as well. Due to presence of strong aroma some time it is not preferred by the consumer. Preparation of leather from ripe fruit, have a influential role on improving shelf life, reducing packaging cost, enhancing appearance, encapsulate original flavor and maintaining nutritional value. To conduct the experiment, fresh jackfruit at two different maturity level (immature and ripe) were collected from the Instructional Farm of Uttar Banga Krishi Viswavidyalaya, during the year 2015and immediately brought to the laboratory of the Department of Pomology and Post Harvest Technology, for storage after necessary treatments. For the preparation of osmotically dehydrated jackfruit cube, independent variables were Salt concentration (1-15%), Time (30.00- 240.00min) and $Ca(OH)_2$ concentration(0 and 1%), and the response variable were Water loss(%), Mass reduction(%), Change in dry matter content (%),Water activity and Rehydration ratio. For this experiment the highest amount of water loss (90.54%) was observed in Run 13, Mass reduction was highest (91.61%) in Run 18, highest amount of Change in dry matter (37.26 %) was found in Run 19 and Rehydration ratio (3.77) was in Run 10.The lowest amount of Water activity (0.724 a_w), which is essential for enhancing post harvest period of the product, was observed in Run 15. For the evaluation of storage study of immature jackfruit cube, Water activity, Rehydration ratio and Total plate count were estimated as experimental parameter and was recorded for 6 month at 1 month interval. In

case of mix fruit leather, independent variables were mango pulp, jackfruit pulp and aonla pulp, and response variables were TSS(^{o}B), RS(%), NRS(%), Acidity(%), Ascorbic acid (mg/ 100g), Water activity and Hardness (gf). For the treatments, highest amount of TSS(22.86 ^{o}B) was observed in Run 6, optimum RS(4.75%) was in Run 7,NRS was highest(14.89) in Run 2,acidity (1.71) in Run 1,ascorbic acid content(38.05 mg/100 g) was in Run 3 and hardness (177.4) was found to be highest in Run 10. The least amount of water activity (0.773) was found in Run 1.For the evaluation of the storage study of mix fruit leather, Water activity, Ascorbic acid content and Total plate count was recorded for 6 month at 1month interval.

Prof. S.K. Ghosh

Priyam Chattopadhyay

INTRODUCTION

The world wide, there is a heavy reliance of population on rice, wheat and maize to meet food requirement of the mankind. These three crops altogether meet more than 50% of the total dietary energy requirement across the globe. There are many other crops which can grow well in marginal soil with low inputs. Jackfruit is one of them. (Singh *et al*., 2015).

Jackfruit (*Artocarpus heterophyllus* L.), is a dicotyledonous compound fruit and is a member of the family Moraceae which encompasses about 1,000 species in 67 genera, mostly tropical shrubs and trees, but also a few vines and herbs were also reported (Bailey, 1949; Merill, 1912). Jackfruit is a very long lived evergreen tree, 10 to 15 m tall with dark green oval shaped leaves, and all parts of it contain sticky white latex, and generally has a life span of 60 to 70 years. The inflorescences are solitary, both male and female flower produced separately on short axillary leafy twigs, either on the tree trunk or on older branches of the same tree. In some cases they can also be borne on the underground parts of the tree, producing fruits protruding from the ground. The individual flowers are borne on an elongated axis and are grouped into a racemoid inflorescence, also called a spike or head. The female flower, which has a fleshy ring at the base, is larger than the male flower (Haq, 2006)

Jackfruit is the largest tree borne fruit in the world, reaching up to 50 kg in weight and 60-90 cm in length. A full grown tree produces up to 700 fruits per year, each weighing 0.5 to 50 kg. On an average, 50-80 tons of fruits can be harvested from a hectare of land (Sidhu, 2012). The fruit surface is warty with numerous protruding pyramidal sections. The perianths of the individual flowers become the fleshy pericarp and surround the seeds, each pericarp and seed being an individual fruit. The pericarp is yellow-white or yellow and waxy-firm (Corner, 1938). Hossain and Haq (2006) classified jackfruit into two groups: (i) soft pulp varieties having plenty of juice, and (ii) firm pulp varieties, which are crispy and less juicy. Apart from the above two groups, an intermediate type is also found in jackfruit.

Harlan (1987) reported that jackfruit has only one identified center of origin, the Indo-Malayan region (Barrau, 1976; Zielenski, 1955). More specifically, the species reportedly originated in the rainforests of the Western Ghats of India (Chandler, 1958; Popenoe, 1974; Purseglove, 1968)

and in Malaysia (Brown, 1941; Merill, 1912; Wester, 1921). It is now widely cultivated in south and south-east Asia including Bangladesh, Malaysia, Myanmar, India, Indonesia, Philippines, Sri Lanka, South China, Thailand and Vietnam, Latin America particularly Brazil, and parts of Africa, including Kenya and Uganda (Hossain and Haq, 2006), but is particularly abundant in India and Bangladesh. Jackfruit is recognized as the National Fruit of Bangladesh (Mondal *et al*., 2013). The tree is a major component of subsistence and small farmers' farming systems and the fruit often assumes the role of a secondary staple food as well as contributing to the livelihoods of the poor.

India is the second biggest producer of the fruit in the world and is considered as the motherland of jackfruit. India accounts for an area of 102 thousand ha, with an annual production of 1436 thousand ton and 11.40 t/ha productivity. In India, it has a wide distribution in Assam, Tripura, Bihar, Uttar Pradesh, the foothills of the Himalayas and South Indian States of Kerala, Tamil Nadu and Karnataka. Apart from the above West Bengal accounts for a good position with 10 thousand ha area, 143 thousand mt. production and 13.76 t/ha productivity. In West Bengal Jalpaiguri leads in area (1539 ha) and production (36100 t) followed by Nadia, Murshidabad, North 24 Pargana and Coochbehar. Devi *et al.*, (2014,) reported that the name jack is originated from its Malayalam name *Chakka.* It is also called *kathhal* (hindi and urdu), *pala* (tamil), *halasina hannu* (kannada) *panasa pandu* (telugu) and *phanos* (marathi and Konkani).

Generally in India, more specifically in West Bengal, jackfruit is grown as home stead crop and no commercial cultivation is followed. Being a hardy crop it can perform well without much care. The whole part of the plant has a lot of economic importance. Jackfruit is referred as "poor man"s fruit" as well as "nutrients of giant" (Singh *et al*., 2015). The fruit can consumed both as ripe (raw fruit or by means of prepared processed products) and unripe or immature (as vegetable) condition. Both tender and ripe fruits and the seeds are rich in minerals and vitamins. Hossain and Haq (2006) reported that ripe fruits are rich in vitamin A, B complex and Iron. Apart from the above, they also showed that 100g of jackfruit pulp contain- 77.2% moisture, 18g carbohydrate, 1.9g protein, 0.1g fat, 540 IU Vitamin A. Mondal *et al*., (2013) reported that Jackfruit content more protein, calcium, thiamine, riboflavin and carotene than banana, but less nutritious than mango (Hossain *et al*.,1979). The yield of jackfruit is manifold higher than many

other fruit due to its bulky weight. Therefore, vitamin and mineral production per unit area are higher in jackfruit than many other fruit. Edible bulbs of ripe jackfruit are consumed for their fine taste and pleasant aroma. Devi *et al.,* (2014) reported that it can act as source of complete nutrition to the consumers. The fruit is equivalent to Avocado and olive in terms of the healthier mix of nutrients for human dietary needs, almost having the exact nutrient equivalents of mother's milk. It is rich in vitamin C, potassium, calcium, proteins and high level of carbohydrates, affordable and readily available supplement to our staple food. Its seeds are rich in proteins and can be relished as a nutritious nut. The fruit is also the source of chemical "Jacalin" useful in preventing colon cancer, AIDS *etc.*

According to the Global Hunger Index 2013 (GHI), India ranks 63rd, out of the 78 hungriest countries, significantly worse than neighboring Sri Lanka (43rd), Nepal (49th), Pakistan (57th), and Bangladesh (58th). Despite India's considerable improvement over the past quarter-century – its GHI rating has risen from 32.6 in 1990 to 21.3 in 2013 – the United Nations Food and Agricultural Organization believed that 17% of Indians are still too undernourished to lead a productive life. In fact, one-quarter of the world's undernourished people live in India, more than in all of Sub-Saharan Africa. India is the second largest producer of fruits and vegetable (1st China) but 70% of fruit and vegetable output is wasted, accounting for 40% of the total cost. The Indian Institute of Management in Kolkata estimated that cold-storage facilities are available for only 10% of perishable food products, leaving around 370 million tons of perishable products at risk. So proper post harvest handling can check the massive wastage of most of the perishable fruits and vegetable and can also meet the food demand. (World economic forum, 2014)

Among various fruit, which are wasted abundantly, jackfruit is one leading fruit of them. Mondal *et al*,.(2013) reported that the fruit is perishable in nature due to presence of high amount of moisture and cannot be stored for long time because of its inherent compositional and textural characteristics. A considerable amount of jackfruit, specially obtained in the glut season (June-July) in every year goes waste due to lack of proper postharvest knowledge during harvesting, transporting and storing both in quality and quantity. Jackfruit is a heavy and bulky fruit and hence transportation is not very easy and is costly as well. Due to presence of strong aroma sometime it is not preferred by consumer. Proper postharvest technology for prolonging shelf life

is therefore necessary. Besides alternate ways of using jackfruits in on-season play significant roles in reducing postharvest losses. Among them, processing is an important one. Oliveros *et al*., (1971) reported that the demand for ripe jackfruit has increased 100-fold in the Philippines following modern advances in food technology. Reduced post-harvest losses, increased shelf-life and preserved fruit for the out of season period can improve the use of fruits through processing. Raw materials transformed into edible products can increase food security and add variety to the diet, improving nutrition and health. Creation of employment opportunities in production areas is an added bonus. (Haq, 2006).

According to different research work, it is found that various processed products can be prepared from jackfruit at different maturity level. In this proposed work emphasise was given on two different product prepared from different maturity level. Osmotically Dehydrated jackfruit cube was prepared from immature fruit. Being a strong aromatic fruit, sometimes it is not preferred by the consumer. Keeping the above status in mind, a mix fruit leather was prepared using jackfruit pulp as a major component and mango pulp and aonla pulp as mixing component , as blending becomes one of the way of utilization of more number of fruits for high quality in respect of both sensory and nutritional aspects.

Keeping above in view, the experiment entitled "Standardization of different value added products from jackfruit grown in Terai region of West Bengal and evaluation of its storage stability" was undertaken with the following objectives-

Objective

- To prepare a self stable osmotically dehydrated tender jackfruit product
- To find out a optimized process condition for preparation of dehydrated Jackfruit product
- To prepare a mix fruit leather utilizing jackfruit pulp as major component

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REVIEW OF LITERATURE

For the fulfillment of any scientific study, review of literature is an essential work to be done. It reveals the theoretical platform had been done related to this study. The main objective of this review is the interpretation of the findings into present investigation for the suitable occurrence of this study.

The present post harvest experiment of jackfruit consists of preparation of two products at different maturity level *viz*., osmotically dehydrated jackfruit cube from tender jackfruit and jackfruit leather blended with mango and aonla. For the preparation of jackfruit cube, the fruits were cut into 1.5 cm^3 and then were blanched for 3minutes. The blanched fruits were then dipped in $Ca(OH)_2$ solution (1 and 0%) and then dehydrated using common salt (NaCl) at different concentrations for different time period. After dehydration the cubes were dried in cabinet drier at 60^0C for 6 hrs. For the preparation of jackfruit leather, the pulp from the individual fruits were extracted and then were blended with aonla and mango pulps at different blending ratio followed by drying at 60^0C in the cabinet drier for 14–18 hrs. With this view, a brief review works has been prepared which were already experimented by different researchers as follows:

For preparation of dehydrated jackfruit cube, tender fruit harvested between 165-195 days from spike appearance, gave a good quality dehydrated product. Ramli (2009) reported that Agricultural products are very perishable due to their high water content, which ranged from 60–95%. Fruits and vegetables continue with their metabolic reactions/processes, such as respiration and transpiration even after harvest. These processes will use up their food and water reserves, making the product less fresh, and start to deteriorate.

2.1 Blanching

Blanching is a very common and essential pre treatment to destroy enzymic activity as well as to reduce microbial load, to soften tissue for easy processing and to reduce intercellular air to prevent oxidation in many vegetables and fruits, prior to further processing.

Blanching plays an effective role on physicochemical property of product. Patil *et al.,* (2014) reported that blanching has a greater impact on moisture, TSS, reducing sugar, non-reducing sugar, β-carotene, pH and starch content and amount of titable acidity on dehydrated jackfruit chips. They observed dehydrated jackfruit chips after blanching contained 8.81% moisture, 11.12 ^{o}B TSS, 0.37% titable acidity, 1.16% reducing sugar, 3.97% total sugar, 5.47 pH, 14.71% starch and 581.48 µg/100g ascorbic acid.

Antioxidental activity of the osmotically dehydrated product is also influenced by blanching treatment. Koushal *et al.,* (2013) reported that after blanching treatment in Colocasia showed 3.9% antioxidental activity.

It has long been established that blanching as a pretreatment for vegetable preservation, significantly reduces the enzymatic detoriation by inactivating the enzyme responsible for detoriation. (Williams *et al*., 1986).

Blanching also have beneficiary role on the heat stable enzyme. Peroxidase (POD) and lipoxygenase (LOX) are the most heat stable enzymes present in vegetables. Raw vegetable soybeans also contain trypsin inhibitors and saponins that are not easily digested in the human body. Savage *et al*., (1995) reported that soaking and blanching soybeans inactivated 80% of initial trypsin inhibitor and 99% of initial LOX (Lyposygenase) activity, which reduced off-flavors of soybeans.

Barrett and Theerakulkait (1995) found that LPO (Lepoxygenase) in sweet corn catalyzed off-odor formation, can be inactivated by means of blanching treatment which also enhanced desirable characteristics, such as sweetness and flavor of the corn.

Mercer (2016) reported that blanching deactivate the enzyme responsible for detoriation and halt its negative impact of sliced florets of the cauliflower by raising the temperature to a sufficient level.

Blanching as a pre treatment, have a greater impact on retaining the color as well as the texture of processed product. Mercer (2016) reported that blanching helps to set the color and slow the softening of pea and carrot during post operation.

Shewfelt *et al*., (1984) reported that loss of green color is a primary factor limiting the shelf life of fresh broccoli. Klein (1992) reported that stability of color could be improved by blanching in broccoli.

2.1.1 Temperature-

Temperature has a strong correlation with blanching. For blanching treatment different temperature required depending upon different vegetable and fruits. Olivera *et al.,* (2008) reported that firmness of Brussel sprouts was increased along with radical scavenging activity; total flavanoids and ascorbic acid content were observed after blanching operation at 50^{o}C and 100 ^{o}C for 5 and 3 min respectively. This might be attributed to the loss of integrity of cell membranes and organelles.

Blanching as a pre-treatment for vegetable slices at 100°C for 10-30 sec before the osmotic dehydration showed increase in the effective diffusion coefficients of water as well as sucrose, this was due to the death of cells in the tissue (Escobar *et al*., 2007).

High temperature during blanching sometimes has some negative effect. Zhang *et al.,* (2011) reported that Blanching at 95^{0}C markedly reduced the protein content of bamboo shoot in comparison to 75^{0}C and 85^{0}C. At high temperature most of the labile protein denatured. Crude fat have been found significantly affected by blanching treatment.

