PRODUCTION TECHNOLOGIES FOR VALUE ADDED PRODUCTS FROM PUMPKIN SEEDS

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ABSTRACT

Utilization of by-products as functional food ingredients boost new markets in functional food industry. Pumpkin seeds are nutritionally dense by-product of pumpkin but commonly discarded as waste. The pumpkin seeds have many health benefits and are considered as nutritional powerhouses, with a wide variety of nutrients ranging from magnesium and manganese to copper, protein and zinc. The purpose of the study was to explore utilization of pumpkin seeds to supplement food products to enhance nutritional content. The physical characteristics; length, width, thickness, geometric mean diameter, true density, bulk density, porosity and 1000 seed weight were observed to be 6.81±0.91 mm, 8.87±0.61 mm, 2.75±0.18 mm, 7.42±0.35 mm, 398±0.80 kg/m^3, 1157±1.02 kg/m^3, 65.60±0.47% and 55.52±0.55% for whole pumpkin seed while the corresponding values for kernel were 11.65±0.69 mm, 5.80±0.26 mm, 2.52±0.29 mm, 5.54±0.29 mm, 475±0.95 kg/m^3, 1068.81±0.94 kg/m^3, 202.2±0.75g and 148.1±0.87g respectively. The husk content of the pumpkin seed was found to be 26.75±0.98%. The chemical composition; moisture, protein, crude fat, crude fibre, ash, carbohydrate and phytic acid content were observed to be 5.53±0.26%, 28.90±1.36%, 31.75±0.45%, 4.59±1.01%, 6.90±0.14% and 27.86±1.50% for whole pumpkin seed while the corresponding values for kernel were 4.43±0.44%, 31.98±1.18%, 38.29±1.51%, 4.26±0.43%, 2.36±0.10% and 33.11±2.94% respectively. The average fatty acid and mineral composition of pumpkin seed kernel were observed to be linoleic acid (37.89%), oleic acid (27.75%), palmitic acid (17.63%), stearic acid (14.96%), palmitolic acid (0.33%), arachidic acid (0.30%), erusic acid (0.21%), behenic acid (0.21%) and linolenic acid (0.18%) and zinc (907 mg), phosphorus (848.6 mg), manganese (487 mg), potassium (404.9 mg), magnesium (335.6 mg), copper (124 mg), calcium (25.7 mg), iron (16.1 mg), sodium (2.2 mg) and cobalt (0.6 mg).

Completely Randomized Design (CRD) was adopted for experimental design and the optimization was carried out by using Design expert 10.0.1 software for the standardization of roaster and value added products from pumpkin seed kernels. The effect of roasting temperature and roasting time for four different roasters; halogen oven (180, 190 and 200^{o}C for 4, 6 and 8 min), hot air oven (150, 160 and 170^{o}C for 10, 20 and 30 min), microwave oven (P-80, P-90 and P-100 for 3, 4, and 5 min) and sand roasting (150, 160, 170^{o}C for 2, 3 and 4 min) were evaluated with respect to sensory attributes, texture profile analysis and phytic acid content in roasted pumpkin seed kernels. The optimized sample from each of the four roasters were then compared and the best roaster was selected for roasting pumpkin seed kernels for further preparation of value added products. The best roaster was found to be halogen oven with roasting temperature and roasting time as 190^{o}C and 5 min.

Standardization of process parameters for roasted salted pumpkin seed kernels was carried out with respect to overall acceptability score (OAA) and texture profile analysis (hardness and fracturability). The effect of moisture conditioning (5, 10 and 15%) and salt concentration (10, 15 and 20%) were studied with three factorial complete randomized design. The optimized conditions were found with 12% moisture conditioning and 20% salt concentration.

The optimization of hydrogenated vegetable oil (10, 15 and 20%) and lecithin levels (0.5, 1.0 and 1.5%) for preparation of pumpkin seed spread was carried. It was found that that 20% hydrogenated vegetable oil and 0.7% lecithin were the optimum conditions for preparation of pumpkin seed spread which had most acceptable sensory attributes, textural parameters (hardness, adhesiveness, cohesiveness) and L*, a*, b* colour values.

The unroasted, roasted and sprouted pumpkin seed were studied for the preparation of pumpkin seed flour with respect to protein, fat and water absorption capacity. The optimized conditions were observed in sprouted defatted pumpkin seed flour with 66.92% protein, 5.92% fat and 20.12% water absorption capacity.

Storage studies of value added pumpkin seed products were carried out for 90 days. The roasted salted pumpkin seed kernels and defatted pumpkin seed flour were packed in aluminium laminate pouches and stored at ambient (30±2^{o}C) storage conditions while the pumpkin seed spread was stored at ambient (30±2^{o}C) as well as refrigerated (5±2^{o}C) storage conditions. During storage, samples were analysed for physicochemical characteristics, sensory attributes and microbiological parameters at an interval of 15 days. It was found that the value added products from pumpkin seed viz. roasted salted pumpkin seed kernels, pumpkin seed spread and defatted pumpkin seed flour can be successfully stored in aluminium laminate pouches and glass jars with adequate shelf-life with respect to physicochemical, microbiological, as well as sensory characteristics.

Keywords: Pumpkin seeds, kernels, roaster, halogen oven, hot air oven, microwave oven, sand roasting, value added product

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CERTIFICATE

This is to certify that the thesis entitled **"Production Technologies for Value Added Products from Pumpkin Seeds"** submitted by **Ningthoujam Manda Devi** (Reg. No. 04-2759-2015) in partial fulfillment of the requirement for the award of the degree of **Doctor of Philosophy** in **Food Processing Technology** to the Anand Agricultural University is a record of bonafide research work carried out by her under my guidance and supervision.

Place: Anand **(R. V. Prasad)**

Date: **Major Advisor**

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Place: Anand ***(N. Manda Devi)***

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

ABBREVIATIONS AND SYMBOLS

Particular	Description
>	Greater than
%	Percent
/	per
+	Plus
µL	Micro litter
µg	Microgram
-	Minus
±	Plus or Minus
*	1% Significant
**	5% Significant
***	10% Significant
ε	Porosity
Δ	Delta
ΔH	Enthalpy
&	And
β	Beta
γ	Gamma
α	Alpha
µm	Micrometre
^{0}C	Degree Celsius
Adj. R^2	Adjusted Regression Co-efficient
ANOVA	Analysis of Variance
A.O.A.C	Association of Official Analytical Chemist
A.O.C.S	American Oil Chemists' Society
AP	Anand pumpkin
BIS	Bureau of Indian Standards
CD	Critical difference
cfu/g	Colony forming unit per gram
cm	Centimetre

cm^3	Cubic meter
Coeff.	Coefficient
Cons.	Constant
CCD	Central composite design
CRD	Completely randomized design
$CuSO_4$	Cupric sulfate
CV	Co-efficient of variance
db	Dry basis
DF	Degree of freedom
Dg	Geometric mean diameter
DSC	Differential scanning calorimeter
DPPH	2,2-diphenyl-1-picrylhydrazyl
et al.	Et ally
Eqn	Equation
FAMES	Fatty acid methyl esters
FBD	Fluididized bed dryer
FFA	Free fatty acid
Fig.	Figure
FTIR	Fourier-transform infrared spectroscopy
F_{cal}	F calculated
$F_{tab.}$	F tabulated
g	Gram
g/kg	Gram per kilogram
g/sec	Gram per second
g/100g	Gram per hundred gram
GC	Gas chromatography
h	Hour
HVO	Hydrogenated vegetable oil
H_2SO_4	Sulphuric acid
HCL	Hydrochloric acid
HNO_3	Nitric acid
HPO	Hydrogenated palm oil

HWD	Hardness work done
ICP-OES	Inductive couple plasma-optical emission spectrometry
ISTA	International seed testing Association
IU	International unit
IVPD	In-vitro protein digestibility
i.e.	That is
Kcal	Kilo calorie
kg	Kilogram
kg/m^3	Kilogram per meter cube
Kg/s	Kilogram per second
KJ/100g	Kilojoule per hundred gram
KOH	Potassium hydroxide
K_2SO_4	Potassium sulfate
L	Length
LDL	Low density lipoproteins
LOF	Lack of fit
mg	Milligram
mg/kg	Milligram per kilogram
meq/kg	Milli equivalent per kilogram
mg/100 g	Milligram per hundred gram
ml	Mililitre
mm	Millimetre
m^2/sec	Square meter per second
mm/sec	Millimetre per second
min	Minute
mm	Millimetre
MHz	Megaher
MUFA	Monounsaturated fatty acid
MS	Mean square
MW	Megawatt
N	Normality

NaOH	Sodium hydroxide
NHB	National horticulture board
NS	Non-significant
NPU	Net Protein Utilization
P	Power
PDA	Potato dextrose agar
PER	Protein Efficiency Ratio
pH	percentage of H+ ions
PUFA	Polyunsaturated fatty acid
PV	Peroxide value
Pvt. Ltd.	Private Limited
R^2	Regression co-efficient
RDA	Recommended Dietary Allowance
RH	Relative humidity
RPSF	Roasted pumpkin seed flour
RPO	Red palm oil
RSM	Response surface methodology
s	Seconds
SD	Standard deviation
SEm	Standard error of mean
SFI	Solid fat index
SICART	Sophisticated instrumentation centre for applied research and testing
SPI	Soy protein isolates
SPSF	Sprouted pumpkin seed flour
SS	Sum of square
T	Thickness
T_o	Onset temperature
T_p	Peak temperature
TPA	Total plate count
TVC	Total viable count
U.S.A	United states of America

U.S.D.A	United States Department of Agriculture
UPSF	Unroasted pumpkin seed flour
V	Volume
VRBA	Violet red bile agar
viz.	namely
wt.	Weight
w.b.	Wet basis
w/v	Weight by volume
w/w	Weight by weight
W	Width
WAC	Water absorption capacity

CONTENTS

CHAPTER I
INTRODUCTION

Value addition of food products helps in opening new markets and also is one of the important components of nutritional security. Value addition creates diversification and quality enhancement of foods products, leading to more agriculture competitiveness in agricultural trade at national as well as international level in the present scenario. Food products have grown tremendously during the last decade as various food movements have raised awareness.