Blanching at higher temperature some time negatively affects the products. Gupta *et al*., (2008) reported that ascorbic acid content of all green colocasia leaves blanched at 80^{o} c, showed a reduction of 25-50% compare to the leaves without blanching.

Agiriga *et al.,* (2015) reported that highest amount of β-carotene [70.05±0.070a] was reported in carrot when it was blanched at 90 ºC, and highest amount of crude protein was [3.55±0.325b] at 80^0C.

Bahceci *et al*., (2005) reported that blanching process increased the half-life of ascorbic acid in green beans. They observed that half-life of ascorbic acid in unblanched green beans was 1.89 months, but increased to 2.15 and 3.48 months when blanched at 70 ºC for 2 min and 90 ºC for 3 min, respectively .

2.1.2 Time

Along with temperature, time of blanching is also an important factor. Song *et al*.,(2003) reported that retention of vitamin C in vegetable soybeans after blanching at 100 ºC for 10 min had the minimal loss of vitamin C as compared to blanching at 80 ºC for 30 min and 90 ºC for 20 min. They also reported that high temperature and short time (HTST) blanching have been recommended as the best conditions for fruit and vegetable, as they preserved nutrients, vitamins and organoleptic properties.

Blanching for long duration affected the nutritional status of the produce. Hunter *et al.,* (2002), Amin *et al.,* (2006) and Sveto *et al.,* (2007) reported that the antioxidant components reduced after blanching due to blanching time and temperature. They observed that, spinach blanched for 10 min, leached out 49% - 51% of its antioxidant contents into boiling water.

Price *et al.,* (1997) and Chu *et al.,* (2000) observed that blanching for less than 1min retained the high antioxidant activity in green leaves of sweet potatoes. In addition to the above Papetti *et al*., (2002) reported a decrease in total antioxidant components when vegetables juices were cooked at 102°C for 10 min.

Koushal *et al.,* (2013) pointed out that water blanching at 98^oC for 10 sec inactivated peroxidase enzyme responsible for browning. In addition to the above they also stated that 13.74% ascorbic acid was degraded at 10 sec, 43.12 % at 1 min and 63.19 % at 3 min.

Peroxydase and lypoxygenase , the major thermo stable component present in various products ,were responsible for browning of products. Barrett and Theerakulkait (1995) found that LPO inactivation in sweet corn at 93^{o}C was accomplished in 6 to 9 min while POD inactivation under the same conditions required 18 to 20 min. Inactivation of POD and LPO at 93 ^{o}C in green beans required 2.0 and 0.5 min, respectively. Sheu and Chen (1991) reported that POD activity was reduced by 90% after blanching for 1.14 min at 100 °C.

Blanching for higher time affect the textural property of the products. Barret *et al*.,(2000) reported that the firmness in blanched corn increased with blanching time up to 6 min and then declined.

Suwan (2015), observed that blanching of carrots at high temperature for short-time (HTST) contained more total galacturonic acid , total sugars and pectins than carrots blanched for a long time at low temperatures (LTLT).

Xu *et al.,* (2012) reported that enzyme activity in vegetable soybeans was reduced significantly by blanching. 98% loss in activity of the detoriating enzyme after 2.5 min was observed by them.

2.2 Treatment by Calcium hydroxide

Calcium was involved in maintaining the textural quality of produce by forming cross-links or bridges between free carboxyl groups and calcium ions of the pectin chains. These bridges resulted in strengthening of the cell wall (Garcia *et al*., 1996). Saftner *et al.,* (2003) found that treatments with calcium inhibited color changes and development of tissue translucency in honeydew chunks.

Ca treatment also protect the product from various physiological disorders during storage. Manganaris *et al.,* (2007) suggested that immersion of whole peaches in 62.5 mM calcium chloride, increased firmness of tissue and reduced the susceptibility to physiological disorders and salt-related injuries.

Calcium retained fresh-like appearance of minimally processed fruits and vegetables for long time by controlling the development of browning. Control of the flesh browning was observed in fruits by means of different calcium treatments in different studies, like peaches (Manganaris *et al*., 2007) and pineapple (Hewajulige *et al.*,2003).

Calcium treatment also increases the amount of Ca in fruit and vegetable matrix. Anino *et al.*, (2006) reported that Calcium content of fresh-cut lettuce significantly increased when treated with calcium lactate compared with chlorine treatments.

Ramli and Ahmad (2013) reported that calcium maintained the texture of ripe jackfruit pulps and the intactness of the cell wall structures. In calcium-treated ripe jackfruit pulp, the cell wall structures were still undamaged as infusions were done at low and room temperatures. Thus the texture was enhanced through the interaction of the calcium and the pectin in the cell walls. Lefever *et al.,* (2004), pointed out that the cell wall was responsible for the texture of the tissue and structure integrity of processed fruits. They also reported that the calcium immersed ripe jackfruit pulps showed good rating for color during storage as compared to the other samples. The osmotic process which occurred during immersion might be helped to improve the optical characteristics of the pulps. .

Ramli (2009) reported that ripe jackfruit treated with different calcium infiltration treatment when stored at 8^{o}C, showed an increased amount of TSS (5 ^{o}B at immature stage from 28 ^{o}B at ripe fruit), and water soluble pectin. They also stated that the above treatment also helped to increased the pH content which coincide with the decrease in titrable acids. Although the polygalacturonase (PG) and pectin esterase (PE) activities were low in green and mature pulps, the ripe pulp exhibited a sharp increase in both activities. These changes resulted in the jackfruit to be suitable for human consumption.

2.2.1 Duration of treatment

Calcium chloride has been widely used as preservative and firming agent in the fruits and vegetables industry for whole and fresh-cut commodities. Chardonnet *et al.,* (2003) reported that dipping time ranges from 1 to 5 min in most of the published work.

Luna-Guzman *et al.,* (1999) used periods of 5 min for immersion of fresh-cut cantaloupe. Martin-Diana *et al.,* (2005a) treated fresh-cut lettuce and carrots for 1-5 min. Manganaris *et al.,* (2007) used a time period of 5 min for immersion of whole peach fruits.

2.2.2 Temperature

Bartolome and Hoff, (1972); Garcia *et al*., (1996); Rico *et al*., (2007) reported that use of warm temperature (40-60 ^{o}C) increased the beneficial effects of the treatment by Ca due to higher washing solution retention inside the product. Luna-Guzman *et al.,* (1999) reported that the use of 60 ^{o}C improved the beneficial action of the calcium solutions in comparison with 40 or 20 ^{o}C.

Rico *et al.,* (2007) reported that the use of higher temperatures increased the diffusion of calcium into carrot tissues and improved the quality, especially related to texture maintenance and browning reduction in comparison with lower temperatures.

2.2.3 Concentration of solution

Luna-Guzman and Barrett, (2000); Luna-Guzman *et al*.,(1999); Main *et al*., (1986); Manganaris *et al*.,(2007); Martin-Diana *et al*.,(2005b) and Morris *et al*. (1985) reported that the concentrations of the calcium salts used as washing treatments were usually within a range of 0.5-3%.

Ramli and Ahmad (2013) reported that, ripe jackfruit pulp treated with calcium concentrations of 1.5 % and 2.0 % for 18 hrs resulted products with bitter taste whereas in immersion for 15 minutes resulted in no detection of bitterness.

2.3 Dehydration

Dehydration is a very primitive and oldest form of fruit and vegetable preservation. Dehydration lowers the cost of packaging, storing, and transportation by reducing both the weight and volume of the final product. In addition to the above Dehydration also improve the quality of produce. The potential of dehydrated fruits and vegetables is greater than ever.

Sutar and Sutar (2013) reported that dehydration is an ideal process of water removal by immersion of water containing cellular solids in a concentrated aqueous solution of sugar/salt. This resulted in intermediate moisture product with lower water activity. At low water activity, most of the chemical reactions which deteriorated the food as well as the growth and toxins production by microorganisms were ceased. Besides, it improved the color, flavor and texture and was less energy intensive process compared to other drying techniques as no phase change takes place during the moisture removal from the substrate. In addition to the above that osmotic dehydration affected the rehydration characteristics as well as rehydration ratio of the final product. Generally osmo dehydrated products result in to low rehydration ratio due to increased solid gain and the solid loss (salt and sugar) by dissolution in to water during rehydration. But this effect could be counted as loss of original solids of the products.

Ertekin and Cakaloz **(**1996) reported that osmotic dehydration can removed 30 to 40% moisture from the product. The amount of water loss was high during initial period and as dehydration period increased, the rate of water loss decreased and rate of solute gain increased.

The use of sucrose and salt mixture as osmotic agent also have beneficial effects as it developed high osmotic potential, thereby causing higher water loss, retarding oxidative and nonenzymatic browning, and obtained better quality product (Islam and Flink, 1982).

Moreira and Sereno (2003) reported that osmotic dehydration (OD) of fruits as a pretreatment has been reported to reduce energy consumption and improved product quality with a high content of naturally occurring vitamins and microelements. The main advantages of osmotic

dehydration included better color, texture and flavor retention along with minimum heat damage (Ponting *et al.*, 1996).

Panagiotou *et al*., (1998) observed that the size of fruit samples had a negative effect on water loss during osmotic treatment. Rahman (1992) observed that the distribution coefficient of water decreased with increase in temperature and surface area and it increased with the increase in syrup concentration and thickness of minimum geometric dimension. In general, a sample size of 3 mm to a maximum of 10 mm in rectangle, ring or cube shape was suggested for the use in osmotic dehydration process.

Nishadh and Mathai (2014) reported that the osmotic pretreatment was more efficient in reducing a_w. A considerable amount of water was removed during osmosis and an incorporation of sugars occurred. The sample without pretreatment and dried at lower temperature (50 ^{o}C) did not lower a_w to a safe value.

Dehydration allowed for long-term storage of fruits thus allowing preservation of vitamins and other nutrients in fresh fruits and vegetables that are beneficial for human health (Cadenas, 2002).

2.3.1 Type of Osmotic agent

The type of osmotic agent is very important factor for determining the rate of diffusion. Torreggiani (1995) reported that the solute cost, organoleptic compatibility with the end product and additional preservation action by the solute were considered in selecting osmotic agents,. Various osmotic agents such as sucrose, fructose, glucose, corn syrup, sodium chloride, and so on plus their combination have been used for osmotic dehydration.

Suttar and Suttar (2013) studied osmotic dehydration of sweet potato (*Ipomoea batatas*) using salt and sucrose solutions. The osmotic process was carried out by them at different sucrose concentrations (40-60 % w/w), salt concentrations (0-10 % w/w) and solution temperatures (30-50^{o}C). They reported that water loss and solid gain of sweet potato increased with osmosis time.

Sucrose and sodium chloride were most commonly used as osmotic agents. Sodium chloride was found to be an excellent agent for vegetables as it changed cell permeability, but has limited use in dehydration of fruits due to salty taste (Yang and Le Maguer, 1992; Erketin and Cakaloz, 1996).

In this proposed work osmotically dehydrated jackfruit cube was prepared from immature stage. As because tender jackfruit generally use as vegetable, so for dehydration of tender jackfruit cube NaCl was used here as dehydrated solute.

2.3.2 NaCl as osmotic solute

El Wakeil (1958) reported that no identifiable quality changes was observed when using iodone/iodide mixtures, iodized salt and iodophor in canned sweet corn, canned tomato juice and canned sauerkraut. Only a flavor change in tomatoes at high level of the iodine/iodide mixture (200 ppm) was observed.

Kaymak-Ertekin *et al*., (2000) reported that Sodium chloride decreased water activity and higher osmotic pressures than the same sugar concentration used. But several disadvantages is also associated for organoleptic properties and due to the small sizes of the sodium and chloride ions, both penetrate into food structure by diffusion reaching high osmotic solute contents called solid gain.

Sodium chloride was employed to assess the possibility to increase the process rate without affecting the sensory acceptability of treated fruit. Salt concentration improved water loss at equilibrium but showed a negative interaction effect with sucrose concentration. (Sacchetti *et al*., 2001).

Doyle (2008) observed that Sodium and lithium were the only cations with salty taste. Some other minerals, such as potassium and calcium, have some component of saltiness to their taste

but there were other flavors as well, sometimes described as "metallic" or "bitter." Sodium chloride was considered as saltiest sodium compound.

Kilcast and Den (2007) reported that Sodium chloride affected the taste of specific foods by providing the flavor of saltiness, by enhancing or masking other flavors, and by controlling growth of microbes. In addition to the above they also observed that sodium chloride also affected flavor by regulating the growth of certain microbes and the activity of particular enzymes. Salt concentrations significantly improved the activities of proteolytic and lipolytic enzymes that produced important characteristic flavor compounds or bitter compounds during ripening of cheese.

Duche *et.al* (2002) stated that Salt has been used to preserve meat, fish, vegetables, eggs, and even some fruit, such as olives for thousands of years. Its primary effect was to reduce water activity of foods so that not enough water was available for growth of pathogenic or spoilage organisms. Most food borne bacteria, including *Clostridium botulinum*, *E. coli*, *Listeria monocytogenes*, *Salmonella* spp., and the spoilage bacteria *Pseudomonas* spp., could not grow below a water activity of 0.92.

Salt was very effective as a preservative because it reduced the water activity of foods. The water activity of a food is the amount of unbound water available for microbial growth and chemical reactions. Salt's ability to decrease water activity was thought to be due to the ability of sodium and chloride ions to associate with water molecules (Fennema, 1996; Potter and Hotchkiss, 1995).

It has also been suggested that for some microorganisms, salt might limit oxygen solubility, interfere with cellular enzymes, or force cells to expend energy to exclude sodium ions from the cell, all of which could reduced the rate of growth of the detoriating micro organism (Shelef and Seiter, 2005).

Foods using sodium as a hurdle to retard microbial growth and survival present a reformulation challenge, since changing the sodium content altered the impact (or height) of the water activity hurdle. Changing this single hurdle may impact the safety and quality of the food because other hurdles that were present (pH, temperature, etc.) may work only in combination with the original

sodium level. To maintain a safe, good-quality product, reformulation may have to include the introduction of additional hurdles or an increase in the impact of existing hurdles. If such additional measures were not taken during sodium reduction efforts, the remaining products might not be stable. For example, in cured meats, reducing the sodium content (by removing both salt and sodium nitrite) could allow for rapid growth of lactic acid bacteria and action by proteolytic microorganisms, resulting in a product that spoiled more rapidly (Roberts and McClure, 1990;Stringer and Pin, 2005).

Salt can play a role in the development of physical properties of foods that were beneficial for processing or developing final product qualities. For example, salt levels played an important role in controlling the stickiness of some doughs, easing the processing of some baked goods (Hutton, 2002 and Vetter, 1981).

In meats, cheeses, and extruded snack products (e.g., cheese balls, shaped potato snacks), use of salt developed the characteristic texture expected by consumers (Desmond 2007; Guinee and Fox, 2004; Guinee and O'Kennedy, 2007; Hedrick *et al*., 1994).

Adding salt to foods can also caused microbial cells to undergo osmotic shock, resulting in the loss of water from the cell and thereby causing cell death or retarded growth (Davidson, 2001).

2.3.3 Concentratiom of the solute

Water loss and solid gain were significantly influenced by the concentration of the osmotic solution. A high rate of water loss and solid gain could be achieved by increasing the solute concentration. But the optimum concentration was ultimately governed by the sensorial quality of the finished products.

Guinee and Kenedy (2007) reported that in case of natural cheeses, sodium chloride levels generally vary from 0.7% to 6% and play important roles in ensuring the quality, texture, and flavor of different types of cheese.

Salt concentrations at 10 per cent, 14 per cent and 18 per cent were used as the process variable to investigate the kinetics of water loss and salt uptake in potato cubes (Khin *et al*., 2006).

In addition to *C. botulinum* and *L. monocytogenes*, the growth of other foodborne pathogens may be more rapid in foods with reduced contents of salt and other sodium-containing preservatives. These pathogens included *Bacillus cereus*, *Staphylococcus aureus*, *Yersinia enterocolitica*, *Aeromonas hydrophila*, *Clostridium perfringens*, and *Arcobacter* (D'Sa and Harrison, 2005; Reddy and Marth, 1991; Stringer and Pin, 2005).

Chenlo *et al*., (2006) studied the osmotic dehydration of chestnut using aqueous solution of sodium chloride at different concentrations *viz.*, 17 per cent, 22 per cent and 26.55 per cent as osmotic media. The analysis of Water Loss/Solid Gain parameters revealed that the optimal values in the range of experimental conditions as said, were obtained at 22.0 per cent sodium chloride concentration.

Etchells *et al.,* (1943) reported that use of small amount of solid salt or brine of low salt concentration resulted, an active fermentation with the formation of decided amount of acid. The preserving effect of brine was obtained by the combined action of salt and acid. However use of large amount of salt is used either in solid or in solution form, caused very little or no amount of acid production.

Pedreschi *et al.,* (2009) observed that, 3% NaCl solution reduced non-enzymatic browning in potato chips by leaching the reducing sugars and reducing the acrylamide content. Nishat and Mathai (2014) reported that 28.3 % moisture, 71.6 % dry matter content was observed in osmotically dehydrated radish kept at 6% NaCl concentration.

Manivannan and Rajasimman (2008) observed that osmotic dehydration in Beetroot at 35^{o}C temperature, 90 min processing time, 14.31% salt concentration and 8.5:1 solution to sample ratio was found beneficial. At these optimum values, water loss, solid gain and weight reduction were found to be 30.86 (g/100 g initial sample), 9.43 (g/100 g initial sample) and 21.43 (g/100 g initial sample) respectively.

2.3.4 Temperature of the solution

The effect of temperature is a important phenomena of osmotic dehydration as it affects the drying rate and also influence the quality of the osmotically dehydrated product. Conway *et al.*, (1983) observed that every 10 °C increase in temperature caused 5 per cent increase in final water loss percentage.

The effect of temperature was more pronounced between 30 to 60°C for fruits and vegetables on the kinetic rate of moisture loss without affecting solid gain (Ponting, 1973; Rastogi and Raghavarao, 1995; Pokharkar, 2001).

Chavan, and Amarowicz (2012) indicated that the high temperature above 60 ^{o}C modified the tissue characteristics favouring impregnation phenomena and thus solid gain was enhanced. Rahman and Lamb (1991) stated that the rate of sucrose diffusion is a function of solute concentration and temperature. The diffusion coefficient decreased with the increase in solid content during the osmosis and increased with the drying air temperature.

Kulkarni *et al.,* (2008) reported that processing of dates by blanching in water at 96±1 °C and subsequent dehydration at 60±2 °C for 18–20 h resulted in good quality dehydrated dates as compared to the dates dried without heat treatment. They also pointed out that the dehydrated dates were found to be acceptable with respect to color, flavor, taste and overall quality. The dehydrated dates contained a total sugars of 520 g kg−1, reducing sugars of 415.1 g kg−1, tannins 13.5 g kg−1 and ascorbic acid 33.7 mg kg−1. Equilibrium relative humidity (ERH) of the dehydrated dates was found to be 75.9% with an initial moisture content of 159 g kg−1.

Beristain *et al*., (1990) reported that increase in temperature of osmotic solution resulted in increases in water loss, whereas solid gain was less affected by temperature.

Rahman (1992) reported that Water loss increased with the increase of temperature whereas solid gain was less affected by temperature. In case of high temperature, solute was not diffused as easily as water through the cell membrane, and thus the approach to osmotic equilibrium is achieved primarily by flow of water from the cell.

2.3.5 Duration for osmotic dehydration

Fasogbon *et al.,* (2013) reported that highest amount of solid grain was observed in strawberry when it was osmotically dehydrated for 3 hr.

Tiwari and Jalali (2004) reported that during osmotic dehydration of mango and pineapple increase in osmotic duration resulted in increase in weight loss, but the rate was decreased.

Mayor *et al*., (2006) performed osmotic dehydration experiments in pumpkin using sodium chloride as osmotic agent, with varying the concentration of the osmotic solution (5-25 per cent w/w), temperature (12-38 ºC) and contact time (0-9 h) and reported that the most important changes occurred during the first 3 h of the process; a pseudo-equilibrium was reached after 6-9 h.

2.4 Subsequent Drying-

Swami *et al*., **(**2014) reported that the jackfruit bulbs dried at 60 °C in tray dryer required 330 min to lower the moisture content from 82.13 - 20.75 % w.b. and osmotically dried jackfruit bulbs at 40°C and 60° C required 270 and 240 min. respectively, where moisture content was reduced from 82.13 - 24.42 % and 82.13 - 27. 32% w.b. respectively.

The osmo dried papaya and mango slices were dried in a cabinet dryer at 60 ^{0}C for 6 hrs to obtain 16 per cent moisture content (Gurumeenakshi *et al.*, 2005).

Chavan and Amarowicz **(2012**) reported that the osmotic air-dried products were high in superior quality and the osmosis process removed water from fruits and vegetables slices to the extent of 40 – 50 per cent of the weight, but not enough for storage. Therefore, to remove water up to safe levels further drying was needed.

2.5 Leather

Sidhu (2012) reported that drying of the fruit bulbs to make fruit leathers is a convenient method of marketing the fruit as confectionery and yields a product that is stable for more than two months at room temperature. There might be a good market for jackfruit leather depending on price, packaging, marketing and distribution (Che-Man and Sin, 1997).

Cadenas (2002), reported that the purposes of drying fruit pulps is to produce a stable and easily handled product which will yield maximum quantity for the least volume, improve shelf life, reduce packaging costs, lower shipping weights, enhance appearance, encapsulate original flavour and maintain nutritional value in many agricultural products .

2.5.1 Blending

Kumar *et al.,* (2010) reported that for preparing papaya- guava blended leather, fruit pulps were mixed at a ratio of 80 : 20, 60 : 40, 40 : 60, and 20 : 80. The brix and acidity of all the blends were adjusted to 25^{o}B Brix and 0.5%, respectively. The pulp mixture obtained was heated to 85 ^{o}C to inactivate the enzymes and cooled to about 45 ^{o}C. Potassium metabisulphite (0.2%) was also added as a preservative.

Jain *et al*.,(2011) reported that guava- papaya blended leather prepared by different blending ratio-100:0,80:20, 60:40, 40:60, 20:80, 0:100 contained- TSS(^{o}B)-13.24, 12.95,12.60,12.48,12.30,12.00,pH-4.10,4.27,5.20,5.50,6.05,6.17,Acidity (%) 0.46, 0.43, 0.40, 0.39, 0.36, 0.32 and ascorvic acid(mg/100g) -182.6,172.4,169.3,132.4,108,85.7.

Khan *et al*., (2014) reported that apple- guava blended leather prepared by the blending ratio of 30:70 with sucrose + glucose(1:1) and guar gum (0.25%). In addition to the above they also observed that olive–apple blended leather prepared by 50:50 ratio, was accepted both organoleptically and physiochemically then the others.

Rao and Roy (1980) and Effah-Manu et.al (2013) reported that the acidity content of olive apple blended leather significantly increased with each storage interval. This increase was due the

methyl esterase activity which converted pectin in pectic acid. Reduction in moisture also increased the acidity of the dried product.

Vijayanand *et al.,* (2000) compared conventionally prepared mango leather with a guava leather obtained by dehydration of an enzymatically treated puree added with maltodextrin, sucrose, soluble starch, wheat flour, pectin and anti browning agent. Color, texture, sensory acceptability and nonenzymatic browning were analyzed during storage. Both products maintained a high acceptability after 90 days at 27°C.

Quintero-Ruiz and Giner (2010) have analyzed apple leather quality for formulations with and without preservative agents over a storage period of 6 months at room temperature. Among others, the authors evaluated non-enzymatic browning and antioxidant activity, and found that the formulation added with potassium metabisulphite retarded browning and promoted higher antioxidant retention.

Bhandari *et al*., (1997), Bhandari and Howes, (1999) reported that moisture content of samples increased with increased in citric acid levels and moisture content of samples decreased with storage period, the reason for such trend might be attributed to inversion of sucrose into monosaccharide by citric acid which was more in hygroscopic nature than the sucrose leading to relatively higher affinity for water molecules. Samples with higher level of citric acid undergone inversion of more sucrose and therefore, had higher final moisture content.

Singh *et al*., (2015) reported that TSS of leather samples prepared from papaya decreased with increased in the levels of citric acid but the TSS of all leather samples prepared with different levels of citric acid increased with storage period.

Sivakumar *et al.,* (2005) reported that pH of papaya leather sample decreased with increase incitric acid level.

Fennema (1977) reported that Vitamin-C of the papaya leather samples was decreased with increased in the levels of citric acid. It was due to decreased ascorbic acid content during storage

due to oxidation of ascorbic acid to dehyroascorbic acid. This was due to oxidation or exposure of atmosphere oxygen while preparing the fruit leather.

2.5.2 Thickness

Kumar *et al*., (2010) reported that for drying of papaya- guava blended leather the mixture was poured as a 1.00 cm thick layer in stainless steel trays previously smeared with glycerol.

Che Man and Sin (1997) prepared jackfruit leather prepared by placing the mixture into a 2mm thin layer on aluminum foil.

Chowdhury *et al.,* (2011) dried the jackfruit leather in a thin layer (5mm thickness) at temperatures ranging from 40 to 70 ^{o}C. The relative humidity range was 20–70% and air velocity ranged from 0.5 to 3.0m/s.

Yilmaz *et al*., (2015) prepared pomegranate leather at 3 different thickness level of 1,2 and 3 mm.

2.5.3 Drying Time

Demarchi *et al.,* (2010) evaluated the influence of pretreatment on final product structure as well as the effect of hot air drying on color and antioxidant retention in apple leathers with and without preservative agents. They concluded that losses of antioxidant activity were more dependent on drying temperature than on drying time.

Bains *et al.,* (1989) prepared leathers from a commercial fruit puree, using one and two drying stages, and compared the total drying time. They concluded that the shorter process did not necessarily leads to a better quality product.

Maskan *et al*.,*(*2002) reported that sun drying of leather , have some disadvantage such as a long drying process-exposure of the products to environmental contamination, dependency on

weather conditions, and hand labor requirements. Therefore, alternative drying methods were developed to overcome the problems of hygiene and time, as these methods were rapid, safe, and controllable.

Pinzon *et al*., (2013) reported that 52.3 ^{o}c and 20 hr drying time resulted 7.6% moisture content in orange peel.

2.5.4 Drying Temperature

Kumar *et al*., (2010) reported that papaya – guava blended leather dried in a cross-flow cabinet dryer at 60 ^{o}C until the final moisture of the product reached at15–20%.

Che Man and Sin (1997) prepared jackfruit leather by drying in a cabinet dryer at 50 ^{o}C with an air velocity of 1.6m/s for 24hours. They also stated that drying of durian leather at oven drier, the most acceptable taste could be achieved by drying at 52.24 ^{o}C for 11.63 hours, and for the texture it was 52.5 ^{o}C for 9.00 hours. The best conditions for aroma and appearance were 50.63 ^{o}C for 12.00 hours and 51.7 ^{o}C for 12.58 hours, respectively. For overall acceptability, the most acceptable combination was 50 ^{o}C for 12.75 hours.

Azerado *et al*., (2006) reported that for preparing mango leather, the drying was carried out in an oven drier at 60–80 ^{o}C until the moisture content of the mango leather reached at 15–18%.

Yilmaz *et al*., (2015) reported that highest amount of total phenolic content (mg GAE/kg dry basis) was found 8195.47+-175.38 in pomegranate leather when it was dried at 70 ^{o}C for 2 mm thickness in cabinet drier and highest ascorbic acid (mg/kg dry basis) was found 1243.75±68.25 at 70 ^{o}C for 1 mm thickness.

MATERIALS AND METHODS

The details of the materials used and methods adopted during the course of studies are enumerated below:

3.1. Experimental site

The experiments were conducted in the laboratory of the Department of Pomology and Post-harvest Technology, Faculty of Horticulture, Uttar Banga Krishi Viswavidwalaya, Pundibari, Coochbehar. Fresh jackfruits for the experiments were collected from Instructional Farm of Uttar Banga Krishi Viswavidyalaya at two different maturity level as per the requirement of the experiment (immature/tender and ripe) and were immediately brought to the laboratory for necessary treatments. The experiments were conducted during the year 2015-16.

3.2 Climatic condition

Table 3.1. Climatological data during experimental period

Month	Temparature (^{o}C)			Relative humidity (%)			Avg. Rainfall (mm)
	Max.	Min.	Avg.	Max.	Min.	Avg.	
May 2015	34.00	20.00	27.00	99.00	60.00	80.61	377.80
June 2015	35.00	20.00	27.55	99.00	54.00	87.13	622.00
Jully.2015	37.00	21.00	29.27	98.00	54.00	79.73	296.90
August.2015	36.00	23.20	28.46	98.00	64.00	84.84	25.72
September.2015	36.50	23.00	28.9	97.00	55.00	75.08	9.99
October 2015	34.80	18.30	27.46	91.00	51.00	70.18	0.00
November2015	31.00	20.70	25.97	91.00	64.00	78.27	0.00
December.2015	28.00	17.60	21.63	100.00	62.00	81.29	0.00
January2016	27.00	7.50	16.62	100.00	72.00	85.11	0.00
February.2016	31.80	9.10	20.16	100.00	51.00	75.19	0.00
March.2016	33.20	13.50	23.88	96.00	42.00	64.84	0.03
April 2016	35.70	16.60	26.65	96.00	44.00	77.18	4.59

Source: Department of Agronomy, U.B.K.V (Meteorology)

3.3. Experimental details

3.3.1. Preparation of osmotically dehydrated jackfruit cube from tender fruit

3.3.1.1. Selection of fruits

For the preparation of osmotically dehydrated jackfruit cube, tender fruits were employed as experimental material. Fruits were collected from Instructional Farm of Uttar Banga Krishi Viswavidyalaya and brought immediately to the laboratory of the department of Pomology and Post Harvest Technology for necessary treatments. Tender fruits were cut into cube of 1 × 1 × 1 cm and prepared for treatments.

3.3.1.2. Treatment of the fruits by Blanching

For preparation of dehydrated Jackfruit cube, blanching was done firstly by hot water at boiling temperature for 3 min to control the enzymatic browning for all the treatment.

3.3.1.3. Treatments with $Ca(OH)_2$

Solid lime was bought from local market of Pundibari and brought into laboratory. Solid lime was powdered and 10 g of powder was poured into 1 liter of water to prepare the treatment solution. Treatments with $Ca(OH)_2$ was done in those treatment runs only where $Ca(OH)_2$ was considered as a categoric variables (Table 3.3). The purpose of the treatment was to improve the textural quality and to avoid blackening of the dehydrated cubes.