India is the world's second largest producer of fruits and vegetables. Annually, food industry generate large amount of wastes or by-products from a variety of sources. Fruits and vegetable processing is the second largest generator of wastes into the environment after the household sewage. Large amounts of waste materials such as peels, seeds, stones, and unused flesh generated during processing of fruits and vegetables in different steps of processing chains causes environmental pollution problem if not utilized or disposed-off properly. Therefore, efficient use of these by-products greatly influence the economy of the country as well as environmental pollution. These by-products, which are thrown into the environment, are rich source of valuable compounds. They are novel, natural and economic sources of flavouring compounds, colorants, polysaccharides, proteins, fats, dietary fiber, antimicrobials, antioxidants, and an excellent source of nutraceuticals and bioactives compounds. High-value natural compounds can be found in most of these fruits and vegetables residues and many of them having health-promoting characteristics.

Utilization of by-products also boost new markets in functional food industry, as functional food ingredients. The combined efforts of waste minimization during the production, environmentally friendly preservation of the products, and utilization of by products would substantially reduce the amount of waste, as well as boost the environmental profile of fruits and vegetables processing industry. The food materials generally discarded by industries actually can add nutrients to various preparations and value addition to products.

Pumpkin belongs to the genus *Cucurbita* and family *Cucurbitaceae*. The plants are tendril climbing herbaceous annuals containing some extremely well known edible fruits such as pumpkin, cucumber, musk-melon, and watermelon. Pumpkin family comprises about 25 species, of which *C. maxima*, *C. moschata* and *C. pepo* are of economic importance. Other species such as *C. argyrosperma*, *C. mixta* and *C. ficifolia* are grown commercially in some countries (CSIR, 1950).

Pumpkin is grown all around the world for a variety of reasons for food, animal feed, and for decoration purpose. Most of them are grown throughout India during hot and rainy seasons. The plant is grown abundantly in Austria, Hungary, Rumania, Yugoslavia, Southern Russia, U.S.A. and Indo-Pakistan subcontinent. Pumpkin are variable in size, shape, colour, and weight. Pumpkins weigh 4–6 kg with the largest capable of reaching a weight of over 25 kg. In structure, the fruit features golden-yellow to orange flesh depending upon the polyphenolic pigments in it. They have a moderately hard flesh with a thick edible flesh below and a central cavity containing numerous small, off-white colored seeds interspersed in a net-like structure. The pumpkin is cultivated with good yields even in sandy and fairly fertile soils. Maturity occurs in about 90-120 days. The fruits are often allowed to ripen fully on the vine to ensure good variable in size, round, blunty ribbed and brownish yellow or varied in colours. The immature fruits are consumed as a vegetable. The mature fruit is sweet and used to make confectionery, beverages, roasted, or cooked and can be incorporated into baked goods (Pandey *et al*., 2003).

India is the second largest country producing pumpkin in the world after China. The area and production of pumpkin in India during 2015, 2016, 2017 are 49,000, 68,000 72,000 hectares and 11.22, 15.09, 15.82 lakh tonnes respectively (NHB, 2017). The commercial varieties of pumpkin in India are Arka Suryamukhi, Ambili, Arka Chandan, Saras, Suvarna and Sooraj. The most common variety of pumpkin variety in Gujarat is Anand Pumpkin 1 (AP-1). Pumpkin (English), Kumbra (Bengali), Kohlu (Gujarati), Kaddu (Hindi), Kumbala (Kannada), Paarimal (Kashmiri), Mathan or Chakkara kumbalanga (Malayalam), Lal bhopla,(Marathi), Kakharu (Oriya), Sitaphal (Punjabi), Purangikkai or Pooshanikai (Tamil), Gummadi kayi (Telugu) Dangaree (*Sanskrit)* (Gopalan *et al.*, 2011) are the local name of pumpkin throughout India.

Pumpkin fruit is one of the widely grown vegetables incredibly rich in vital antioxidants, and valuable source of carotenoids which have major role in the form of pro-vitamin A. Carotenoids are the primary source of vitamin A for most of people living in developing countries. *β*-carotene present in pumpkin is converted into vitamin A in the body and plays a crucial role in the prevention of cancer and chronic diseases during the adult life due to their antioxidant abilities and prevent skin diseases and eyes disorder. Pumpkin has a high amount of biological active compounds. Pumpkin is recommended for artheroslerosis, reduction of cholesterol in people suffering from obesity. Pumpkin has been used for pies, curry, soups, stews, jam, sweet, marmalade, beverage, baby foods, ice-cream, instant pumpkin kofta and breads. Leaves, stem, seeds and roots have high food value and provide source of oil and raw material for variety of products. The leaves and flowers of the plants are widely cooked as vegetable soup (Shemi George, 2012).

Though the flesh of different vegetables have found their way into the Indian diet for time immemorial, the seeds have almost always been discarded as waste in spite of having a great nutritive value. One such type of seed is pumpkin seed, also known as pepitas. In Asian countries, pumpkin seeds are considered as a by-product. After harvesting, the seeds are often used as animal feed, ground up for fertilizer or even discarded. In India, seeds go as waste and only little amounts are eaten which are salted and roasted. Generally, the pumpkin fruit is allowed to mature completely in order to obtain good-quality seeds. The seed content of pumpkin fruit varies from 3.52% to 4.27%. The pumpkin seeds are semi-flat, feature typical ovoid shape with a conical tip containing olive-green color kernels, which are sweet, buttery in texture and nutty in flavor, can be enjoyed as snack, added in desserts and in savory dishes. Pumpkin seeds have historically been used to produce oil, fortify breads, consumed as a snack or even for medicinal purposes. The unique flavour of pumpkin seeds and pumpkin seed oil is well known all over the world and contribute to the development of aromatic flavour during the roasting process. Pumpkin has received considerable attention because of its nutritional and health protective values of the seeds (Revathy and Sabitha, 2013).

The pumpkin seeds have many health benefits and are considered as nutritional powerhouses, with a wide variety of nutrients ranging from magnesium and manganese to copper, protein and zinc. The pumpkin seeds have antiparasitic activity due to the presence of cucurbitin. Pumpkin seeds have been used in the treatment of benign prostatic hyperplasia, urinary tract problem, gastritis and to remove tapeworms and roundworms from intestine, most common type of kidney stone, and acrodermatitis enteropathica (Roy and Datta, 2015).

Pumpkin seeds which are discarded after the pre-processing of the fruit, have been nowadays subjected to industrial processing and have been commercialized as a savoury appetizer. The application of these seeds can be considered as a good alternative for the nutritional enrichment of food products and could be consumed as food, having a rich source of oil and nutrients. Pumpkin seeds have a high nutritional value, provides good quality oil and excellent source of protein and also has pharmacological activities. Pumpkin seeds can be used as additives in food industry for food formulation, as these seeds are excellent nutrient source filled with minerals and are responsible for fighting diseases (Dar *et al*., 2017).

Pumpkin seeds play an important role in food by nutritional aspects. They can be consumed regularly without causing any side effects on human health. Pumpkin seeds can be converted into snacks which are rich in fibre, unsaturated lipids, minerals and proteins. Roasted almonds, cashew nuts etc. are few popular and costly snack foods but pumpkin seeds can be cheaper substitute. Pumpkin seeds can be processed into flour, which can be used for biscuit making, bread and cookies. Pumpkin seed flour has potential food uses because of its high protein content. In addition to protein, it is a great source of iron, B vitamins, vitamin E, fiber, oil, and minerals and can be used for fortification of complementary food mix, with highly acceptable sensory qualities and a rich nutritive value by enhancing a longer shelf-life. Pumpkin seeds can also be used as a substitutes for peanuts in peanuts butter, which may be allergic to some consumers. Development of pumpkin seeds spread will also add more variability to the already available seeds and nuts spread such as peanuts, cocoa seeds, sunflower seeds, almonds and cashew nuts etc. in market, along with providing more option and nutritional benefits to the consumers. Fortified foods make an important contribution to diets. Adding nutrients to foods is not a new idea but the types of foods selected and the amounts of nutrients added will depend on the particular nutritional needs of the individual. The application of pumpkin seeds can be considered a good alternative for the nutritional enrichment of food products.

In many developing countries, the supply of animal protein is inadequate to meet the protein needs of the rapidly growing population. This has necessitated contemporary research efforts for potential utilization of protein from locally available food crops, especially from underutilized or relatively neglected high protein oilseed and legumes. Recently increased attention has been given to the utilization of agriculture waste products to produce food, feed, fertilizer and a raw material in industries, to maximize the available resources and at the same time to minimize waste disposal problem. Such utilization could be done economically only in the locations where such resources are available in large quantity.

With increased public awareness in sustainable agriculture, clean and efficient energy and waste management technologies, pumpkin seeds have the opportunity to capture a new and emerging market share in the snack food industry. Currently, pumpkin seeds are gaining momentum in the snack food industry as a healthy alternative to other fried snacks.

In India, during the last decade, the demand for new nutritionally sound and economically viable foods has increased considerably. Consequently, much attention has been given to the use of vegetable by-products that are not commonly used by the food industry and the population. The use of these by-products adds value to the production, besides contributing to the formulation of new food products and minimizing losses. In spite of being highly nutritious and having known medicinal values, pumpkin seeds have still not come into the limelight and are relatively less acceptable amongst the people as compared to other oil seeds like groundnuts and cashew nuts, though nutritionally the seeds of pumpkin can easily be compared to the above mentioned seeds. So, it gives new opportunity to explore the possibilities for the production technologies for value added products from pumpkins seeds like pumpkin seed snack, pumpkin seed spread, and pumpkin seed flour, which are rich in nutrients and as a novel products to combat wastages of pumpkin seeds.

Considering the significant importance of pumpkin seed, the present investigation was carried with following objectives.