3.3.1.4. Treatments of fruits with NaCl

For treatments of immature fruit with NaCl, edible salt was bought from local market of Pundibari. Different amount of NaCl was poured in 1 liter of water for preparing solution of different concentration as per the requirement of the experiment. After preparation of different NaCl solution jackfruit cube were dipped for given period of time as given in Table 3.3.

3.3.1.5 Subsequent drying

After completion of osmotic dehydration process, the cubes from all treatment runs were dried in a cabinet drier at 60^oC for 6 hr.

3.3.1.6. Experimental design

For dehydrated jack cube, the experiment was carried out to study the response surface using Central Composite Rotatable Design with 26 run of which 10 were at central points. The design was generated by software Design-Expert® version 7.1.6 .The details of the variable studied is given in Table 3.2.

Response surface methodology (RSM) was used to determine the best conditions for preparation of dehydrated jackfruit cube from tender jack. Central Composite Rotatable Design (CCRD) was performed to evaluate the effect of NaCl concentration, time and $Ca(OH)_2$ concentration on five responses, viz. Water Loss (WL), Mass Reduction (MR), Change in Dry Matter (CDM), Water Activity (a_w) and Rehydration Ratio (RR). The lower and upper levels for each variable were chosen for the RSM based on the results of a preliminary study: NaCl concentration (3.05-12.95%), time (60.75-209.25 min) and $Ca(OH)_2$ concentration (0-1 %). Table 3.2 provides the details of three process variables along with their coded values five levels (-α, -1, 0, 1, +α). Table 3.3 gives the details of run-wise experimental variable in actual terms.

The experimental data for RSM were fitted to the second order regression equation:

$$Y = \beta_0 + \sum_{i=1}^{k} \beta_i X_i + \sum_{i=1}^{k} \beta_{ii} X_{ii}^2 + \sum_{i=1}^{k-1} \sum_{j=1}^{k} \beta_{ij} X_i X_j$$

where, Y is the predicted response, β_0 is the intercept, β_i, β_{ii} *and* β_{ij} are linear, quadratic and interaction coefficients, respectively, and X_i and X_j are the coded independent variables.

Table 3.2. Experimental variables and their range

Factors	Name	Units	Type	-α	-1	0	1	+α
A	Salt concentration	%	Numeric	1	3.05	8	12.95	15
B	Time	Min	Numeric	30	60.75	135	209.25	240
C	$Ca(OH)_2$	%	Categoric	-	0	-	1	-

Table 3.3. Treatments for preparation of osmotically dehydrated jackfruit cube

Run	Categoric factors	Numeric factors	
	$Ca(OH)_2$ concentration (%)	Salt concentration (%)	Time (min)
T_1	0	15.00	135.00
T_2	1	3.05	60.75
T_3	1	1.00	135.00
T_4	0	8.00	135.00
T_5	1	8.00	135.00
T_6	0	12.95	60.75
T_7	0	8.00	135.00
T_8	1	12.95	209.25
T_9	1	12.95	60.75
T_{10}	0	3.05	209.25
T_{11}	1	8.00	135.00
T_{12}	0	8.00	240.00
T_{13}	0	12.95	209.25
T_{14}	1	15.00	135.00
T_{15}	1	8.00	30.00
T_{16}	0	8.00	30.00
T_{17}	0	3.05	60.75
T_{18}	0	8.00	135.00
T_{19}	1	8.00	135.00
T_{20}	0	8.00	135.00
T_{21}	1	8.00	135.00
T_{22}	0	8.00	135.00
T_{23}	1	8.00	135.00
T_{24}	1	3.05	209.25
T_{25}	1	8.00	240.00
T_{26}	0	1.00	135.00

3.3.1.7. Response variables recorded.

3.3.1.7.1. Moisture content

Moisture content of the raw materials and the final products were determined gravimetrically using a laboratory vacuum oven by drying to constant weight at 60^{o}C according to the method described in AOAC, 1997.

3.3.1.7.2. Percentage of Water Loss (WL)

Total water removal from the raw materials during the process of obtaining final products through two stages of dehydration viz. osmotic dehydration and cabinet drying was calculated and expressed as percentage of raw material as per following equation.

$$Water\ Loss\ (\%) = \frac{\left(\begin{matrix}Initial\ weight\ of\ raw\ material\ \times \\ moisture\ content\ of\ raw\ material\end{matrix}\right) - \left(\begin{matrix}Weight\ of\ final\ product\ \times \\ moisture\ content\ of\ final\ product\end{matrix}\right)}{Initial\ weight\ of\ raw\ material} \times 100$$

3.3.1.7.3. Mass reduction (MR) (%)

Mass reduction after obtaining final product was calculated as a percentage of initial raw material mass as per the following formula. Mass reduction gives us an idea about the probable final product yield.

$$Mass\ Reduction\ (\%) = \frac{Weight\ of\ raw\ material - Weight\ of\ final\ products}{Weoght\ of\ raw\ material} \times 100$$

3.3.1.7.4. Change in dry matter

Percentage change in dry matter was determined to indicate a relative difference in dry matter content of raw material and final product and was calculated as follows

$$Change\ in\ Dry\ matter\ (\%) = \frac{\left(\begin{matrix}Initial\ weight\ of\ raw\ material\ \times \\ dry\ matter\ \%\ in\ raw\ material\end{matrix}\right) - \left(\begin{matrix}Weight\ of\ final\ product\ \times \\ dry\ matter\ \%\ in\ final\ product\end{matrix}\right)}{Initial\ weight\ of\ raw\ material\ \times dry\ matter\ \%\ in\ raw\ material} \times 100$$

3.3.1.7.5 Water Activity (aw)

Water activity (aw) was measured with a water activity meter (Model: Aqua Lab series 3 TE, Make: Decagon Devices, Inc, Pullman, Washington, USA) at 25°C with an accuracy of ±0.003.

3.3.1.7.6 Rehydration ratio

Rehydration ratio of the dried sample was measured by rehydration technique. 5g dried sample were taken and dipped into 1 lt of boiling water (containing 15g salt) for 30 min and finally the weight of the 5 g sample were measured. Rehydration ratio was calculated by the following formula

$$Rehydration\ ratio = \frac{Weight\ of\ the\ rehydrated\ sample}{Weight\ of\ the\ dehydrated\ sample\ taken\ for\ rehydration}$$

3.3.2 Preparation of mix fruit leather using jackfruit pulp

3.3.2.1 Selection of Fruits

Ripe jackfruits were selected from Instructional Farm of Uttar Banga Krishi Viswavidyalaya for the preparation of mix fruit leather. Ripe mango and mature aonla were selected as mixing component and were collected from local markets of Alipurduar and Coochbehar. All the materials for preparation of mix fruit leather were brought immediately to the laboratory. Pulp of all the three fruits were extracted and prepared for mixing as per treatment runs.

3.3.2.2. Statistical design

To study the optimization of different pulp mixture component, a simplex lattice quadratic design was used. A simplex-lattice mixture design of degree *m* consists of *m+1* points of equally spaced values between 0 and 1 for each component. If *m* = 2 then possible fractions are 0, 1/2, 1. For *m* = 3 the possible values are 0, 1/3, 2/3, 1. The points include the pure components and enough points between them to estimate an equation of degree *m*.Various components and their range in actual value and coded value is given in Table 3.4. The details of the experiment as set out using design expert 7.1.6 software, is presented in Table 3.5.

Table 3.4. Experimental range of components for preparation of mixed fruit leather

Component	Name	Units	Type	Low Actual	High actual	Low Coded	High Coded
A	Mango pulp	%	Mixture	0.000	50.000	1.000	0.000
B	Jack pulp	%	Mixture	0.000	50.000	1.000	0.000
C	Aonla pulp	%	Mixture	0.000	50.000	1.000	0.000

Table 3.5. Proportion of different pulp as laid out in simplex lattice quadratic design

	Mango Pulp (%)	Jackfruit Pulp (%)	Aonla Pulp (%)
T_1	25	25	50
T_2	50	0	50
T_3	50	0	50
T_4	50	50	0
T_5	16.67	41.66	41.66
T_6	50	50	0
T_7	0	50	50
T_8	0	50	50
T_9	33.33	33.33	33.33
T_{10}	25	50	25
T_{11}	50	25	25
T_{12}	41.66	16.67	41.66
T_{13}	41.66	41.66	16.67
T_{14}	50	25	25

3.3.2.3. Preparation of fruit leather

For the preparation of fruit leather, mango, jackfruit and aonla at ripe stage of maturity were selected as experimental material. At first the pulp of all the three fruits were extracted and homogenised in mixer. After that, the squeezed fruit pulps were mixed as per treatment requirement and the TSS for all the treatments were adjusted to 20^{o}B by addition of sugar. Then the mixed pulp was poured in an aluminum tray at 3 mm thickness. A little amount of oil was smeared into the aluminum tray before pouring. The aluminum tray filled with mix fruit pulp, were kept in a cabinet tray drier for drying at 60 ^{o}C for 6 hr.

3.3.2.4. Response variables

3.3.2.4.1. Total soluble solid (TSS)

TSS content of the fruit leather was recorded with the help of hand Refractometer which was calibrated at 0^0 Brix at 20 °C with the help of distilled water. A portion of leather was taken from each sample, were smashed and placed on the plate to record the Refractometer reading, in ^{0}Brix at different temperature. The reading was corrected for temperature variation and results were reported as ^{o}B at 20^{o}C. (Mazumdar and Majumder, 2003).

3.3.2.4.2. Reducing sugar

The reducing sugar content of leather were estimated with the help of freshly made mixture containing equal volumes of Fehling's solution A & B by copper reducing method using methylene blue as an ind4icator and was expressed in *percentage*. (Mazumdar and Majumder, 2003).

3.3.2.4.3 Non-reducing sugar

Non-reducing sugar content of leather were determined by subtracting the value of reducing sugar content from that of the total sugar and multiplying the difference value with 0.95 and was expressed in *percentage*. (Mazumdar and Majumder, 2003).

Non-reducing sugar (%) = (Total sugar *percentage* – Reducing sugar *percentage*) X 0.95

3.3.2.4.4. Titratable acidity

The acidity of the fruit leather was estimated by titrating against standard alkali solution (0.1 N NaOH) using the phenolphthalein indicator and is expressed in *percentage* (Rangana, 1977).

3.3.2.4.5. Ascorbic acid

Ascorbic acid content of fruits leather was estimated based on the oxidation of ascorbic acid to dehydro ascorbic acid and then to diketogluconic acid followed by coupling with 2,4 DNPH and expressed as mg per 100g leather (Rangana, 1977).

3.3.2.4.6. Water Activity (aw)

Water activity (aw) was measured with a water activity meter (Model: AquaLab series 3 TE, Make: Decagon Devices, Inc, Pullman, Washington, USA) at 25°C with an accuracy of ±0.003.

3.3.2.4.7 Textural property

Texture measurements were performed on mixed fruit leather using (Model: TA-XT plus, Stable Micro System Limited, Surrey, United Kingdom). The conditions for texture profile analysis (TPA): Cylindrical probe: 2mm; load cell: 50 kg; pre-test speed: 2 mm/s; test speed: 1mm/s; post-test speed: 1mm/s; target mode: strain; trigger force: 5 g; acquisition rate; 200 PPS (points per second). Leather slice was placed on platform and test was conducted to estimate the force required to penetrate through the leather. The peak force (g) was recorded as hardness.

3.4. Storage stability

The products were prepared using the optimized process conditions and were packed in a low density polyethylene pouch. The products were then subjected to 6 month storage. For the evaluation of storage stability for osmotically dehydrated jackfruit cube, parameters like Water activity, Rehydration ratio and Total plate count were recorded in monthly interval in six replications. In case of mix fruit leather Water activity, Ascorbic acid content and Total plate count were recorded in monthly interval to evaluate the storage stability.

3.5. Statistical analysis

Analysis of Variance (ANOVA) for both the experiments i.e., dehydrated jackfruit cube and mixed fruit leather were done using the software Design-Expert® version 7.1.6. In case of experiment for preparing dehydrated jackfruit cube models for the responses were fitted using Central Composite Rotatable Design of Response Surface Methodology. For mix fruit leather, models for the responses were fitted using Simplex Quadratic Design. Optimization of process variables for individual experiment was done by numerical optimization methods using the same software.

Result and Discussion

Results of different experiments, to study the drying behavior and quality improvement of osmotically pre-treated tender jackfruit cube and mixed fruit leather using jackfruit, aonla and mango pulp have been chronologically presented in this chapter.

4.1 Analysis of variance for osmotic dehydration of jackfruit cube

Table 4.1 presents the results of the Central Composite Design with twenty-six runs for the five responses. Experimental analysis resulted in Water loss (WL), Mass reduction (MR), Change in dry matter (CDM), Water activity (a_w), Rehydration ratio (RR) varying between (85.85-90.54%), (86.93- 91.61%), (-35.10 – 37.26%), (0.724-0.804 a_w) and (3.24-3.77), respectively.

From Table 4.1, it can be concluded that the highest amount of Water loss (90.54%) was observed in Treatment 13 which was 3.05 % Salt concentration, 209.25 min Time and 0% $Ca(OH)_2$ concentration, and the lowest amount of Water loss was (85.85%) in Treatment 22 which was 8.00% Salt concentration, 240 min Time and 1% $Ca(OH)_2$ concentration . Similarly Treatment 18 (12.95 % Salt concentration, 209.25 min Time and 0% $Ca(OH)_2$ concentration) resulted the highest amount of Mass reduction (91.61%) and the least amount of Mass reduction (86.93%) was found in Treatment 24 (8 % Salt concentration, 135 min Time and 1% $Ca(OH)_2$ concentration). Similarly Treatment 19 (8% Salt concentration, 135 min Time and 1% $Ca(OH)_2$ concentration) showed the highest positive impact on Change in Dry Matter content (37.26 %) and Treatment 15 (8 % Salt concentration, 30 min Time and without $Ca(OH)_2$ treatment) showed the highest negative impact (-34.20%) on Change in Dry Matter content. In this proposed plan, the aim was to reduce the amount of Water activity for osmotically dehydrated jackfruit cube, as it enhance the post harvest period of the products. So as per the requirements, the least amount of Water activity (0.724 a_w) was observed in Treatment 15 (8 % Salt concentration, 30 min Time and 0% $Ca(OH)_2$ concentration) and the Highest amount of water activity (0.804 a_w) was observed in Treatment 6 (1% Salt concentration, 135 min Time and 1% $Ca(OH)_2$ concentration). Rehydration ratio which is very important for the product, was found highest (3.77) in Treatment 10 (15% Salt concentration, 135 min Time and 1% $Ca(OH)_2$ concentration) and lowest amount (3.24) in Treatment 11 (1% Salt concentration, 135 min Time and 0% $Ca(OH)_2$ concentration).

The treatment for osmotically dehydrated jackfruit cube enlisted in Table 4.1, in which 10 were at central point which were 8% Salt concentration, 135 min time. $Ca(OH)_2$ concentration was categoric factor in this design. Considering Water loss (WL), the average actual values for all the central points (8% Salt concentration and 135.00 min Time period) was found to be 88.86±0.44 (Mean±Standerd daviation) and the predicted value was 89.03. It can be observed that the actual value of Water loss is very close to the predicted value. For Mass reduction (MR), the average actual values for central point was 88.14±0.85, where as the predicted value for central point estimated by Software Design-Expert® version 7.1.6. was 88.62. It was found that here also the actual value and predicted value was more or less similar in range. In case of Change in Dry Matter content the average actual values for central point was 15.84±10.52, and the predicted value of Change in Dry Matter content at central point was 10.35. As well as the above two factors, the mean of actual values of change in dry matter content was near to the predicted value for central points. Similar result was found in case Water activity, where the average actual value for central point was 0.760±0.008, and was very close to the predicted value (0.758). In case of Rehydration ratio the mean of all the actual values for 10 central points was 3.622±0.08.The predicted value of Rehydration ratio for central point were 3.569. From the above it can be concluded that the average actual value was very close to the predicted value of Rehydration ratio for central points.

Table 4.1. Effect of factors on different responses for osmotically dehydrated jackfruit cube

Run order	Factor A: Salt Conc (%)	Factor B: Time (min)	Factor C: $Ca(OH)_2$ (%)	Water loss (%)		Mass reduction (%)		Change in dry matter (%)		Water activity		Rehydration Ratio	
				Actual	Predicted	Actual	Predicted	Actual	Predicted	Actual	Predicted	Actual	Predicted
1	8.00	135.00	0	88.83	89.03	88.57	88.62	6.98	10.35	0.774	0.758	3.640	3.569
2	12.95	60.75	1	90.21	90.03	89.77	89.62	5.14	7.84	0.774	0.775	3.696	3.704
3	8.00	135.00	1	88.91	88.71	87.21	87.68	21.77	21.35	0.761	0.763	3.712	3.681
4	3.05	60.75	1	90.08	89.99	89.70	90.30	16.98	11.93	0.766	0.762	3.446	3.431
5	8.00	135.00	0	89.12	89.03	88.57	88.62	23.05	10.35	0.750	0.758	3.484	3.569
6	1.00	135.00	1	90.26	90.15	88.15	88.22	26.44	27.73	0.804	0.807	3.474	3.480
7	8.00	135.00	0	88.78	89.03	88.13	88.62	8.44	10.35	0.751	0.758	3.516	3.569
8	12.95	60.75	0	88.90	88.47	89.71	90.51	-20.34	-26.43	0.753	0.762	3.668	3.605
9	8.00	135.00	1	89.08	88.71	87.42	87.68	18.64	21.35	0.762	0.763	3.655	3.681
10	15.00	135.00	1	89.01	89.05	89.21	89.64	-2.15	-3.31	0.797	0.791	3.770	3.750
11	1.00	135.00	0	89.96	90.26	89.50	88.75	19.60	27.00	0.803	0.804	3.240	3.271
12	8.00	240.00	0	89.64	89.42	88.70	89.53	-3.50	-7.83	0.745	0.745	3.628	3.639
13	3.05	209.25	0	90.54	90.56	87.65	87.91	31.18	26.22	0.787	0.791	3.504	3.478
14	8.00	135.00	1	88.68	88.71	87.41	87.68	22.53	21.35	0.761	0.763	3.674	3.681
15	8.00	30.00	0	86.93	87.15	91.19	90.97	-35.10	-30.71	0.724	0.722	3.292	3.354
16	3.05	60.75	0	88.41	88.13	90.12	90.63	-2.70	-7.82	0.747	0.751	3.252	3.194
17	8.00	135.00	0	89.68	89.03	89.30	88.62	6.24	10.35	0.763	0.758	3.531	3.569
18	12.95	209.25	0	89.36	89.26	91.61	91.18	-34.20	-28.12	0.748	0.754	3.748	3.725
19	8.00	135.00	1	88.97	88.71	88.89	87.68	37.27	21.35	0.764	0.763	3.682	3.681
20	15.00	135.00	0	89.10	89.58	91.45	90.98	-24.87	-24.59	0.791	0.786	3.704	3.736
21	3.05	209.25	1	88.48	88.36	87.13	86.93	13.42	13.97	0.792	0.786	3.568	3.600
22	8.00	240.00	1	85.85	86.23	88.58	88.12	-23.62	-19.45	0.742	0.739	3.712	3.669
23	8.00	30.00	1	89.38	89.70	91.38	90.50	-0.67	2.92	0.741	0.738	3.528	3.546
24	8.00	135.00	1	87.89	88.71	86.93	87.68	8.90	21.35	0.749	0.763	3.714	3.681
25	8.00	135.00	0	88.74	89.03	89.06	88.62	4.69	10.35	0.770	0.758	3.642	3.569
26	12.95	209.25	1	87.00	86.76	89.58	89.63	-22.13	-25.85	0.750	0.752	3.662	3.709

The experimental data were fitted into the second order polynomial model in terms of actual factors. The second order polynomials and the correlation coefficients for actual and predicted values are presented in Table 4.2.

Table 4.2. Predicted second order polynomial equation and statistical parameters

Response Variable	Final equation in terms of actual factors	R^2	Adj-R^2	Pred-R^2	CV%	Adequate Precision
Y_1: Water loss (%)	**Without $Ca(OH)_2$-** $Y1=+86.69-0.189\times A+0.037857\times B-1.11\times10^{-3}\times A\times B+0.0182\times A^2-6.71\times10^{-5}\times B^2$	0.9097	0.8672	0.7933	0.44	18.775
	With- $Ca(OH)_2$- $Y1=+90.30-0.219\times A+0.010\times B-1.11\times10^{-3}\times A\times B+0.018\times A^2$					
Y_2:Mass reduction (%)	**Without $Ca(OH)_2$-** $Y2=+95.08-0.558\times A-0.065\times B+2.29\times10^{3}\times A\times B+0.025\times A^2+1.48\times10^{-4}\times B^2$	0.8384	0.7642	0.5731	0.75	10.824
	With- $Ca(OH)_2$- $Y2=+95.20-0.615\times A-0.069\times B+2.29\times10^{-3}\times A\times B+0.025\times A^2$					
Y_3:Change in dry matter (%)	**Without $Ca(OH)_2$-** $Y3=-62.03+2.582\times A+1.028\times B-0.024\times A\times B-0.186\times A^2-2.686\times10^{-3}\times B^2$	0.9075	0.8639	0.8081	189.59	13.355
	With- $Ca(OH)_2$- $Y3=-33.67+4.049\times A+0.813\times B-0.024\times A\times B-0.186\times A^2$					
Y_4:Water activity	**Without $Ca(OH)_2$-** $Y4=+0.726-8.77\times10^{-3}\times A+9.64\times10^{-4}\times B-3.23\times10^{-5}\times A\times B+7.42\times10^{-4}\times A^2-2.21\times10^{-6}\times B^2$	0.9080	0.8647	0.8165	1.01	18.682
	With- $Ca(OH)_2$- $Y4=+0.743-8.62\times10^{-3}\times A+8.61\times10^{-4}\times B-3.23\times10^{-5}\times A\times B+7.42\times10^{-4}\times A^2$					
Y_5:Rehydration Ratio	**Without $Ca(OH)_2$-** $Y5=+2.793+0.069\times A+4.03\times10^{-3}\times B-1.11\times10^{-4}\times A\times B-1.34\times10^{-3}\times A^2-6.59\times10^{-6}\times B^2$	0.9180	0.8795	0.8036	1.44	18.269
	With- $Ca(OH)_2$- $Y5=+3.120+0.055\times A+3.26\times10^{-3}\times B-1.11\times10^{-4}\times A\times B-1.34\times10^{-3}\times A^2$					

Where, A=Salt Concentration (%); B=Time (min)

4.1.1. Influence of process variable on Different response

Analyses of variance of the process variables on different response variable were studied to evaluate the adequacy of model fittings. The ANOVA is along with coefficients of estimates are presented in Table 4.3.

Table 4.3. Analysis of variance of different studied responses

Source	Water loss			Mass reduction			Change in dry matter			Water Activity			Rehydration		
	Coefficient of estimate	F-value	*p*-value	Coefficient of estimate	F-value	*p*-value	Coefficient of estimate	F-value	*p*-value	Coefficient of estimate	F-value	*p*-value	Coefficient of estimate	F-value	*p*-value
Model	88.87	21.41	<0.0001	88.15	11.03	<0.0001	15.85	20.84	<0.0001	0.76	20.97	<0.0001	3.63	23.80	<0.0001
A	-0.31	10.30	0.0051	0.65	15.00	0.0012	-14.61	61.71	<0.0001	-5.86×10^{-3}	9.30	0.0072	0.13	101.01	<0.0001
B	-0.21	4.66	0.0454	-0.68	16.44	0.0008	0.089	2.28×10^{-3}	0.9624	4.25×10^{-3}	4.90	0.0409	0.072	31.20	<0.0001
C	-0.16	4.41	0.0510	-0.47	12.88	0.0023	5.50	14.23	0.0015	2.19×10^{-3}	2.11	0.1645	0.056	29.99	<0.0001
AB	-0.41	8.78	0.0087	0.84	12.81	0.0023	-8.93	11.54	0.0034	-0.012	19.05	0.0004	-0.041	5.03	0.0385
AC	-0.076	0.60	0.4495	-0.14	0.74	0.4027	3.63	3.81	0.0675	$3.79^{-}\times10^{-4}$	0.039	0.8460	-0.035	7.16	0.0159
BC	-1.01	107.45	<0.0001	-0.16	0.97	0.3381	-8.00	18.51	0.0005	-3.83×10^{-3}	3.96	0.0628	-0.029	4.92	0.0404
A^2	0.45	18.10	0.0005	0.62	12.19	0.0028	-4.57	5.26	0.0349	0.018	77.73	<0.0001	-0.033	5.62	0.0298
B^2	-0.37	12.44	0.0026	0.82	20.87	0.0003	-14.81	55.16	<0.0001	-0.012	34.90	<0.0001	-0.036	6.88	0.0178
Lack of fit	-	0.62	0.7557	-	1.23	0.3920	-	0.42	0.8929	-	0.57	0.7921	-	0.78	0.6427

A= Salt concentration (%) B= Time (min) C=$Ca(OH)_2$ Concentration (%)

4.1.1.1. Influence of process variable on Water loss:

p-Value (Prob>F) less than 0.0500 indicate that the model terms are significant. From the above table, it can be concluded that in this case individual effect of Salt concentration and Time, interaction effect of Salt concentration and Time, Time and $Ca(OH)_2$ concentration. and quadratic terms of Salt concentration and Time are significant model terms. Lack of Fit F- value 0.62 implies that the Lack of Fit is not significant. As per the value of Coefficient of estimates enclosed in Table 4.3, quadratic effect of Salt concentration and interaction effect of Salt concentration and Time and have a large impact on Water loss. It can be concluded that with the increase in quadratic effect of Salt concentration amount of Water loss was increased and with the increase in Salt concentration and Time, the amount of Water loss was decreased.

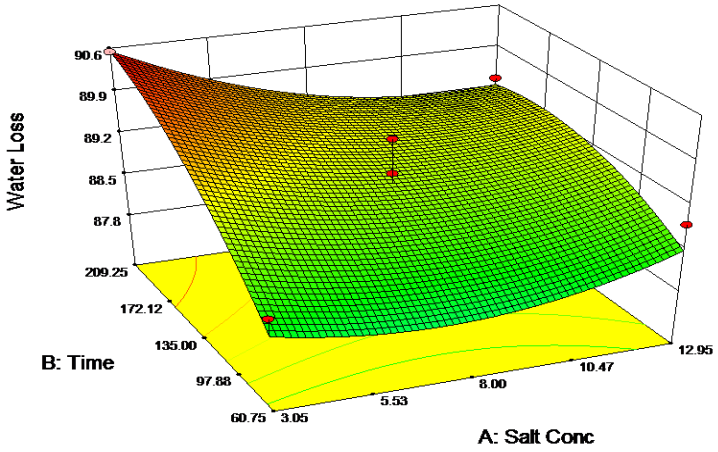

Figure 4.1. Influence of water loss without $Ca(OH)_2$ treatment

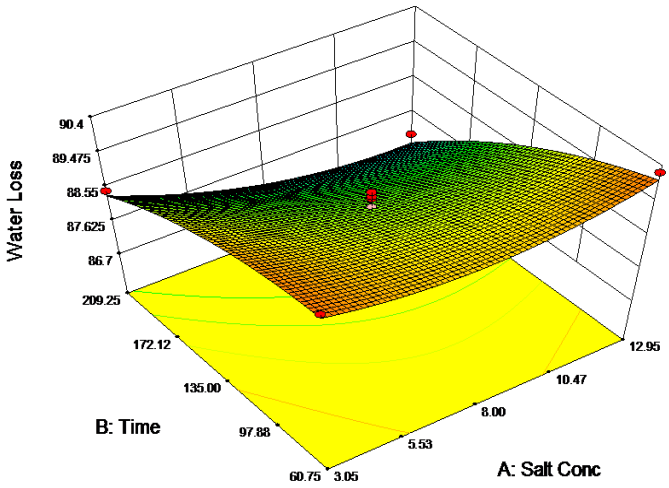

Figure 4.2. Influence of water loss with $Ca(OH)_2$ treatment

It can be concluded from Fig 4.1 and 4.2 that at lower salt concentration, with the increase in time, the amount of Water loss was also increased and the effect was linear. At higher salt concentration, time has a quadratic effect on Water loss. Antonio *et al.* (2004) reported that water loss was increased with the increase in time in papaya, and decreased water loss with increase in temperature. Salt concentration also has beneficial effect on water loss. Higher salt concentration ranging from 5-15% in 50 °B sucrose solution at temperature of 45 °C with solution to fruit ratio of 5, caused higher water loss in case of carrot (Singh *et al*., 2007). Manivannan and Rajasimman (2008) also observed that higher salt concentration increased water loss in beetroot.

4.1.1.2. Influence of process variable on Mass reduction:

p-Value (Prob>F) less than 0.0500 indicate that the model terms are significant. From table 4.3 it can be concluded that in this case individual effect of Salt concentration, Time and $Ca(OH)_2$ concentration, interaction effect of Salt concentration and Time and quadratic terms of both Salt concentration and Time are significant model terms. The Lack of Fit F-value 1.23 implies that the Lack of Fit is not significant relative to the pure error. Table 4.3 provides the information about coefficient of estimate for Mass reduction. Combined effect of Salt concentration and Time and quadratic effect of Time has a positive impact on Mass reduction.