1) To study physicochemical characteristics of pumpkin seeds
2) To optimize the roasting parameters of pumpkin seeds
3) To standardize process parameters for preparation of pumpkin seed snacks
4) To optimize the process parameters for pumpkin seed spread
5) To standardize process parameters for preparation of pumpkin seed flour
6) To evaluate shelf life of value added pumpkin seed products

CHAPTER II
REVIEW OF LITERATURE

This chapter deals with a brief review of research work reported on the benefits and usages of pumpkin seeds for various value added products, composition and nutritional quality of pumpkin seeds, production of roasted salted pumpkin seed kernels, seed spreads and seed flour.

2.1 PUMPKIN

Pumpkin (*Cucurbita maxima)* belongs to the *Cucurbitaceae* family of the genus *Cucurbita.* The colour ranges from light yellow-orange to bright orange in colour. It includes cucumbers which are grown throughout the tropical and sub-tropical countries. The seeds of pumpkins are planted in such a way that harvesting occurs in the month of October. Pumpkin seeds germinate fastest around 34°C but they germinate between lower and upper temperatures of 13 and 45°C. Pumpkin provides a rich source of carotenoids and ascorbic acid which have major role in nutrition as provitamin A, good antioxidant properties and may also boost eye vision. Pumpkin are available in many shapes, sizes and colours. Agriculture, food-processing, pharmaceutical as well as feed industry have taken growing interest in pumpkin fruit and pumpkin derived products in the past few years (Sojak *et al*., 2010).

Recent studies have shown that all current cucurbita varieties can be traced back to a common ancestor originating in Southern Mexico. Pumpkin family comprises about 25 species of which *C. maxima*, *C. moschata* and *C. pepo* are of economic importance. Other species such as *C. argyrosperma*, *C. mixta* and *C. ficifolia* may also be referred to as pumpkins and are grown commercially in some countries. India is the second largest pumpkin producing country in the world after China. The area and production of pumpkin in India during 2015, 2016, 2017 are 49,000, 68,000, 72,000 hectares and 11.22, 15.09, 15.82 lakh tonnes, respectively (NHB, 2017). The commercial varieties of pumpkin in India are Arka Suryamukhi, Ambili, Arka Chandan, Saras, Suvarna and Sooraj. The most common variety of pumpkin variety in Gujarat is Anand Pumpkin 1 (AP-1). Pumpkin (English), Kumbra

(Bengali), Kohlu (Gujarati), Kaddu (Hindi), Kumbala (Kannada), Paarimal (Kashmiri), Mathan or Chakkara kumbalanga (Malayalam), Lal bhopla,(Marathi), Kakharu (Oriya), Sitaphal (Punjabi), Purangikkai or Pooshanikai (Tamil), Gummadi kayi (Telugu) Dangaree (*Sanskrit)* (Gopalan *et al.*, 2011) are the local name of pumpkin throughout the India.

2.1.1 Benefits and Usages of Pumpkin Seeds

Generally pumpkin seeds are by-product in the food industry. Pumpkin fruits bear numerous seeds like other members of *Cucurbitaceae*. The seed content of pumpkin fruit varies from 3.52% to 4.27%. All over the world, pumpkins are grown for a variety of reasons ranging from agricultural purposes to commercial and ornamental sales. They are very versatile in their uses for cooking from the fleshy shell to the seeds. The highly unsaturated fatty acid composition of pumpkin seed oil also makes it wellsuited for improving nutritional benefits from foods.

Pumpkin seed are very nutritious and provide best quality oil and rich source of protein but are generally discarded during the processing of canned pumpkin or pie mix or in other processing treatments. Pumpkin seeds have received considerable attention because of the nutritional and health protective values (Revathy and Sabitha, 2013). The pumpkin seeds are richly endowed in macro elements (magnesium, phosphorus and calcium) and moderate amounts of micro elements (manganese, copper and zinc) and thus the seed could be used as a valuable food supplement. Normally pumpkin seeds are thrown away as a waste, whereas it is a rich source of nutrients and oil and can be used as a food (Dhiman, 2009). Stevenson *et al.,* (2007) reported that the oil content of pumpkin seed ranged from 10.9 to 30.9%. Total unsaturated fatty acid content ranged from 73.1 to 80.5%. The predominant fatty acids present were linoleic, oleic, palmitic, and stearic. The seed of pumpkin have pharmacological activities such as antidiabetic, antifungal, antibacterial and antiinflammation and antioxidant effects (Nkosi *et al*., 2006).

Pumpkins are widely grown for various commercial uses, and also in both food and recreation. Many countries utilize the seeds as a nutritious food source. Pumpkin seeds can be ground, fermented, roasted or eaten raw and can be consumed as either part of a meal or as a healthy snack which is high in fiber, protein, healthy fats and minerals. It is common to roast, salt and flavor pumpkin seeds. Pumpkin have historically been used to produce oil, fortify breads, consumed as a snack or even for medicinal purposes. The unique flavour of pumpkin seeds and pumpkin seed oil is well known and enjoyed all over the world and contribute to the development of aromatic flavour during the roasting process.

In many developing countries, the supply of animal protein is inadequate to meet the protein needs of the rapidly growing population. This has necessitated contemporary research efforts geared towards the study of the food properties and potential utilization of protein from locally available food crops, especially from underutilized or relatively neglected high protein oilseed and legumes.

Recently increased attention has been given to the utilization of agriculture waste products to produce food, feed, fertilizer and a raw material in industries, to maximize the available resources and at the same time to minimize waste disposal problem. With increased public awareness in sustainable agriculture, clean and efficient energy and waste management technologies, pumpkin seeds have the opportunity to capture a new and emerging market share in the snack food industry. Currently, pumpkin seeds are gaining momentum in the snack food industry as a healthy alternative to other fried snacks. In India, during the last decade, the demand for new nutritionally sound and economically viable food has increased considerably. Consequently, much attention has been given to the use of vegetable by-products that are not commonly used by the food industry and the population (Dhiman *et al.*, 2009).

2.2 PHYSICAL PROPERTIES OF PUMPKIN SEED

Since the physical properties of the seed are the pre-requisites for the design of equipment for handling, dehulling and other processes, it is necessary to determine these properties.

Joshi *et al.,* (1993) evaluated several physical properties of pumpkin seeds and kernel as a function of moisture content and reported that the average length, width and thickness of pumpkin seed were 16.91, 8.67 and 3.00 mm respectively, while the corresponding values for kernel were 14.62, 6.89 and 2.50 mm respectively. The average unit mass of seed and kernel was found to be 0.203 g and 0.160 g. In this study, they also observed that all the physical properties of the pumpkin seed varied with moisture content. The bulk density of the seeds were found lower whereas true density was found to be higher than the kernels. For seed, the bulk density increased from 404 to 472 kg/m^3, while true density decreased from 1179 to 1070 kg/m^3 as the moisture increased from 4 to 40% d.b. The corresponding densities for the kernel increased from 481 to 554 kg/m^3 and 1080 to 1143 kg/m^3. The porosity of both the seed and kernel were found to be decreasing from 65.73 to 55.46% and 55.46 to 51.53% respectively.

Milani *et al.*, (2007) studied physical properties of three common Iranian varieties of cucurbit seeds (Riz, Chiny, and Gushty) as a function of moisture content in the range of 5.18 to 42.76% (w.b.). and found that the mean values of all geometric properties increased with increasing moisture content. Among the varieties, Chiny had the highest values of gravimetric properties, in all moisture contents studied. The maximum and minimum values of bulk density were 550.3 kg/m^3 for Riz and 308.3 kg/m^3 for Chiny.

In 2008, Altuntas reported the mean values of length, width, thickness and geometric mean diameter as 19.92, 11.30, 3.22 and 9.71 mm for pumpkin seeds at a moisture content of 9.87% (d.b). The corresponding mean of 1000 seed mass, bulk and true densities and porosity values were 261.2g, 321.3 kg/m^3, 784.3 kg/m^3 and 58.9% respectively.

Similarly, Yildiz *et al*., (2013) also evaluated physical properties of pumpkin seed (‘14 BO 01’) (*Cucurbita moschata* Duch.) and winter squash variety seeds (‘55 CA 15’ and ‘Arican 97’) (*Cucurbita maxima* Duch.) at different moisture content levels. They observed that length, width and thickness increased linearly, as the moisture increased from 8.62 to 25.49% (dwb) for ‘Arican 97’, from 9.60 to 25.60% for ‘55 CA 15’ and for 6.81 to 23.07% for ‘14 BO 01’. The bulk and true densities were found to be decreasing from 411.86 to 366.03 kg/m^3, from 390.35 to 347.37 kg/m^3 and from 375.54 to 316.55 kg/m^3 for ‘Arican 97’, ‘55 CA 15’ and ‘14 BO 01’, with increasing moisture content. The corresponding porosity values ranged between 41.30 to 43.20%, 45.08 to 47.36% and 45.47 to 50.49% for ‘Arican 97’, ‘55 CA 15’ and ‘14 BO 01’, respectively.

2.3 COMPOSITION AND HEALTH BENEFITS OF PUMPKIN SEEDS

Pumpkin seeds are nutritional powerhouses wrapped up in a very small package, with a wide variety of nutrients ranging from magnesium and manganese to copper, zinc and protein. In earlier pumpkin seeds were regarded as a waste but now play an important role in food by nutritional aspects and can be consumed regularly without causing any side effects on human health (Maheshwari *et al*., 2015). Like other members of *Cucurbitaceae*, each pumpkin fruits bear numerous seeds, located at its central hollow cavity, interspersed in between net like mucilaginous network. Pumpkin fruits are variable in size, colour, shape and weight. They have a moderately hard flesh with a thick edible flesh below and a central cavity containing the seeds. Generally, the pumpkin fruit is allowed to mature completely in order to obtain good-quality seeds. The seeds are semi-flat, feature typical ovoid shape with a conical tip. Inside its kernels are olive-green color, sweet, buttery in texture and nutty in flavor which can be enjoyed as snack, added in desserts and in savory dishes. The composition of pumpkin seed is summarised in Table 2.1.