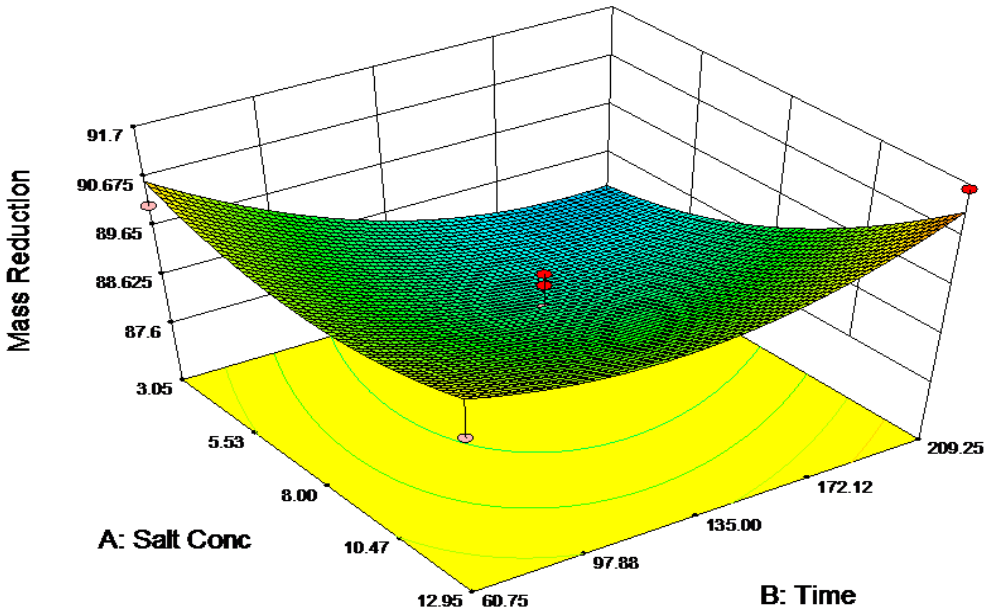

Figure 4.3. Influence of Mass Reduction without $Ca(OH)_2$ treatment

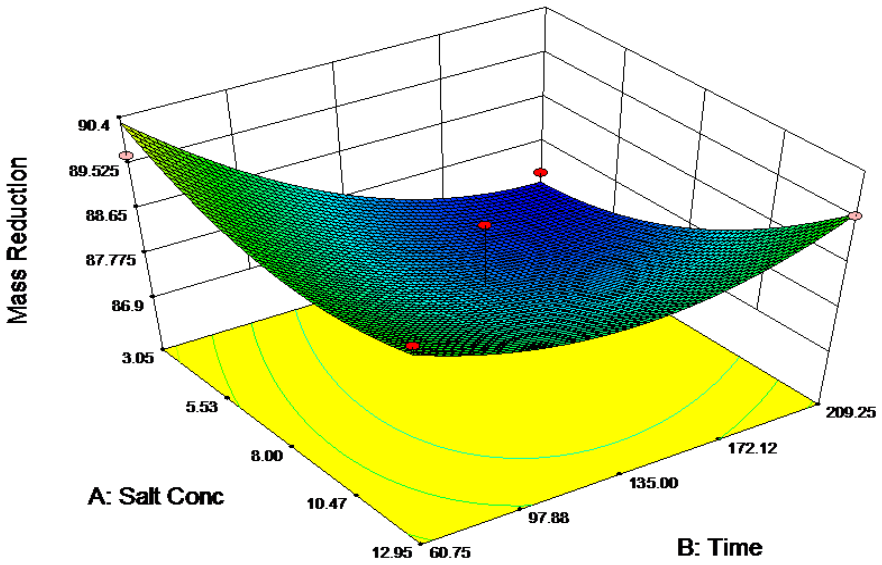

Figure 4.4. Influence of Mass Reduction with $Ca(OH)_2$ treatment

It was observed from Fig 4.3 and 4.4 that Salt concentration and Time has a quadratic effect on Mass reduction. At higher Salt concentration, Mass reduction was increased with the increase in time, which is also supported by many other authors. Kaymak-Ertekin and Sultanoglu (2000) found that mass reduction was increased with the increase in time in case of apple.

4.1.1.3 Influence of process variable on Change in Dry Matter:

p-Value (Prob>F) less than 0.0500 indicate that the model terms are significant. From Table 4.3, it can be said that in this case individual effect of Salt concentration and $Ca(OH)_2$ concentration, interaction effect of both Salt concentration and Time and Time and $Ca(OH)_2$ concentration, quadratic terms of both Salt concentration and Time are significant model terms. The Lack of Fit F-value 0.42 implies that the Lack of Fit is not significant relative to the pure error. From Table 4.3, it can be concluded that individual effect of Salt concentration and quadratic effect of Time have negative effect on Change in Dry Matter content.

It can be stated from the above Fig 4.5 and 4.6 that as well as Mass reduction, Time and Salt concentration have a same quadratic effect on Change in Dry Matter. Change in Dry Matter was found highest at lower Salt concentration and higher Time period.

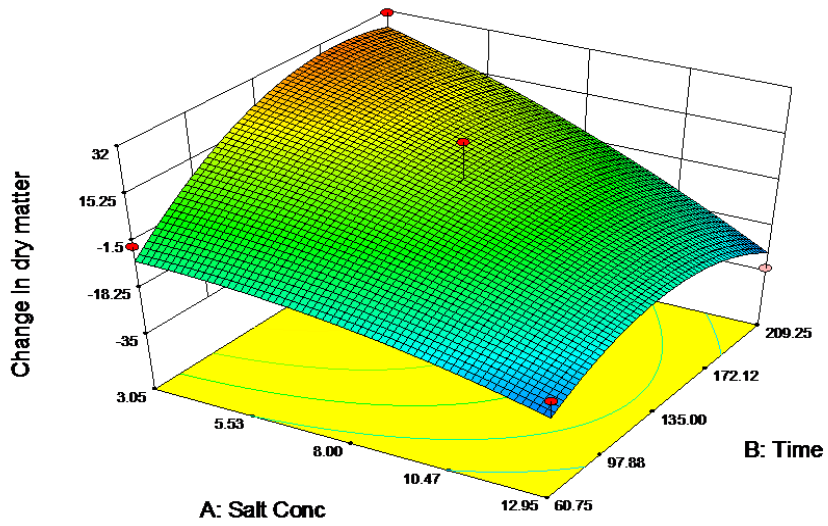

Figure 4.5 Influence of Change in Dry Matter without $Ca(OH)_2$ treatment

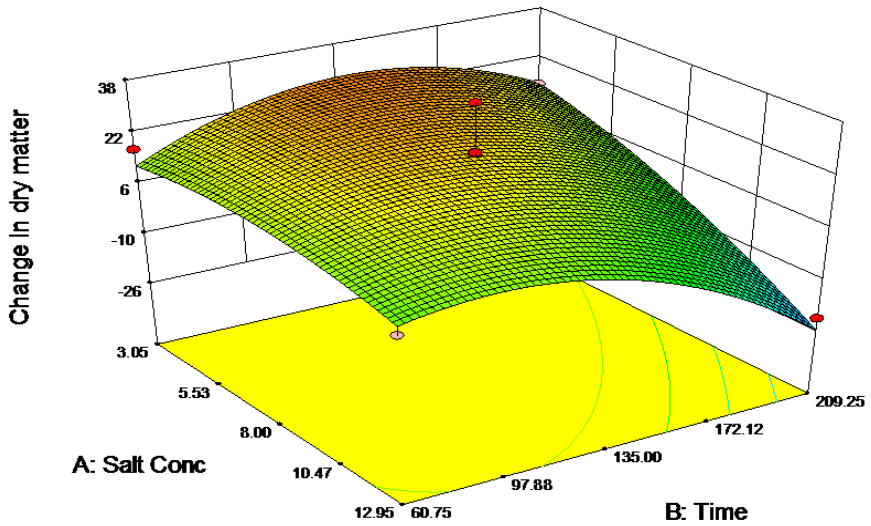

Figure 4.6 Influence of Change in Dry Matter with $Ca(OH)_2$ treatment

4.1.1.4. Influence of process variable on Change in Water Activity:

p-Value (Prob>F) less than 0.0500 indicate that the model terms are significant. From table 4.3 it can be concluded that in this case individual effect of Salt concentration and Time, interaction effect of Salt concentration and Time, quadratic terms of both Salt concentration and Time are significant model terms. The Lack of Fit F-value 0.57 implies that the Lack of Fit is not significant relative to the pure error. From the value of co-efficient of estimates enclosed in Table 4.3, it can be stated that the individual effect of both Salt concentration and Time have a large negative impact on Water activity.

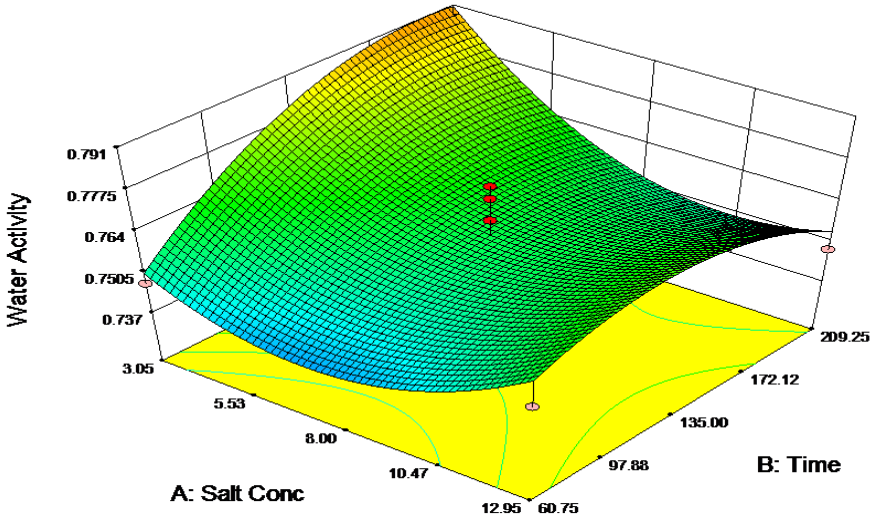

Figure 4.7. Influence of Change in Water Activity without $Ca(OH)_2$ treatment

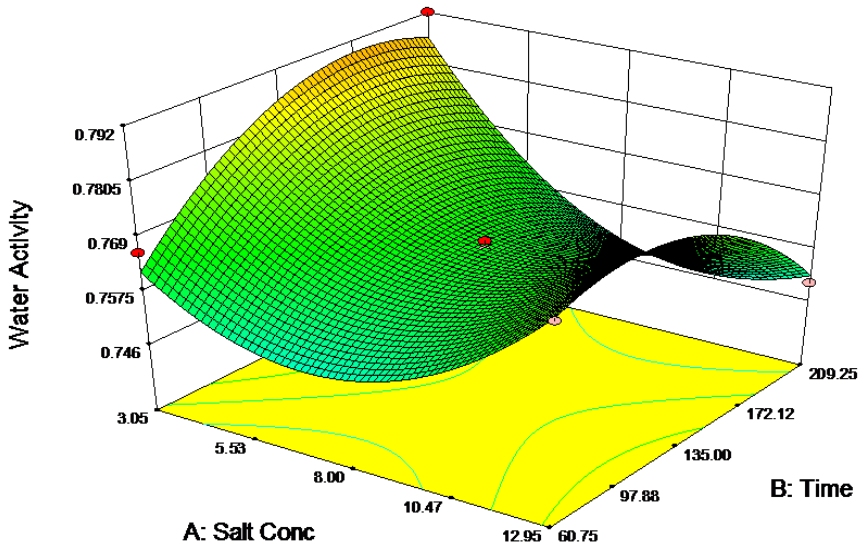

Figure 4.8 Influence of Change in Water Activity with $Ca(OH)_2$ treatment

Fig 4.7 and 4.8 showed that both the effect of Salt concentration and Time are quadratic on Water activity. As it is well known, the stability and safety of foods does improve if water activity (a_w) of the product decreases. The reduction of a_w to about 0.93 would be enough to suppress the growth of most pathogenic bacteria (Chirife & Favetto, 1992). Ozen *et al.* 2002, reported that Water activity has a negative co relation with concentration of osmotic solutes as resulted with increase in concentration the Water activity decreases.

4.1.1.5. Influence of process variable on Change in Rehydration Ratio:

p-Value (Prob>F) less than 0.0500 indicate that the model terms are significant. From Table 4.3 it can be concluded that in this case individual effect of Salt concentration, Time and $Ca(OH)_2$ concentration, interaction effect of Salt concentration and Time, Salt concentration and $Ca(OH)_2$ concentration and Time and $Ca(OH)_2$ concentration, quadratic terms of both Salt concentration and Time are significant model terms. The Lack of Fit F-value 0.78 implies that the Lack of Fit is not significant relative to the pure error.

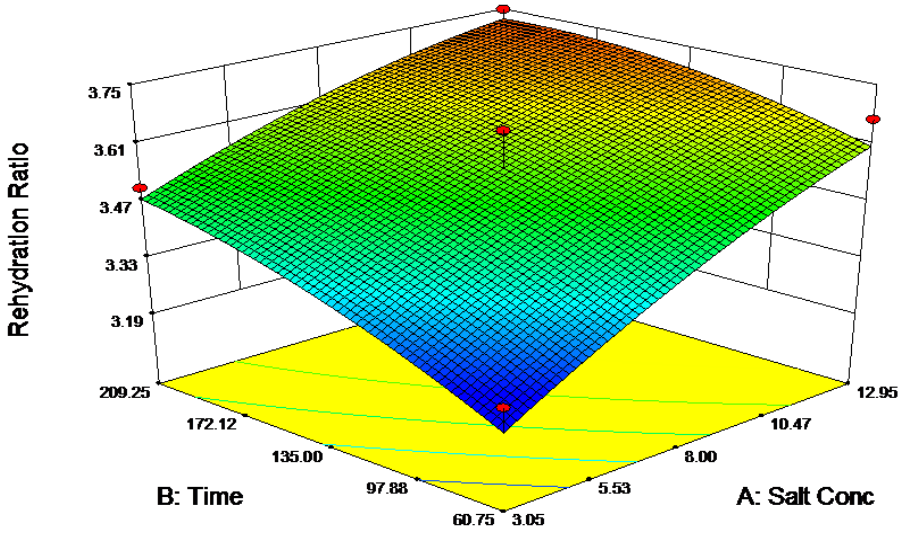

Figure 4.9. Influence of Rehydration ratio without $Ca(OH)_2$ treatment

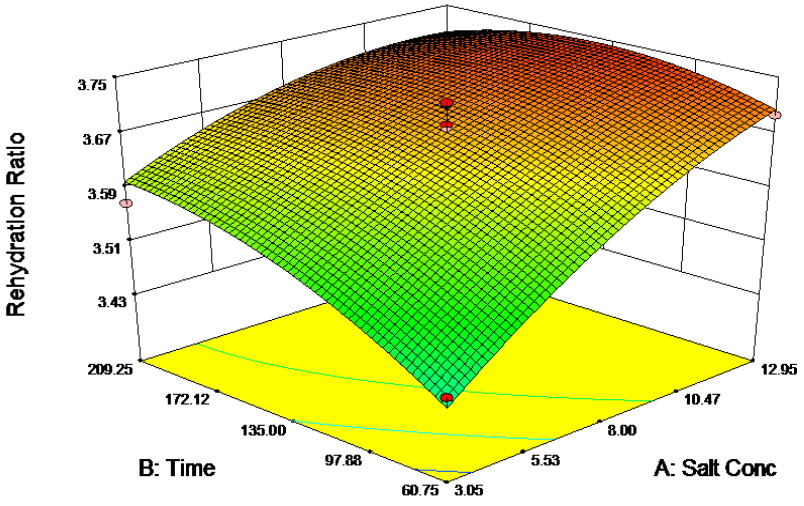

Figure 4.10. Influence of Rehydration ratio with $Ca(OH)_2$ treatment

From Fig 4.9 and 4.10, it can be stated that here the effect of both Salt concentration and time were to some extent linear. It can be concluded from the above that Rehydration ratio was increased with the increase in both Salt concentration and Time. In support of the above, Nishadh and Mathai (2014) reported that higher salt concentration increase the rehydration ratio in radish. Apart from the above, Singh *et. al*. (2015) observed that higher rehydration coefficient with increase in solute concentration in papaya which was 60°brix (0.715) was highest followed by 55°brix (0.688), 50°brix (0.662), and control (0.255).

4.1.2. Optimization of Process variable

After analyzing the response for ANOVA, the process variables were optimized by numerical optimization method using Design Expert 7.1.6 software. The details of the optimization criteria is given in Table 4.4

Table 4.4. Optimization of the constrains

Name	Goal	Lower limit	Upper limit	Lower weight	Upper weight	Importance
Salt Conc.	Is in range	3.05025	12.9497	1	1	3
Time	Is in range	60.7538	209.246	1	1	3
$Ca(OH)_2$	Is in range	0	1	1	1	3
Water loss	Maximize	85.85	90.54	1	1	3
Mass reduction	Minimize	86.93	91.61	1	1	3
Change in dry matter	Targeting "0"	-35.095	37.267	1	1	5
Water activity	Minimize	0.724	0.804	1	1	3
Rehydration ratio	Maximize	3.24	3.77	10	1	5

Considering the above table, for optimizing the process variable as stated in table 8, 12.95% Salt concentration and 1% $Ca(OH)_2$ concentration for a Time period of 155.57 min, was found ideal for maximizing water loss (88.28%) and rehydration ratio (3.740), for minimizing mass reduction (88.86%) and water activity (0.771) and for targeting change in dry matter content (9.41×10^{-5}).

4.2 Analysis of variance for jackfruit leather mixing with aonla and mango

Table 4.5 presents the results of the Central Composite Design with fourteen runs for the seven responses. Experimental analysis resulted in TSS, Reducing sugar, Non reducing sugar, Acidity, Ascorbic acid content, Water activity, Hardness varying between (19.10-22.86) ^{o}B, (4.36-4.75%), (9.78-14.89%), (1.18-1.71%), (10.61-38.05 mg/100g), (0.773-0.883 a_w) and (24.4-177.4) gf, respectively.

Table 4.5 Effect of factors on different responses for mix fruit leather

Run	A: Mango pulp	B: Jack pulp	C: Aonla pulp	TSS (^{o}B)	Reducing sugar (%)	Non reducing sugar (%)	Acidity (%)	Ascorbic acid (mg/100g)	Water activity	Hardness (gf)
1	25.00	25.00	50.00	19.10	4.603	12.89	1.71	10.61	0.773	98.2
2	50.00	0.00	50.00	20.26	4.73	14.89	1.41	35.32	0.796	113.3
3	50.00	0.00	50.00	20.56	4.69	14.21	1.36	38.05	0.790	92.9
4	50.00	50.00	0.00	22.53	4.41	10.44	1.18	15.75	0.826	77.9
5	16.667	41.667	41.667	21.06	4.64	11.84	1.51	14.97	0.833	75.8
6	50.00	50.00	0.00	22.86	4.36	10.44	1.20	12.62	0.833	77.6
7	0.00	50.00	50.00	20.63	4.75	12.11	1.39	22.32	0.876	44.6
8	0.00	50.00	50.00	20.7	4.67	12.85	1.40	19.33	0.883	55.7
9	33.33	33.33	33.33	22.3	4.54	12.20	1.27	15.93	0.863	27.7
10	25.00	50.00	25.00	20.82	4.57	9.78	1.63	21.44	0.880	177.4
11	50.00	25.00	25.00	20.87	4.61	12.32	1.25	17.84	0.903	35.3
12	41.667	16.667	41.667	20.76	4.70	12.39	1.33	17.13	0.830	25.7
13	41.667	41.667	16.667	22.26	4.52	10.49	1.24	14.11	0.860	63.2
14	50.00	25.00	25.00	21.11	4.60	12.50	1.30	20.27	0.873	24.4

According to Table 4.5 highest amount of TSS (22.86) was observed in Run 6 and lowest amount was (19.10) in Run 1. Similarly highest amount of Reducing sugar (4.75)was found in Run 7 and lowest amount was (4.36) in Run 6.Highest amount of non reducing sugar (14.89) was found in Run 2 and lowest amount (9.78) in Run 10. Run 1 showed the Highest amount of Acidity (1.78) and lowest amount (1.14) was observed in Run 4. Higher amount of Ascorbic acid (38.05mg/100g) was found in Run 3 and lowest amount of Ascorbic acid (10.61mg/100g) was observed in Run 1. Similarly, Run 1 resulted in the least amount of Water activity (0.773) which was desired for enhancing the storage life of the product. Highest amount of water activity (0.880) was observed in Run 10. Higher amount of hardness (177.1) was observed in Run 10, and lowest amount of Hardness (24.4) was obtained in Run 14.

The experimental data were fitted into the second order polynomial model in terms of actual factors as given in Table 4.6, where A=Magno pulp , B=Jackfruit pulp, C= Aonla pulp

Table 4.6. Predicted second order polynomial equation and statistical parameters

Response of variable	Final equation in terms of actual components	R^2	Adj-R^2	Pred-R^2	CV %	Adequate precision
X_1 :TSS (^{0}B)	X1=-0.312×A-0.327×B-0.422×C + 0.021×A×B + 0.022×A×C+0.023×B×C - 4.84×10^{-4} ×A×B×C	0.9867	0.9753	0.9431	0.76	31.878
X_2 : RS (%)	X2=+0.049×A+0.046×B+0.043×C-1.65×10^{-4} ×A×B+2.69×10^{-5}×A×C+$9.50\times10^{-5*}$×B×C	0.9294	0.8852	0.8141	0.83	13.256
X_3 : NRS(%)	X3=+0.20×A+0.04×B+0.20×C-8.20×10^{-4} ×A×B -2.33×10^{-3}×A×C-8.12×10^{-5}×B×C	0.9439	0.9089	0.8465	3.62	15.514
X_4 : Acidity (%)	X4=+0.079×A+0.108×B+0.11×C-3.28×10^{-3} ×A×B-3.25×10^{-3}×A×C-3.81×10^{-3}×B×C +7.59×10^{-5}×A×B×C	0.9844	0.9710	0.9390	1.94	28.039
X_5 :Ascorbic acid (mg/100g)	X5=+0.621×A+1.14×B-0.19×C-0.02×A×B +5.98×10^{-3}×A×C-0.01×B×C	0.9674	0.9470	0.9047	9.27	21.993
X_6 :Water activity	X6=+0.01×A+$8.63\times10^{-\times}$B+1.92×10^{-3}×C-9.90×10^{-5}×A×B+2.13×10^{-5}×A×C+1.40×10^{-4} ×B×C	0.9757	0.9606	0.9436	0.94	24.048
X_7 :Hardness	X7=+16.77×A+29.90×B+22.67×C-0.90×A×B -0.74×A×C-1.03×B×C + 0.01×A×B×C	0.9740	0.9517	0.8231	13.02	24.123

4.2.1. Influence of process variable on Different response

The Analysis of variance of process variable on different response has been presented in Table 4.7.

4.2.1.1 Influence of process variable on Total Soluble Solid (TSS)

p-Value (Prob>F) less than 0.0500 indicate that the model terms are significant. From Table 4.7 it can be concluded that, the interaction effect of mango pulp and jack pulp, mango pulp and aonla pulp, jack pulp and aonla pulp and interaction effect of all three fruit pulps are significant model terms. "Lack of Fit F- value" of 0.50 implies that Lack of Fit is not significant relative to the pure error. The values of Coefficient of estimates enclosed in Table 4.7 showed the effect of different factors on response variables. From Table 4.7 it can be stated that in case of TSS content, the combined effect of all the three fruit pulps have a positive interaction.

Table 4.7. Overall effects of factors on responses

Source	TSS			Reducing sugar (%)			Non-reducing sugar (%)			Acidity (%)			Ascorbic acid (mg/100g)			Water activity			Hardness (gf)		
	Coefficient of estimate	F-value	p-value	Coefficient of estimate	F-value	p-value	Coefficient of estimate	F-value	p-value	Coefficient of estimate	F-value	p-value	Coefficient of estimate	F-value	p-value	Coefficient of estimate	F-value	p-value	Coefficient of estimate	F-value	p-value
Model	_	86.57	<0.0001	-	21.05	0.0002		26.94	<0.0001	-	73.67	<0.0001	-	47.46	<0.0001		64.33	<0.0001		43.68	<0.0001
Linear mixture component		177.71	<0.0001		47.11	<0.0001		60.36	<0.0001		90.26	<0.0001		55.04	<0.0001		38.34	<0.0001		0.20	0.8206
A	20.68	_	_	4.71	_	_	12.52	_	_	1.40	_	_	20.93	_	_	0.88	_	_	50.77	_	_
B	20.39	_	_	4.72	_	_	14.45	_	_	1.38	_	_	36.44	_	_	0.79	_	_	101.00	_	_
C	22.70	_	_	4.39	_	_	10.41	_	_	1.19	_	_	14.06	_	_	0.83	_	_	78.44	_	_
AB	-5.81	68.16	<0.0001	-0.41	7.48	0.0257	-2.05	1.42	0.2675	1.29	121.70	<0.0001	-74.10	106.41	<0.0001	-0.25	62.97	<0.0001	77.43	3.67	0.0968
AC	-3.37	23.01	0.0020	0.067	0.20	0.6671	-5.84	11.50	0.0095	1.36	136.09	<0.0001	14.96	4.34	0.0708	0.053	2.93	0.1252	461.69	130.65	<0.0001
BC	-2.31	17.41	0.0042	0.24	3.55	0.0962	-0.20	0.020	0.8911	-0.043	0.21	0.6573	-26.59	19.69	0.0022	0.35	181.59	<0.0001	-245.11	59.50	0.0001
ABC	60.50	154.12	<0.0001	-	-	-	-	-	-	-9.49	137.20	<0.0001	-	-	-	-		-	-2333.05	69.51	<0.0001
Lack of fit	-	0.50	0.7018	-	1.55	0.3404	-	1.96	0.2655		0.87	0.5263	-	0.66	0.6500	-	3.22	0.1416	-	1.07	0.4557

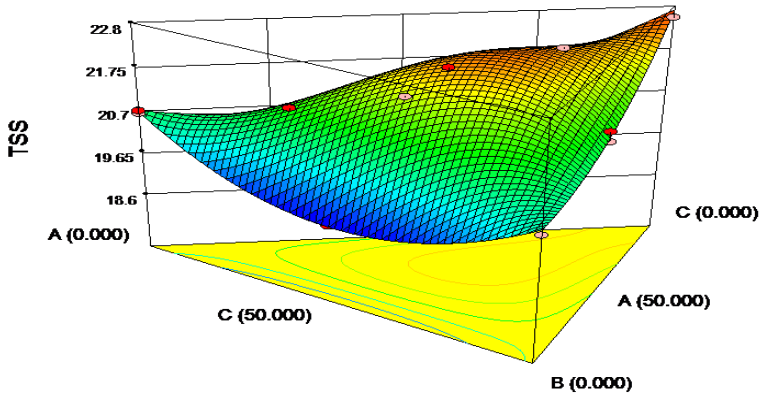

Figure 4.11. Influence of process variable on TSS

From Fig 4.11, it can be concluded that the effect of all the three factors on TSS were to some extent linear. The concentration of Aonla pulp has a negative impact on TSS content, but with the increase in both Mango and Jackfruit pulp concentration, TSS was increased.

4.2.1.2 Influence of process variable on Reducing Sugar

p-Value (Prob>F) less than 0.0500 indicate that the model terms are significant. From Table 4.7, it can be concluded that in this case , the interaction effect of Linear Mixture Component mango pulp and jack pulp are significant model terms. "Lack of Fit F- value" of 1.55 implies that Lack of Fit is not significant relative to the pure error. The value of coefficient of estimate showed that both mango and jackfruit pulp concentration effect the Reducing sugar content positively.

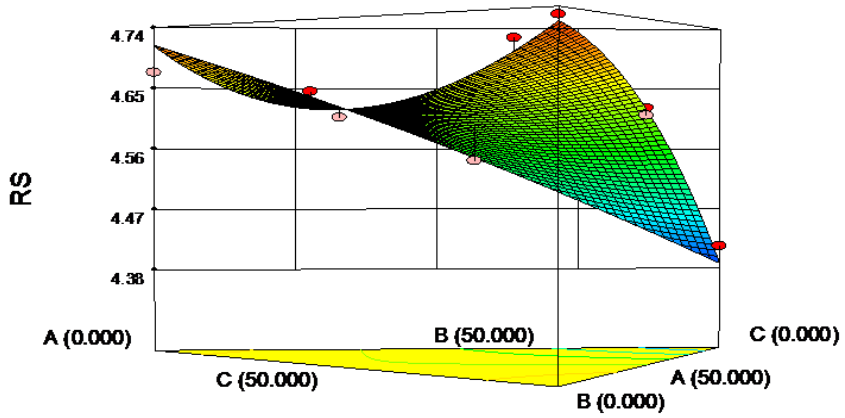

Figure 4.12. Influence of process variable on Reducing Sugar

Fig 4.12. showed that here also the effect of all the three factor responses on process variables were quadratic. It can be stated from the above Fig. that the amount of Reducing sugar was increased with the increase in both mango and jackfruit pulp as they have a positive impact on Reducing sugar content.

4.2.1.3 Influence of process variable on Non Reducing Sugar

p-Value (Prob>F) less than 0.0500 indicate that the model terms are significant. From Table 4.7, it can be stated that in this case, the interaction effect of Linear Mixture Component mango pulp and aonla pulp are significant model terms. "Lack of Fit F- value" of 1.96 implies that Lack of Fit is not significant relative to the pure error. The values of coefficient of estimate showed that jackfruit pulp has the highest positive interaction on Non Reducing Sugar content followed by mango pulp.

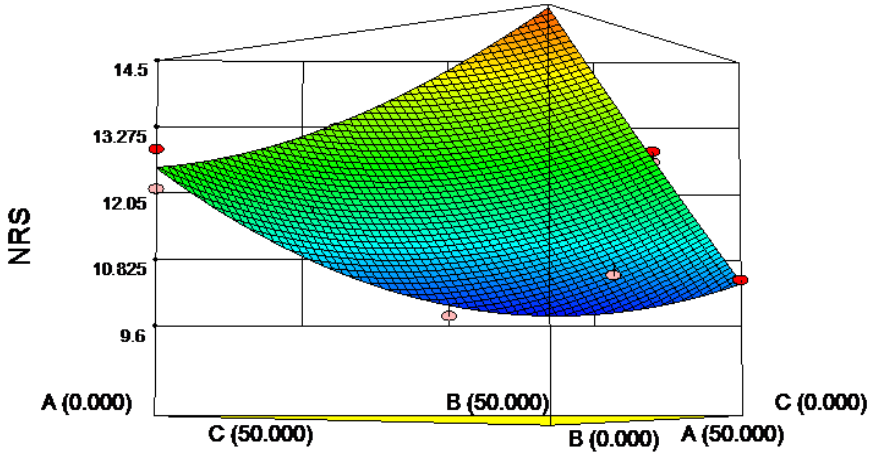

Figure 4.13. Influence of process variable on Non Reducing Sugar

For Non Reducing Sugar content, the effect of the three different factors variables were linear. From Fig 4.13 it can be concluded that with the increase in mango pulp and jackfruit pulp concentration the amount of Non Reducing Sugar content was increased. For aonla pulp, the higher concentration was lower the amount of Non Reducing Sugar.

4.2.1.4 Influence of process variable on Acidity

p-Value (Prob>F) less than 0.0500 indicate that the model terms are significant. From Table 4.7, it can be observed that in this case, the interaction effect of linear mixture component mango pulp and jack pulp, mango pulp and aonla pulp, and mango, jack and aonla pulp are significant model terms. "Lack of Fit F- value" of 0.87 implies that Lack of Fit is not significant relative to the pure error. It can be stated from the coefficient value in Table 4.7 that individual effect of mango pulp and combined effect of both mango and aonla pulp have a large impact on Acidity percentage of the prepared mix fruit leather. The combine effects of all the three fruit pulps concentration have a negative impact on Acidity content of the mix fruit leather.