Alfawaz (2004) investigated the chemical composition and oil characteristics of pumpkin (*Cucurbita maxima*) seed kernels and reported that the pumpkin seeds contained 39.25%, 27.83%, 4.59% and 16.84% crude protein, crude oil, ash, and crude fiber while the corresponding values for the kernels were 39.22, 43.69, 5.14, and 2.13%, respectively with moderate concentrations of minerals, especially P, Mg, and K. were present. Their amino acid profiles indicate that methionine and tryptophan were the most limiting amino acids, while arginine, glutamic, and aspartic acids were the most plentiful amino acids. The saturated and unsaturated fatty acid content were found to be 27.73% (16.41% palmitic acid and 11.14% stearic acid) and 73.03% (18.14% oleic acid and 52.69% linoleic acid) and concluded that the pumpkin seed kernels can be a quite promising for commercial exploitation considering the lipid and protein content in the kernels, and their fatty and amino acid compositions.

Achu *et al.*, (2005) reported that cucurbit seeds from different regions in Cameroon contained protein content of 28-40%, fat 44-53% and carbohydrate 7-10%, showing that they could be exploited as oil and protein sources.

Table 2.1: Composition of dried pumpkin seed.

(* Nutritional value per 100 g)

Principle	Nutrient Value	Percentage of RDA	Principle	Nutrient Value	Percentage of RDA
Energy	559 Kcal	28%	**Electrolytes**		
Carbohydrates	10.71 g	8%	Sodium	7 mg	0.5%
Protein	30.23 g	54%	Potassium	809 mg	17%
Total Fat	49.05 g	164%	**Minerals**		
Cholesterol	0 mg	0%	Calcium	46 mg	4.5%
Dietary Fiber	6 g	16%	Copper	1.343 mg	149%
Vitamins			Iron	8.82 mg	110%
Folates	58 µg	15%	Magnesium	592 mg	148%
Niacin	4.987 mg	31%	Manganese	4.543 mg	198%
Pantothenic acid	0.750 mg	15%	Phosphorus	1233 mg	176%
Pyridoxine	0.143 mg	11%	Selenium	9.4 µg	17%
Riboflavin	0.153 mg	12%	Zinc	7.81 mg	71%
Thiamin	0.273 mg	23%	**Phyto-nutrients**		
Vitamin A	16 IU	0.5%	Carotene-ß	9 µg	--
Vitamin C	1.9 µg	3%	Crypto-xanthin-ß	1 µg	--
Vitamin E	35.10 mg	237%	Lutein-zeaxanthin	74 µg	--

(Source: USDA National Nutrient data base)

Gohari Ardabili *et al*., (2011) determined the chemical composition and physicochemical properties of pumpkin seeds and fatty acids of their oil. Results showed that the seeds contained 41.59% oil, 25.4% protein and moisture, crude fiber, total ash, and carbohydrate contents were 5.20%, 5.34%, 2.49%, and 25.19%, respectively. The specific gravity, dynamic viscosity, and refractive index of the extracted pumpkin seed oil were 0.915, 93.659 cp, and 1.4662, respectively. Acid value (mg KOH/g oil), peroxide value (meq O_2/kg oil), iodine value (g I_2/100 g oil), saponification number (mg KOH/ g oil), and unsaponifiable content (%) of the extracted oil from pumpkin seeds were 0.78, 0.39, 10.85, 104.36, 190.69, and 5.73, respectively. Total phenolic compounds (mg gallic acid/kg oil), total tocopherols (mg α- tocopherol/kg oil), total sterols (%), and waxes (%) were 66.27, 882.65, 1.86, and 1.58, respectively. Specific extinctions at two wavelengths of 232 nm (K_{232}) and 270 nm (K_{270}) and R-value (K_{232}/K_{270}) were 3.80, 3.52 and 0.74, respectively. Gas chromatographic analysis of the pumpkin seed oil showed that the linoleic (39.84%), oleic (38.42%), palmitic (10.68%) and stearic (8.67%) acids were the major fatty acids. The study revealed that pumpkin seed oil can be a valuable source of edible oil.

Achu *et al*., (2013) has worked on the chemical evaluation of protein quality and phenolic compound levels of some *Cucurbitaceae* oilseeds from Cameroon. In the study, the *Cucurbitaceae* oilseeds taken are *Cucumeropsis mannii*, *Cucurbita maxima*, *Cucurbita moschata*, *Lagenaria siceraria* and *Cucumis sativus*. It was found that defatted cakes had high total protein contents and the trichloroacetic acid soluble fraction of these proteins ranged from 25% (*C. maxima* from North West) to 94% of total proteins (*C. sativus* from Adamawa and South West), due to the postharvest treatment of the seeds. All the Cucurbitaceae oilseeds were rich in most essential amino acids, giving protein digestibility. Corrected amino acid scores of 0.67 for *C. sativus* and 0.48 for *C. mannii* which was for lysine, indicating that in the absence of tryptophan and methionine, lysine was the limiting amino acid in these seeds and low levels of phenolic compounds (0.34 to 0.43%). They indicated that defatted *C. mannii* could be good for preparing infant formula, especially when mixed with soybean, in order to increase its lysine content.

Elinge *et al.*, (2012) analysed the nutritional and anti-nutritional composition of pumpkin seeds and the results obtained were; moisture (5%), ash (5.5%), crude fat (38%), crude fibre (1%), crude protein (27.48%), available carbohydrate (28.03%) and calorific value (564 kcal/100 g). Elemental analysis shows that potassium was the most abundant (273 mg/100 g) and manganese was least (0.06 mg/100 g). The anti-nutritional parameters analysed were; phytate (35.06 mg/100 g), oxalate (0.02±0.10 mg/100 g), hydrocyanic acid (0.22±0.04 mg/100 g) and nitrate (2.27±002 mg/100 g). They reported that the pumpkin seeds if properly utilized can serve as good source of minerals.

Srbinoska *et al*., (2012) determined the chemical composition of seeds of *C. maxima* D. and *C. pepo* L. cultivated in the Republic of Macedonia. The physico-chemical characteristics, fatty acid profiles, and sterol and tocopherol contents in pumpkin seed extracts were studied. They found that higher kernel yield and content of moisture, ash, total nitrogen, proteins and carbohydrates in the *C. pepo* than in *C.*

maxima seed. The highest extract yield of 487.4 g/kg dry matter was obtained from *C. pepo* kernel, while 388.2 g/kg dry matter was extracted from *C. maxima* kernel, when *n*-hexane was used as solvent. In all extracts, the palmitic, stearic, oleic and linoleic acids were predominant. The linoleic/oleic acid ratio was higher in *C. maxima* extracts. D7-Sterols were predominant in all extracts, while D5-sterols content was higher in the whole seed than in the kernel extracts. Higher tocopherol content was determined in the extracts of *C. pepo* whole seed and kernel (153.79 mg/kg and 117.81 mg/kg, respectively), than in those of *C. maxima* (121.24 mg/kg and 117.55 mg/kg, respectively). In all extracts γ-tocopherol content was higher than α-tocopherol.

The Pumpkin seeds were well endowed in crude oil, protein, carbohydrates and crude fibre. Karanja *et al.*, (2013) studied on the nutritional composition of the pumpkin (*cucurbita spp.*) seed cultivated from selected regions in Kenya and found that all groups of *Cucurbita spp.* seeds were rich in oil, fibre and protein. The fatty acid profile, was similar to that from sesame, sunflower and soybean oils which were rich in polyunsaturated fatty acids. The pumpkin seeds were found to consist crude fibre (11.69-24.85%), crude fat (31.9-41.37%), crude protein (14.05-33.29%) and carbohydrates (8.66-27.35%). Fatty acid profile showed a high content of unsaturated fatty acids and the dominant fatty acids were palmitic (1.16-20.81%), stearic (0.16-5.56%), oleic (15.56-30.79%), and linoleic acids (26.18-81.21%). The highest elemental minerals were potassium and sodium (124-335 and 70-148 mg/100 g). The α-tocopherol content ranged between 8.33 and 122.65 μg/g. They concluded that the pumpkin seed could be incorporated in foods to increase the nutritional value especially in diets that are deficient in the said nutrients.

Steiner-Asiedu *et al*., (2014) determined the nutrient composition and protein quality of four species of the *Curcubitaceae* family and found that the moisture, crude protein, fat and ash content of the seeds were 5.44-6.66, 30-36, 44-58 and 3.18-4.90%, respectively. Crude fibre was less than 2.5%. The *Curcubitaceae* seeds contained high amounts of Zn (5.0-7.1 mg/100 g), Cu (1.4-7.9 mg/100 g) and Fe (5.6-8.5 mg/100 g). All the seeds had good protein quality as judged by the PER (0.75-1.36) and NPU (46.10-69.10). They concluded that *Curcubitaceae* seeds were an important food resources and thus their consumption should be promoted.

Kwiri, *et al*., (2014) determined the proximate composition of pumpkin (*Cucurbita pepo*) seeds from Zimbabwe and found that *C. pepo* seeds were good alternative source of food with high nutritional content for instance proteins, lipids, fibres, carbohydrates and minerals (Mg, Ca, Zn, P and Fe).

Studies on chemical composition of some Egyptian and Chinese pumpkin (*Cucurbita maxima*) seed varieties indicated that moisture percentage in these varieties ranged between 3.38 to 5.53%, and contained crude fiber (4.12-4.69%), total lipids (35.2-41.95%), crude protein (34.19-39.75%), total carbohydrate (4.8-10.96%) and ash (4.22-5.3%). Amino acid analysis revealed that seeds of these varieties have higher level of glutamic acid ranging from 33.03 to 34.76 g/100 g protein (Al-Anoos *et al.*, 2015).

Pumpkin seed oil has received considerable attention in recent years due to its nutritional and health-protective value. Montesano *et al*., (2018) reported that pumpkin seed oils are interesting vegetable oils with important nutritional value, related to the presence of MUFA, PUFA, phytosterols, and carotenoids and it can be used as a preservative and as a functional ingredient in different areas, e.g., cosmetics, nutraceuticals and also can be incorporated into food formulations to benefit human health.

2.4 VALUE ADDED PRODUCTS FROM NUTS AND SEEDS

Many researchers have reported on different process developments on value added products from nuts and seeds such as roasted and salted snacks, seed spreads, butters and seed flour, which can be used to enhance the nutritional profile as well as increase the variability of food items.