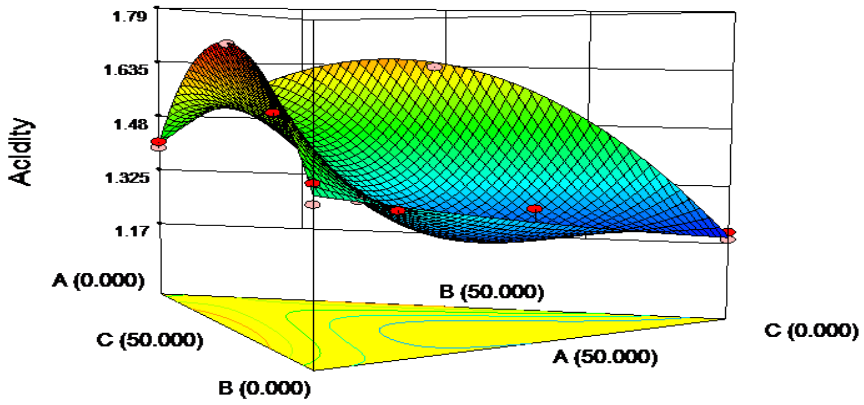

Figure 4.14. Influence of process variable on Acidity

Fig 4.14. showed that the effect of the three mixing component on response variables were highly quadratic in nature. The amount of Acidity was increased with the increased in aonla pulp concentration, as aonla pulp has a positive impact on Acidity content. Acidity was found decreased with the increase in mango and jackfruit pulp concentration.

4.2.1.5 Influence of process variable on Ascorbic Acid

p-Value (Prob>F) less than 0.0500 indicate that the model terms are significant. From Table 4.7, it can be concluded that in this case, the interaction effect of linear mixture component mango pulp and jack pulp, jack pulp and aonla pulp are significant model terms. "Lack of Fit F- value" of 0.66 implies that Lack of Fit is not significant relative to the pure error. From Table 4.7, keeping the value of coefficient of estimate in mind, it can be stated that the individual effect of jackfruit pulp has a positive impact on Ascorbic acid content while the combined effect of mango and jackfruit pulp concentration influenced the Ascorbic acid content negatively.

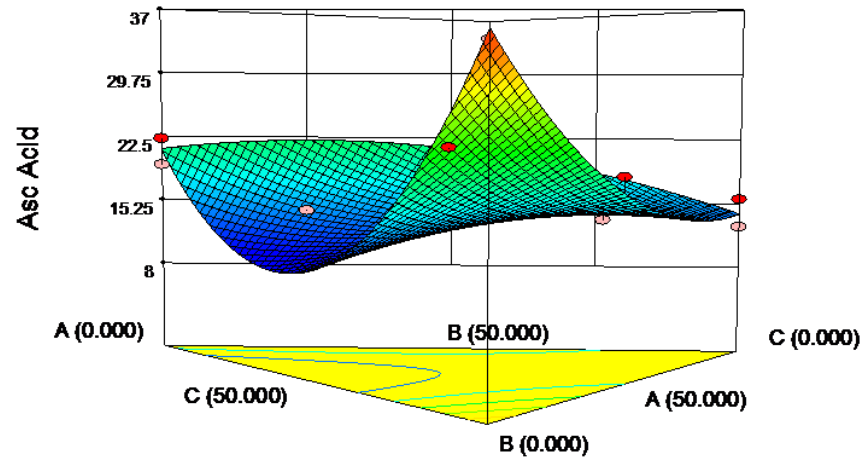

Figure 4.15. Influence of process variable on Ascorbic acid

The above Fig 4.15 showed that the effect of three different fruit pulp used as mixing component have a clear quadratic effect on Ascorbic acid content. It can be said from the above, that the amount of Ascorbic acid was increased with the increase in jackfruit pulp content.

4.2.1.6 Influence of process variable on Water activity

p-Value (Prob>F) less than 0.0500 indicate that the model terms are significant. From Table 4.7, it can be concluded that in this case, the interaction effect of linear mixture component mango pulp and jack pulp and jack pulp and aonla pulp are significant model terms. "Lack of Fit F- value" of 3.22 implies that Lack of Fit is not significant relative to the pure error. It can be observed from Table 4.7 that the combined effect of mango pulp and jackfruit pulp concentration negatively affect the Water activity , that means with the increased amount of mango and jackfruit pulp the water activity was decreased in prepared mix fruit leather.

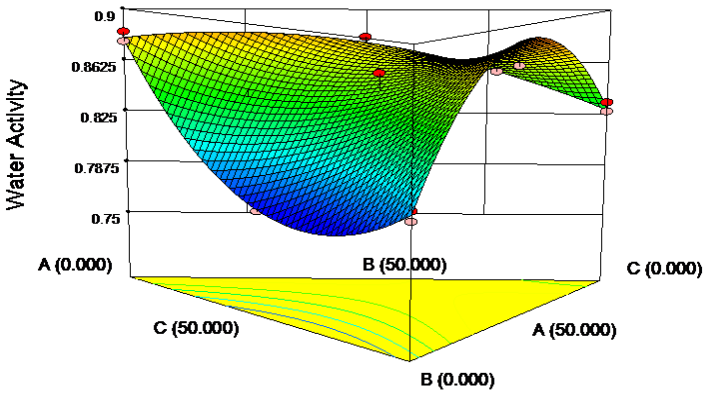

Figure 4.16. Influence of process variable on Water activity

From the Fig 4.16, it can be stated that here also the effect of all the three factors were quadratic on the response variables. Water activity was found to be reduced with the increased in aonla pulp concentration.

4.2.1.7 Influence of process variable on Hardness

p-Value (Prob>F) less than 0.0500 indicate that the model terms are significant. From table 4.7, it can be said that in this case, the interaction effect of linear mixture component mango pulp and aonla pulp, jack pulp and aonla pulp, and mango, jack and aonla pulp are significant model terms. "Lack of Fit F- value" of 1.07 implies that Lack of Fit is not significant relative to the pure error. The value of coefficient of estimates showed that, the individual effect of jackfruit pulp concentration and combine effect of mango pulp and aonla pulp have a positive

correlation with hardness, while the combined effect of all the three mixing component have a large negative impact on Hardness of the mix fruit leather.

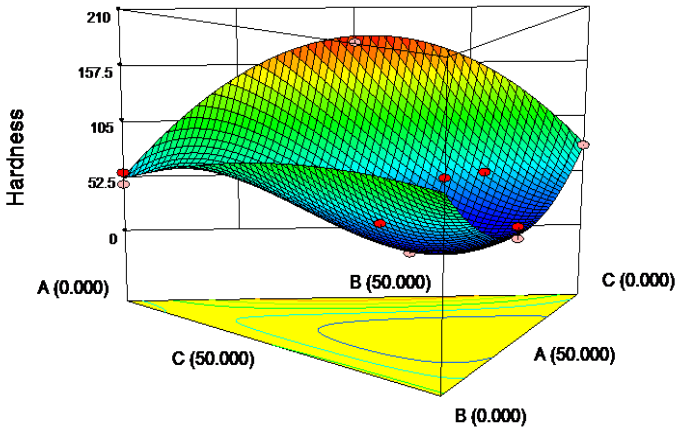

Figure 4.17. Influence of process variable on Hardness

The information provided by the Fig 4.17, showed that here also the effect of all the three mixing component were quadratic in nature.

4.2.2 Optimization of Process variable

After analyzing the response for ANOVA, the process variable was optimized by numerical optimization method using Design Expert 7.1.6 software. The details of the optimization criteria is given in table 4.8

Table 4.8. Optimization of the constrains

Name	Goal	Lower limit	Upper limit	Lower weight	Upper weight	Importance
Mango pulp	Is in range	0	50	1	1	3
Jack pulp	Maximize	0	50	1	1	5
Aonla pulp	Is in range	0	50	1	1	3
TSS	Is in range	19.10	22.86	1	1	3
RS	Is in range	4.367	4.75	1	1	3
NRS	Is in range	9.783	14.896	1	1	3
Acidity	Is in range	1.18	1.711	1	1	2
Ascorbic acid	Maximize	10.61	38.05	1	1	5
Water activity	Minimize	0.773	0.903	1	1	3
Hardness	maximize	24.4	177.4	1	1	3

For optimizing the process variable stated in Table 4.8, a mixing ratio of 27.887 % mango pulp, 50.000 % jack pulp and 22.113% aonla pulp was found ideal for maximizing jackfruit pulp, Ascorbic acid content (20.789mg/100g) and Hardness (180.088 gf) and for minimizing water activity (0.863 a_w).

4.3. Storage stability

4.3.1 Evaluation of storage stability of osmotically dehydrated jackfruit cube

For evaluation of the storage stability of osmotically dehydrated jackfruit cube, water activity, rehydration ratio and total plate count were considered as experimental parameter. The observations were recorded up to 6 months at 1month interval. Change in the experimental parameter during storage period is presented in Table 4.9.

Table 4.9. Changes during storage of osmotically dehydrated jackfruit cube

Storage month	Water activity	Rehydration ratio	Total plate count
0	0.771±0.002	3.74±0.28	Not detected
1	0.775±0.004	3.18±0.31	Not detected
2	0.777±0.003	2.89±0.29	Not detected
3	0.778±0.003	2.78±0.34	Not detected
4	0.780±0.005	2.46±0.25	Not detected
5	0.782±0.004	2.41±0.28	Not detected
6	0.783±0.002	2.11±0.30	Not detected

4.3.2. Evaluation of storage stability of mix fruit leather

In case of mix fruit leather, water activity, Ascorbic acid content and Total plate count were considered as experimental parameter for evaluation of its storage stability. Here also observation were recorded at 0-6 months of interval. Change in water activity during storage period is enclosed in Table 4.10.

Table 4.10. Changes during storage of mixed jackfruit leather.

Storage period	Water activity	Ascorbic acid content (mg/100g)	Total plate count
0	0.864± 0.003	20.23 ± 0.60	Not detected
1	0.864±0.005	13.79± 0.63	Not detected
2	0.867±0.003	12.41± 0.58	Not detected
3	0.868±0.006	10.77± 0.65	Not detected
4	0.871±0.005	9.89± 0.57	Not detected
5	0.874±0.004	9.56± 0.62	Not detected
6	0.877±0.003	8.78± 0.60	Not detected

Summary and Conclusion

Most fruits and vegetables have a definite harvesting time and a limited shelf-life. The harvested fruits quickly deteriorate due to several biochemical and microbial activity. However, different preservation methods are used to extend the shelf-life by a few weeks to one year or more. Due to presence of higher moisture content, jackfruit is perishable in nature and cannot be stored for long time because of its inherent compositional and textural characteristics. In India, after a good production, massive amounts of jackfruit have been wasted in every year due to its bulky weight and strong aroma. Several post harvest practices especially value addition was found very effective for utilization of the fruit and to check its abundant wastage. Apart from the above, value addition also makes this underutilized fruit available throughout the year. In this proposed plan two products have prepared from two different maturity stages, which already have discussed. For preparation of osmotically dehydrated tender jack fruit cube, the independent variables were salt concentration, $Ca(OH)_2$ concentration and time and the response variables were water loss, mass reduction, change in dry matter, rehydration ratio and water activity. The experiment was carried out to study the response surface using Central Composite Rotatable Design with 26 run of which 10 were at central points. The design was generated by software Design-Expert® version 7.1.6 . Response surface methodology (RSM) was used to determine the best conditions for preparation of dehydrated jackfruit cube from tender jack. Keeping the above factors in mind, the range of the process variables on response variables were optimized by the software. The optimized range was 12.95% salt concentration and 1% $Ca(OH)_2$ concentration for a time period of 155.57 min. For the above factors variables, the response variable were water loss (88.28%), mass reduction (88.86%), change in dry matter content ($9.41x10^{-5}$), rehydration ratio (3.740), and water activity (0.771 a_w). Mix fruit leather was prepared by using jackfruit pulp as principal component from ripe stage of maturity. To reduce its strong aroma and to make the product preferable for everyone, ripe mango pulp and mature aonla pulp were used. To study the optimization of different pulp mixture component, a simplex lattice quadratic design was used. Here the factors variables were the three fruit pulp and the response variables were Total soluble solid (%), Reducing sugar (%), Non reducing sugar (%), Ascorbic acid (mg/100 g), Acidity (%), Water activity (a_w) and Hardness (gf). The optimized range of process variables were set by the software were mixing ratio of 27.887 % mango pulp, 50.000 % jack pulp and 22.113% aonla pulp. For the above process variable range the, response variables were TSS

(21.11^{o}B), reducing sugar (4.53%), non reducing sugar (9.84%) , acidity (1.59%), Ascorbic acid content (20.287mg/100g) and Hardness (177.400 gf) and water activity (0.869 a_w). For evaluation of storage stability of osmotically dehydrated jackfruit cube, water activity, rehydration ratio and total plate count were considered as experimental parameter. The observations were recorded up to 6 months at 1month interval. It was observed that, water activity was increased with the storage period, where as rehydration ratio was decreased during the storage period for osmotically dehydrated jackfruit cube. In case of mix fruit leather, water activity, Ascorbic acid content and Total plate count were considered as experimental parameter for evaluation of its storage stability. Here also water activity was increased with the storage period. Ascorbic acid content in mix fruit leather was found to be decreased with the increase in storage period.

FUTURE SCOPE OF RESEARCH

Post harvest practices have a great influence on maximizing the utilization and minimizing it abundant wastage throughout the year. Value addition is a very popular and economic practice for this underutilized fruit. To check the wastage, make the product available and to increase the utilization of Jackfruit, two products (osmotically dehydrated jackfruit cube and mix fruit leather) from two different maturity level (immature/tender and ripe) were prepared in this study plan. There is ample scope for further research and development in getting value added product from jackfruit. Some aspects that were not covered in the present work and where further research work can be carried out are as follows:

- Effect of packaging types and storage time on the quality of mix fruit leather
- Apart from mango and aonla, other fruit pulp can be utilized as mixing component and the concentration of jackfruit pulp can also increased
- Cause of blackening of cube can be studied for osmotically dehydrated jackfruit cube

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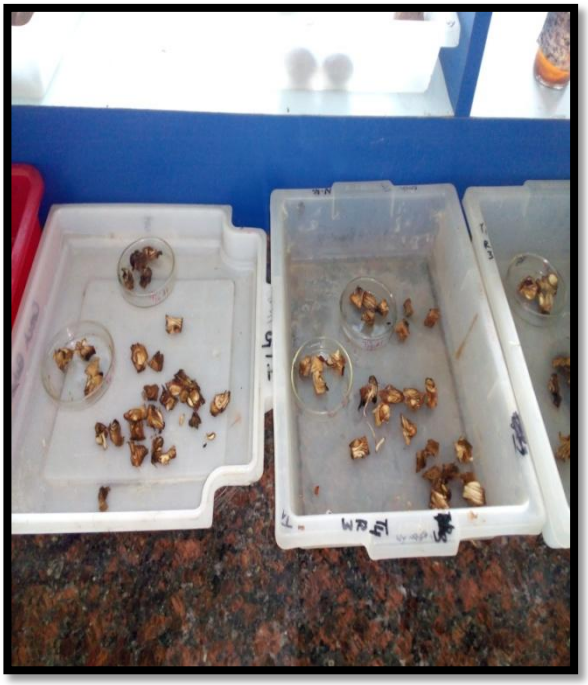

Picture.2: Different preparation of the products

Picture. 1: Different observation recorded