2.4.1 Roasting and Salting

Roasting is a basic operation done to promote the flavour, to obtain desired color and changes in texture which ultimately increase the overall palatability of the products. Pumpkin seeds are usually served after salting and roasting. Pumpkin seeds are often disliked because of a thick fibrous outer shell that make mastication difficult and unenjoyable. Pumpkin seeds can be made more palatable by de-hulling the seeds, roasting, seasoning or even using alkaline maceration to soften the shell (Caramez *et* *al.*, 2008). Roasting has been classified into four categories for cocoa beans through sensory tests; slight (100-120°C), normal (120-140°C), strong (140-160°C), and over-roasted (>160°C) (Ramli *et al*., 2006). Depending on the roasting conditions chosen certain volatile chemicals may be higher or lower than others (Siegmund and Murkovic 2004). These volatile compounds can and have been correlated with sensory analysis to determine optimal roasting conditions and human perception of measured flavor volatile chemical concentrations (Leunissen *et al*., 1996).

Siegmund and Murkovic (2004) reported that the roasting process of pumpkin seeds at significantly higher than $100^{o}C$ are necessary to obtain the typical roasty and nutty aroma notes of the pumpkin seeds. Several flavour compounds have been reported to be formed during the roasting process, including compounds from the strecker degradation, lipid peroxidation, as well as the maillard reaction. The main chemical compounds that contribute to the roasted flavor of pumpkin seeds are pyrazines, aldehydes, alcohols, sulfur compounds and furan derivatives.

Savage *et al.*, (2005) studied the sensory evaluation of different levels of roasting of New Zealand grown hazelnuts. They designed to investigate three different roasting treatments, blanching, light roast and full roast using a conveyer type roasting oven set at 200°C. The roasted samples were then analysed for proximate contents and evaluated using a taste panel. The blanched nuts were appreciated for its colour but it was considered too chewy and bland in taste compared to the roasted nuts. Each one of the heat treatments gave an improved rating for all of the attributes measured. Roasting in the oven set at 200°C for 6 minutes (full roast) was the treatment appreciated most by all tasters. Analysis of the correlation coefficients showed that the overriding impression about the hazelnuts comes from the flavour of the nut followed by its texture.

Applequist *et al*., (2006) studied comparative fatty acid content of seeds of four Cucurbita species grown in a common garden. The four varieties were *Cucurbita pepo*, *C. moschata*, *C. maxima*, and *C. argyrosperma*. They observed that considerable variation in total lipid content and composition, within as well as among species and on average, *C. pepo* had the lowest whereas *C. maxima* had the highest proportion of saturated fatty acids.

Kahyaoglu and Kaya (2006) investigated the effect of heating time and temperatures on the moisture content, color and texture of sesame seeds roasted using conventional method at 120, 150, and 180^{o}C for 120 min. and observed that as the roasting temperature and time increased the moisture content of sesame seeds decreased for all roasting methods. The whiteness of seeds initially increased and then decreased during the roasting process and increase in the redness and yellowness of sesame seeds were observed by increasing temperature and exposure time. It also stated that sesame seeds become more fracture and less hard with the effect of roasting that might be evidence of crisp texture.

Ozdemir *et al.,* (2006) studied the quality characteristics of tehina prepared at different roasting powers (399, 665, 931, 1330 W) for different exposure periods (3-50 min.) and depths of sesame seeds (1-2 cm) using a domestic home microwave oven and compared with those prepared in a conventional tehina sample. They found that erratic fluctuations for all treatments and there were significant ($p<0.05$) differences in composition of fatty acids in tehina oils processed by microwave roasted methods. The acid value decreased with increasing roasting power between 399 and 1330 watts. A longer roasting time in each applied power resulted in more acid value; however the acid value of oil of tehina roasted in the conventional method was much less than the acid value of oil of tehina roasted through microwave treatments. The acid value of oil from microwave roasted seeds occurred in relation to increasing the depth of seeds in a dish from 1 cm to 2 cm and there was no pronounced difference in peroxide value for the oils of tehina from seeds roasted using different powers of the microwave oven or roasted by conventional methods.

Yoshida *et al.,* (2006) studied the microwave roasting effects on the oxidative stability of oils and molecular species of triacylglycerols in the kernels of pumpkin seeds in which pumpkin seeds of the two cultivars were exposed to microwaves for 6, 12, 20 or 30 min at a frequency of 2450 MHz using a microwave oven and they stated that with a few exceptions, microwave roasting for 12 min caused no significant loss or changes in the content of tocopherols and polyunsaturated fatty acids (PUFAs) in the kernels compared with those of an unroasted sample.

Sacilik, (2007) studied on the effect of drying methods on thin-layer drying characteristics of hull-less seed pumpkin (*Cucurbita pepo* L.) and reported that during the hot air drying experiments, the air temperature had a significant effect on the moisture content of samples and the time to reach the final moisture content for samples were found to be 9.0, 7.5 and 6.0 h at the air temperatures of 40, 50 and 60^{o}C, respectively. The increase in the air temperature resulted in a decrease in the drying time.

Kita and Figiel (2007) determined the effects of roasting temperature (100-180^{o}C), the roasting time (5-30 min) as well as the type of heating medium (hot air or vegetable oil) on sensory and physical characteristics of Walnuts. They found that the best sensory properties exhibited in the samples roasted at 130-150^{o}C for 15-20 min in both methods. Nuts roasted at lower temperatures showed too hard texture, light colour as well as taste and flavour typical of fresh nuts. Walnuts roasted at higher temperatures and for longer time were too dark and featured slightly burned taste and flavour.

Uquiche *et al*., (2008) studied the effect of microwave (MW) radiation on hazelnut seed (*Gevuina avellana* Mol) as a substrate pretreatment prior to oil extraction by pressing. In their study, samples were MW-treated at a frequency of 2450 MHz using a microwave oven. Six MW pretreatments were established, combining two potencies (400 W and 600 W) and three pretreatments (120, 180 and 240 s). They observed that extraction oil yield increased with MW pretreatments of hazelnut seed with respect to untreated seeds (control). Conditions of 400 W and 240 s were selected (45.3% of extraction oil yield). Observations under light microscopy showed that the microstructure of treated samples to 400 W and 240 s, was modified comparing with that of untreated samples, thereby improving the extraction efficiency. MW pretreatment had a positive effect on oxidative oil stability (induction time of 23.9 h) with respect to untreated oil (8.8 h).

Hamed *et al*., (2008) determined the effect of roasting on proximate composition and the levels of antinutritional factors, protein digestibility, minerals extractability and physiochemical properties of pumpkin seeds consumed in Sudan and found that processing of pumpkin seed significantly reduced protein content but its roasting significantly reduced tannin and phytic acid content to 125.01 and 56.1 mg 100^{-1} g with a concomitant improvement in protein digestibility. The roasting also significantly improved total and extractable minerals as well as physiochemical properties of the seed flours.

Nikzadeh and Sedaghat (2008) studied the physical and sensory changes in pistachio nuts as affected by roasting temperature and storage, in which the pistachio nuts were salted (in 15% NaCl (99.98%) in water (w/v) for 5 h) and roasted with conventional method at 90, 120 and 150°C for 30 min. The changes of moisture, textural properties including hardness, fracture force and firmness as a sensory attribute of salted roasted pistachio nuts were determined during 3 months of storage and found that increasing in the roasting temperature, moisture content, hardness and fracture force were significantly decreased.

Uysal *et al*., (2009) investigated the possibility of using microwave-infrared combination oven for roasting of hazelnut and they found that 2.5 min roasting time at 90% microwave power, 60% upper halogen lamp power, and 20% lower halogen lamp power to be optimum roasting conditions and hazelnuts roasted at this optimum point had comparable quality with conventionally roasted ones with respect to color, texture, moisture content and fatty acid composition.

Embaby, (2010) studied the effect of heat treatments (boiling, autoclaving, microwave cooking and roasting) on certain antinutrients and in vitro protein digestibility (IVPD) of peanut and sesame seeds. All heat treatments significantly reduced the levels of all the investigated antinutrients and improved the IVPD of peanut seeds. Of the attempted treatments, autoclaving, boiling, roasting-salting and oil-roasting were the most effective in reducing the levels of antinutrients and improving IVPD of peanut. Roasting in both brown and white sesame seeds partially eliminated the antinutrients (the reduction ranged from 15.6% to 61.2% in all antinutrients) and improved IVPD (increased by 10% and 9.1%, respectively). Tehineh (sesame butter-like) contained lower levels of antinutrients than raw sesame seeds and exhibited a higher IVPD (82.8%).

Shakerardekani *et al.*, (2011) studied the effect of roasting conditions on hardness, moisture content and colour of pistachio kernels paste. The effect of hot air roasting temperatures (90-190°C) and times (5-65 min) on the hardness, moisture content and colour attributes (‘L’, ‘a’ and ‘b’ values and yellowness index) of both whole-kernel and ground-state were investigated using response surface methodology (RSM) and found that hardness and colour attributes (‘L’ and ‘b’ values, yellowness index) of kernels and ‘a’ value of ground-state could be used to monitor the roasting quality of whole-kernels and recommended the roasting temperature and time of whole-kernel for the production of pistachio paste at 130-140°C and 30-40 min respectively.

Salting process improves the taste of the pumpkin seeds as a snack food. Jittanit, (2011) conducted salting process of the pumpkin seeds by soaking them in 25% w/w NaCl solution for 1 h, followed by draining the soaking solution, in the ratio between seeds and soaking solution as 5 kg of seed per 8 L of solution before hot-air drying with a tray dryer or a fluidized bed dryer (FBD) at drying temperatures of 60, 70 and 80°C. The FBD was operated at an air velocity of 1.8 m/s and a bed depth of 3 cm, whereas the seeds were dried as a single layer in the tray dryer with the air velocity over the sample in the range 0.23-0.28 m/s. According to the sensory test results, they found that the pumpkin seed samples dried in both the dryers were acceptable to the consumers to a comparable level with products sold in the supermarket.

Mariod, *et al.*, (2012) studied the effects of roasting and boiling on compositional and oil stability of safflower seeds and reported that the proximate chemical analysis as well as seed cake amino acids and oil fatty acids of safflower seeds can be affected by roasting and boiling. It was observed that boiling and roasting heat has significantly affected the stability of safflower oils as shown by peroxide values and absorbance in the FTIR spectra of safflower oil. Roasting at 180^{o}C for 10 min seems to be the best technique for the quality of safflower seeds. Roasting and boiling techniques improve the nutritional value of safflower seeds by increasing the total and few individual amino acids.

Ciarmiello *et al*., (2013) evaluated physical (colour, temperature, moisture) and chemical (taste, lipoxygenase activity, fatty acids, vitamins, sensory attributes) features of inshell nuts and kernels of three Italian hazelnut varieties (Tonda di Giffoni, Tonda Romana and Nocchione) after conventional oven or microwave roasting. It was found that microwave roasting for 360 and 450 seconds (for inshell nuts and kernels, respectively) allowed high peeling, good colour and taste of hazelnuts. Low energy input and short processing time were required as compared to conventional oven.

Das *et al.*, (2014) investigated the effect of microwave power levels (240, 360, and 480 W) and exposure times (30, 60, 90, 120, 180, and 240 s) on various properties of cashew nuts and analysed for moisture content, water activity, colour change, temperature rise, and compositional analysis (PV and FFA values). In their study, they found increase in microwave power level and exposure time caused a decrease in moisture content and increase in temperature and colour change. It was also observed that untreated cashew nuts exhibited higher peroxide and FFA values than short time microwave treated kernels under equivalent conditions and it increase the storability of nuts with no adverse effects on product quality for 6 months under ambient conditions as compared to untreated control samples which got infested/spoiled at the end of 1 month of storage. Short time microwave treatment of cashew nut did not promote rancidity which in turn helped in increased shelf life.

Ngozi and Nkiru (2014) evaluated the tannin, phytate and composition of different indigenous dishes based on pumpkin (*Cucurbita pepo*) such as raw seeds, uncooked pulp, leaves, roasted seeds and cooked pulp. The results of the analysis showed that the raw seed sample have about 0.26% tannin and 0.17% in roasted seeds while phytate was found to be 0.37% in raw seeds and 0.08% in roasted seeds. They concluded that in order to absorb all the bio-available nutrients, pumpkin pulp, leaves or seeds should be boiled or roasted to remove the anti-nutritional factors that might hinder utilization.

Hojjati *et al*., (2015) studied the effects of microwave roasting on physicochemical properties of pistachios (*Pistaciavera* L.) and investigated the effects of 480 and 640 W power levels and 2, 3 and 4 min of roasting pistachios using microwaves (MW) on the physicochemical properties in comparison with an Iranian traditional method of soaking in salty water and drying under hot-air at 135^{o}C for 20 min. They found that MW roasting of pistachios decreased water activity values, producing a softer nut and it was observed highest volatile concentration and sensory odour intensity scores for hot air roasted pistachios and MW at 640 W for 4 min. It also stated that roasting reduced the force needed to cut pistachios. Unsaturated fatty acid contents in MW roasted pistachios were higher (82.0%) than in hot-air produced nuts (74.7%) and the total phenolic content values increased with roasting time and with the MW power level. It was concluded that pistachios can be successfully roasted using microwaves as a fast and economical method.

Roasting of pumpkin seeds also help to relax nerve and muscles, strengthen bones and help with circulation. It was observed that phytosterol, present in the seeds helps to reduce LDL cholesterol levels, enhance the immune response and decrease the risk of cancers particularly prostate and ovarian. L-tryptophan, a compound which improves mood naturally and may even be effective against depression (Mala *et al*., 2015).

Soleimanieh *et al*., (2015) investigated the effect of roasting method and conditions on some physicochemical properties of sunflower seed kernel. Sunflower seed kernels were roasted under two different conditions, i.e. by microwave at 2450 MHz and 900 W and by electrical oven at 190^{o}C for different time periods. The results showed that roasting had significant effect on color as the kernels became darker over time. Roasting resulted in reduced moisture content, extracted oil percentage and hardness of the kernels while acidity and peroxide values increased as the time of roasting was prolonged. Fatty acid composition was found within the standard range for both methods. Regarding the sensory property, the kernels roasted by electrical oven showed more total acceptability than microwave roasted ones.

Folasade and Subomi (2016) determined the effects of soaking, blanching, autoclaving and roasting on the proximate, mineral, vitamin and anti-nutritional concentrations of almond kernel and reported that compared to untreated kernels, soaking, blanching and autoclaving decreased fat content but there was an increase during roasting of the kernels. Mineral concentrations were significantly increased by various treatments compared to raw kernel. However, roasting for 15 min resulted in highest increase in potassium (41.2%), calcium (45.1%), phosphorus (43.3%) and magnesium (43.6%). Vitamin content was significantly lowered upon processing. Vitamin loss was much pronounced during roasting (thiamine: 62.9-85.7 percent; riboflavin: 20-40 percent; niacin: 68.4-89.5 percent). A reduction trend was observed in the level of phytate, oxalate and tannin in the various samples with processing time, however, greatest reduction was observed in roasted samples compared to other treatments.

Moghaddam *et al*., (2016) investigated the effect of hot air roasting temperature (90, 120 and 150°C), time (20, 35 and 50 min) and air velocity (0.5, 1.5 and 2.5 m/s) on textural and sensory characteristics of pistachio nuts and kernels. They found that increase in roasting temperature decreased the fracture force (82-25.54 N), instrumental hardness (82.76-37.59 N), apparent modulus of elasticity (47-21.22 N/s), compressive energy (280.73-101.18 N.s) and increased amount of bitterness (1-2.5) and the hardness score (6-8.40). Higher roasting time also improved the flavor of samples. The results of the consumer test showed that the roasted pistachio kernels have good acceptability for flavor (score 5.83-8.40), color (score 7.20-8.40) and hardness (score 6-8.40).

2.4.2 Production Technology of Seed Spreads

Gills and Resurreccion (2000) determined the sensory properties of peanut butters stabilized with 0%, 1.5%, 2.0%, and 2.5% palm oil and hydrogenated vegetable oil and stored for 153 d at 0, 21, 30, and 45°C. They found that shelf-life of unstabilized peanut butter stored at 21, 30, and 45°C was 75 days and peanut butter with 2.5% palm oil had a shelf-life of 113 days. Regression analysis indicated a linear association for the attributes graininess, hardness, oiliness, mouthdryness, and spreadability with day, treatment, and temperature and no linear relationships existed between stickiness, adhesiveness, and gumminess with day, temperature, and levels of palm oil.

Singh *et al*., (2000) studied viscosity and texture attributes of reduced-fat peanut pastes (more than 50% fat reduction) using combinations of protein based simplesse-500TM (S), starch-based PCR 352-1 (P), and water (W) at 23°C. They found that reduced fat peanut pastes were lighter in color, easier to spread, and less firm and grainy than commercial reduced fat (30% fat reduction). Peanut butter and formulated pastes also showed similar adhesiveness and mouth-coating characteristics but were more oily than the control. They recommended the formulations to produce > 50% reduced fat peanut paste with acceptable textural and rheological characteristics.

Dubost *et al*. (2003) studied the consumer acceptability, sensory and instrumental analysis of peanut soy spreads. The textural properties of commercial peanut butter, commercial soy nut spread and three fonnulated peanut soy spreads with 8, 14, and 20% isolated soy protein were characterized using the texture analyser. Based on consumer acceptability testing (three-point scale), the commercial peanut butter and peanut soy spreads were found to be the acceptable products while the commercial soy nut butter was not acceptable.

Chu and Resurreccion (2004) studied the optimization of a chocolate peanut spread using response surface methodology (RSM). Six formulations with varying levels of peanut (25-90%). chocolate (570%) and sugar (555%) were processed using a three-component constrained simplex lattice design and found that optimum formulations for chocolate peanut spread were the combinations of 29-65% peanut, 9-41 % chocolate, and 17-36% sugar, adding up to l00%, at a medium roast.

Lima and Guraya (2005) studied on optimization of sunflower butter to produce wide range of flavor, aroma, color, and texture attributes. In their studies, 2 roasting levels (high and low), 2 sugar levels (7% and 9%), 2 salt levels (0.9% and 1.1%), and 3 stabilizer (Dritex-C) levels (1.6%, 1.7%, and 1.8%) were selected. Sunflower butter formulations were rated more healthy and less salty than peanut butter, but differences in the sweet attribute were small. Largest differences in the textural sensory attributes were denoted for the initial firmness and spread ability, with panel judging sunflower butter samples less spreadable and having a higher initial firmness. The panel rated sunflower butters more adhesive at the 1st bite; however, once chewed, sunflower butters were rated as less adhesive and higher on the ease of swallow. Cluster analysis on sensory data revealed the best formulation to have 1.8% stabilizer, 7% sugar, 1.1% salt, and a low roast level.

Mazaheri-Tehrani *et al*., (2009) studied the physicochemical and sensory properties of peanut spreads fortified with soy flour. Peanut spreads were replaced by whole soybean flour and soy nut flour at 0, 5, 15, 20 and 30% (w/w) and reported that replacing peanut spread by soy flour at 30% resulted in the lowest fat content. Regardless of type of flour used, replacing peanut spreads by soy flour increased the protein content of spreads and as the amount of soy flour increased, the average hardness increased. All peanut soy spreads received flavor ratings similar to control, while spreads containing 20% soy nut flour received the highest score for flavor and even more than control.

Radocaj *et al.*, (2011) studied on the optimization of the texture of fat-based spread containing hull-less pumpkin (*Cucurbita pepo* L.) seed press-cake, a by-product of the pumpkin oil pressing process, was used to formulate a fat-based spread which resembled commercial peanut butter; both in the appearance and in texture. Response surface methodology was used to investigate the effects of a commercial stabilizer and cold-pressed hemp oil added to the pumpkin seed press-cake, on the texture of the formulations using instrumental texture profile analysis. The responses were significantly affected by both variables tested in a central composite, two factorial experimental design on five levels. Strong and firm spreads, without visible oil separation were formed and had an appearance and texture comparable to commercial peanut butter. In terms of the primary food texture attributes such as hardness, cohesiveness and adhesiveness, determined by the instrumental texture analysis, the optimum combination of variables with 1-1.2% of added stabilizer and 20-40% of added hemp oil produced desirable spreads.

Emadzadeh *et al*., (2012) analyzed the effect of three fat replacers (xanthan gum, reihan seed gum, and balangu seed gum) and two sweeteners (sucrose and isomalt) on time dependent rheological properties of low-calorie pistachio butter using response surface methodology. In their study, the levels taken for reihan seed gum (0.01-0.023 wt. %), xanthan gum (0.06-0.1 wt. %), isomalt (0-1 wt. %), and sucrose (0.25-1 wt. %) respectively. They reported increasing sweetener level led to a significant decrease in consistency coefficients. However, the effect on the flow behavior index was not significant and the effect of gum concentration on the rheological parameters was not significant ($p \leq 0.1$), except for formulas prepared using balangu seed gum.

Lima *et al*., (2012) evaluated influence of cashew nut kernel grades and qualities in the characteristics of butter obtained by grinding kernels (89.9 g/100 g) with sugar (8.0 g/100 g), salt (0.1 g/100 g) and soy lecithin (2.0 g/100 g). They observed minor differences among the different grades and qualities. Nut kernels and corresponding butter showed high nutritive food value containing 18.3-26.9 g/100 g of protein and 35.7-52.6 g/100 g of oil. Fecal coliforms, *E. coli*, *Salmonella sp.* or coagulase positive Staphylococcus, were not detected and sensory acceptability of the butter made from B (butts), S (splits) and P (pieces) kernel grades were found to be of better quality.

Dhamsaniya and Patel (2013) studied on standardizing of peanut roasting process for peanut butter production. Based on instrumental measurements and sensory evaluation; it was found that the roasting of peanut kernels at 130ºC for 60 min was effective and its butter showed superior quality from the point of view of overall acceptability.

Shakerardekani *et al*. (2013a) studied on the development of pistachio (*Pistacia vera* L.) spread by using pistachio paste as the main component, icing sugar, soy protein isolate (SPI), and red palm oil (RPO), at different ratios. The highest mean scores of all the sensory attributes were depicted by spreads that were made without addition of SPI. It was found that the work of shear was 0 to 11 kg s for an acceptable spread. Sensory, spreadability, overall texture, spreadability, and overall acceptability were negatively correlated ($R>0.83$) with the work of shear of spreads. The findings indicated that the presence of RPO had a direct effect on the viscoelastic behavior of the pistachio spreads. The a values, which are related to the green color of the pistachio product ranged from 1.7 to 3.9 for spread without addition of RPO, and 4.0 to 5.3 in the presence of RPO.

Shakerardekani *et al*. (2013b) described the flow chart for the production of nut spread in 7 steps viz., pre-cleaning and shelling of nuts, grading, roasting, blanching, grinding (adding ingredients), cooling and packing.

Matsiko, *et al*. (2014) studied the comparison and evaluation of the quality and storage stability of soy and peanut butter. Soy butter and peanut butter were processed and stored for 40 days at ambient temperature (25^oC on average) in plastic containers and analysed for comparison of their proximate composition, sensory quality, oxidation and fungal stability. It was observed that soy butter was organoleptically as acceptable as peanut butter and provide human body more proteins than peanut butter but more susceptible to oxidation and less invaded by yeasts and moulds than peanut butter.

Shakerardekani, (2015) reported on factors affecting production, sensory properties and oxidative stability of nut butters and nut spreads. In addition to the ingredients (nuts, sugar, vegetable oil, and emulsifier), they concluded that the roasting conditions of nuts, particle size distribution and type and amount of stabilizer affected consumer acceptability, and oxidative stability of nut spreads.

Ruth (2015) studied on production technology of sesame fat spread. Central composite design (CCD) was used for planning experimental design. Four factors; roasting temperature (180-220^{o}C), roasting time (10-20 min.), sugar (4-6%) and lecithin (0.8-1.2) were selected and evaluated with respect to overall acceptability, texture profile analysis and L*, a*, b* color values. The best combination for product was found to be 180^{o}C, 20 min, 7.3% sugar and 1.2% of lecithin. The fatty acid profile of sesame fat spread was, palmitic acid 13.31 %, palmitic acid 0.17%, stearic acid 6.57%, oleic acid 40.07%, linoleic acid 37.95%, linolinic acid 0.31%, unknown fatty acids 1.62%. FFA (% oleic acid), peroxide value (meq/kg oil) of the sesame spread was 0.282 and 0.4 respectively. More than 50% of sesame spread has particles less than 6.55 µm. The oxidative induction time was 244 h at 22^{o}C. A four week storage study at 7^{o}C and 22^{o}C was carried out for its sensory, texture profile, L*, a*, b* color values and microbial parameters. Sesame fat spread was found stable and acceptable for 4 weeks at both storage conditions.

Abd-Elsattar and Abdel-Haleem (2016) performed the nutritional, textural, microbiological and sensory evaluation in soybean butters produced from defatted flour, cooked, sprouted and fried seeds. The commercial peanut butter served as control. They observed that soybean butters had the highest amounts of moisture (3.7-5.4 g/100 g) and protein (25.8-30 g/100 g) and commercial peanut butter had the highest amounts of fats (58.7 g/100 g) and energy (2768 KJ/100 g). The peroxide value of commercial peanut butter was lower (0.13-10.4 meq/kg) than that of soy butters (0.2-30.2meq/kg) over the storage period of 5 months/25^{o}C. For microbiological evaluation, sprouted and cooked soy butters were much stable than commercial peanut butter and texture analysis of sprouted soy butter was less hard (1.2 N) and the least adhesive (1.3 NS^{-1}) and chewy (0.48 N) of all treatments. Fried soy butter had the lowest overall acceptability (6.3) of sensory scores among all the soy butters; while sprouted soy butter had the highest (7.5) one.

Aydin and Ozdemir (2017) developed and investigated the carob flour enriched functional spread and evaluated textural, sensory, colour, and some nutritional properties of the product. Spread samples were prepared with major ingredients for optimisation and minor ingredients for improving texture and aroma. Major ingredients were carob flour and hydrogenated palm oil (HPO) and minor ingredients were commercial skim milk powder, soya flour, lecithin, and hazelnut puree. The amounts of minor ingredients (milk powder, 10%; soybean flour, 5%; lecithin, 1%; hazelnut puree, 4%) were kept in constant ratio (20%). They found that addition of hydrogenated palm oil (HPO) decreased the hardness work done (HWD) values in contrast to carob flour. Higher rates of carob flour were linked to lower lightness, greenness, and yellowness values. Spread was optimised at 38 g carob flour/100 g and 42 g hydrogenated palm oil/100 g spread and the formulation tended to receive the highest sensory scores compared to other spreads and showed closer instrumental spreadability values to control samples.

Shakerardekani (2017) studied the consumer acceptance and quantitative descriptive analysis of pistachio spread. Pistachio spread were made from pistachio paste, icing sugar, soy protein isolate and red palm oil and found that red palm oil has a direct effect on the sensory acceptance of pistachio spread($P<0.05$) and no significant difference was observed in all pistachio spread formulation attributes, except for sweetness ($P<0.05$).

2.4.3 Production Technology of Seed Flour

The pumpkin is economical and a nutrient dense source, the pumpkin seed flour fortified complementary food mix is economical, with highly acceptable sensory qualities and a rich nutritive (Adhau *et al*., 2015). Pumpkin seeds can be processed into flour which has a longer shelf-life.

El-Soukkary, (2001) studied on the evaluation of pumpkin seed products for bread fortification and pumpkin seed products (raw, roasted, autoclaved, germinated, fermented, pumpkin protein concentrate and pumpkin protein isolate) were incorporated into wheat flour to produce blends with protein levels of 15, 17, 19 and 21%. Results indicated that pumpkin seed products can be added to wheat flour up to a 17% protein for raw, roasted and autoclaved pumpkin meal, 19% level for germinated, fermented and pumpkin protein concentrate and 21% level for pumpkin protein isolate without a detrimental effect on dough or loaf quality. On the other hand, the addition of pumpkin seed proteins resulted in increasing protein, lysine and mineral contents compared to the control. While lysine and tryptophan were the first and second limiting amino acids in the control bread, tryptophan and lysine were the first and second limiting amino acids for raw, roasted, autoclaved, germinated and fermented pumpkin meal; valine and lysine and valine and total sulfur amino acids were the first and second limiting amino acids for pumpkin protein concentrate and isolate, respectively. In vitro protein digestibility improved when the pumpkin seed proteins were added.

Functional properties such as water absorption, fat absorption, emulsification properties and foam stability of defatted pumpkin seed flour has a good potential to food systems as bakery products and ground meat formulations. Pumpkin seeds are rich source of protein and lipid. The kernel flour possessed higher chemical score, essential amino acid index, and in vitro protein digestibility than paprika and watermelon seeds (El-Adawy *et al*., 2001).

Aryana *et al*., (2003) studied the functionality of palm oil as a stabilizer in peanut butter. Peanut butters without and with palm oil added at concentrations of 1.5, 2.0, and 2.5% (w/w of peanuts), and Fix-X™ (hydrogenated rapeseed and cottonseed oils as commercial control) were prepared and stored at 0, 21, 30, and 45°C for 23 weeks and found that palm oil improved the oil holding capacity of peanut butters, but had no effect on their adhesiveness and hardness characteristics. The unstabilized and palm oil-stabilized peanut butters were not as good as the Fix-X™ stabilized peanut butters with regard to their OHC, hardness, and adhesiveness characteristics.

Fagbemi, (2007) studied on the effects of processing on the nutritional composition of fluted pumpkin (*Telfairia occidentalis*) seed flour. The pumpkin seeds were boiled, fermented, germinated and roasted, dried at 50^{o}C, milled and sieved and found that fermentation and germination improved the protein quality while boiling and roasting reduced them. Giami (2003) also reported that improvement of the nutritional value of fluted pumpkin seeds by germination, boiling and defatting.

Hussain *et al.*, (2008) described the process for the production of flaxseed flour by cleaning the seeds manually, drying in air, roasting in microwave, milling, oil extraction, grounding the defatted seed again, sieving (200-mesh sieve) flour, packing, and storage at room temperature.

Fedha *et al.,* (2010) described the processing of pumpkin seed flour by collecting the seeds manually after cutting the pumpkins and washing with water followed by oven drying at 60^{o}C for 12 h using hot air rapid drying oven. The dried seeds were shelled to remove the kernels, which were ground to pass through a 60 mesh.

Fekria *et al*., (2012) investigated the nutritional and functional characterization of defatted seed cake flour of two sudanese groundnut (*Arachis hypogaea*) cultivars. Defatting of groundnut flour was done by placing in a conical flask and mixing with hexane, the mixture was stirred by mechanical shaker for 16 h and then filtered. The filtrate was washed again with hexane and filtered. The resulting filtrate was dried in an open air at room temperature. The dried flour was then ground to pass a 70 mesh screen and stored at 0°C for further analysis.

Ogunbusola *et al.,* (2012) studied on chemical and functional properties of full fat and defatted white melon (*Cucumeropsis mannii*) seed flours. Product was made by shelling the seeds manually, washing and later drying in a hot air oven at 50°C. The seeds were pulverized using a blender and sieved to pass through a 500 µm sieve. The flour obtained was divided into two portions, one part was defatted continuously for 8 h using n-hexane while the other part was packaged and kept in cool dry area for further analysis and found that *Cucumeropsis mannii* seed flour is a potential source of dietary oil, proteins and mineral elements for use in food formulation and has potential for use as functional ingredients in soups and frozen desserts.

Kar *et al.,* (2012) reported the utilization of protein concentrates from protein rich seed materials like soy, sesame and sunflower to make protein rich biscuits products and found higher protein content (15-20%) compared to the control market product (7%). In the study they prepared the defatted soy and sesame flour by drying decorticated soybeans and sesame, roasted in oven and then grinding it in mixer to get whole flour. Oil extraction was done by solvent extraction method. The deoiled cake was made solvent free and grinded in mixer to get defatted soy and sesame flour. Defatted sunflower flour was prepared by first extracting the oil from decorticated sunflower seeds by solvent extraction method. The deoiled cake was made solvent free and grinded in mixer to get deoiled sunflower flour. Sunflower flour thus produced was made chlorogenic acid free before use.

Adelekan Aminat *et al.*, (2013) reported that pumpkin seeds can be used to improve the nutritional composition (especially the protein content) of foods high in carbohydrate and low in other nutrients. Pumpkin seed can be used as a substitute for soya bean and other protein rich seeds. The pumpkin seed flour can be incorporated in flavored drink for enhancing the nutrients such as energy, carbohydrate and protein (Santhanam, *et al.*, 2014).

Nyam *et al*., (2013) determined the proximate composition, functional properties and antioxidant activity of pumpkin seeds and rind and also evaluated the effects of dietary fibre in pumpkin seeds and rinds on bread quality and properties. Formulations for bread substituted with 0%, 5% and 10% pumpkin seed and rind, respectively were produced. Sample which was formulated with 5% level of pumpkin rind bread gave the best overall acceptability and sensory attributes, followed by 5% pumpkin seed bread. Total dietary fibre, total phenolic compounds and DPPH radical scavenging activity in breads substituted with 5% pumpkin seed and 5% pumpkin rind flour were higher than the values in control bread and concluded that pumpkin seeds and rinds can be used as dietary fibre sources in bakery, which can be use to reduce the total carbohydrate content of the end product. Pumpkin seeds and pumpkin rind flour can be added into bakery products to enhance the texture, flavour and nutritional value of the food product.

Revathy and Sabitha (2013) studied the development, quality evaluation and popularization of pumpkin seed flour incorporated bakery products and reported that, incorporation of pumpkin seed flour in bakery products increased its nutritive value and also adds a different variety in bakery products which can be used as a snack item for all age groups. Nutrition education and popularization of pumpkin seeds and pumpkin seed flour incorporated bakery products to homemakers showed significant change in their usage of pumpkin seeds in cooking.

Yang *et al.*, (2013) evaluated the shelf-life of almonds roasted with three different approaches, namely infrared, sequential infrared and hot air and regular hot air. In their study, nine medium roasted almond samples were produced by the aforementioned heating methods were processed at three different temperatures (130, 140 and 150^{o}C), packed in paper bags and then stored at 37^{o}C for three, six or eight months. They observed no significant difference in moisture content and water activity among the almond samples processed with different roasting methods and stored under the same conditions. GC/MS analysis showed that aldehydes, alcohols, and pyrazines were the main volatile components of almonds. Aliphatic aldehydes such as hexanal, (E)-2-octenal, and nonanal were produced as off-odours during storage. Although the overall quality of roasted almonds produced with sequential infrared and hot air heating was similar during the first three months of storage, their peroxide value and concentration of aliphatic aldehydes differed significantly for different roasting methods and increased significantly in all roasted samples during storage.

Eke- Ejiofor *et al.,* (2014) studied on the effect of processing methods on the functional and compositional properties of jackfruit seed flour and reported that roasting prior to flour production gave the best results by increasing protein availability and the water absorption capacity with reduced oil absorption.

Makinde and Akinoso (2014) investigated the effect of roasting and fermentation on the nutritional quality of sesame flour. They found that roasting and fermentation could enhance the nutritional quality of sesame seeds without detrimental effect on human. Roasted and fermented sesame seeds contained high protein, fat and energy values with nutritionally valuable minerals comparable with known protein-rich plant foods, such as groundnut and soybean and processing also enhanced the amino acid and fatty acid profile of sesame.

Silva *et al*., (2014a) studied chemical constituents of the pumpkin seeds flour and found that the pumpkin seeds flour had high contents (g 100 g-1 of dry matter - DM) of protein: 28.37; lipids: 33.27 and dietary fiber: 31.65, and minerals (mg 100 g-1 DM) phosphorus: 780; manganese: 4.45 and zinc: 9.25. Among the bioactive compounds, phytate was found to be high content (2.66 g 100 g-1 DM) and oleic acid (42.33%) among the fatty acids as the major one. They concluded that the pumpkin seeds flour was a good source of nutrients and fiber, and thus can be used in the preparation of food products, enriching the diet.

Silva *et al.,* (2014b) reported that the use of pumpkin seeds flour in the formulation of the cereal bars enhances the products with a higher nutritional value, meeting the current demands of the consumer market with a low sodium content and energy value, and these products can be classified as light products with high contents of dietary fiber, and they are therefore an alternative to consumers of healthy and functional food.

Borhade, (2014) reported on the extraction of oil from *Cucurbita mixta* seeds by soxlet method using n-hexane as a solvent at $40^{o}C$ and found that 46 % of oil yield and seed oil had 94 % pure triglyceride esters and the rest free fatty acids.

Wordu *et al*., (2016) investigated the effect of blending wheat flour with fluted pumpkin (*Telfairia accidentalis* Hook) seed flour at levels of 0-25% on the dough quality and chemical properties of bread using grindamyl alpha amylase enzyme as an improver. In their study, bread loaves were baked using the straight-dough procedure and evaluated for baking quality, chemical composition and sensory properties. The results showed that the loaf volume of bread decreased from $5630cm^3$ to $5200cm^3$ for the 0.4% level of dough improver representing 25% decrease while the 1% level of dough improver showed a decrease in loaf volume from $5500cm^3$ to $4500cm^3$ representing 18% reduction. Sensory evaluation showed that there were no significant differences between 5 and 10% substitution levels of the fluted pumpkin flour and the control and the values obtained showed that the flour blends can still produce acceptable bread but the 0.4% level of the alpha amylase enzyme gave a better loaf volume than the 1% level.

CHAPTER III

MATERIALS AND METHODS

This chapter deals with the materials and methodologies employed in the present study. The present investigation pertains to the development of processes for the preparation of value added products from pumpkin seeds, besides the description of different materials used. The experimental design and the statistical analysis are explained along with the procedures for quality determination. The entire study was conducted at College of Food Processing Technology and Bio-energy, Anand Agricultural University, Anand, Gujarat. The experiments were carried out in three replications and average values were reported.

3.1 RAW MATERIALS

3.1.1 Pumpkin Seeds

Whole pumpkin seeds were procured from single source from local market, Anand, Gujarat. Seeds were cleaned manually to remove any unwanted particles like damaged seeds, undersized and immature seeds and other extraneous materials. Cleaning was done by winnowing and hand sorting and then dehulled manually. Samples were then packed in airtight plastic bags and stored in refrigerator till further analysis. Whole pumpkin seeds and pumpkin seed kernels are shown in Plate 3.1.

Plate 3.1: Whole pumpkin seeds and pumpkin seed kernels

3.1.2 Other Materials

Other materials hydrogenated vegetable oil, soya lecithin, sugar, salt, spices (cinnamon, nutmeg, ginger powders) were purchased from standard suppliers and local market, Anand.

3.2 PHYSICO-CHEMICAL CHARACTERISTICS OF PUMPKIN SEEDS

3.2.1 Physical Characteristics

Three principal diameters viz. length, width and thickness of whole pumpkin seeds and kernels were measured by using a digital micrometer with an accuracy of 0.01 mm (0-25mm). Measurement was made on 100 randomly drawn seeds from the test samples for both whole pumpkin seeds and kernels. These values were used to calculate the geometric mean diameter of pumpkin seeds by using standard relationships (Mohsenin, 1986).

Plate 3.2: Digital micrometer

3.2.1.1 Geometric mean diameter

The geometric mean diameter (Dg, mm) of the seeds were calculated using the following relationship (Mohsenin, 1986).

$$Geometric\ mean\ diameter\ (Dg) = (LWT)^{1/3} \qquad \text{…. (3.1)}$$

Where, L is the length, W is the width and T is the thickness (all in mm).

3.2.1.2 True density

The true density defined as the ratio of mass of the sample to its seed volume, was determined using the water displacement method. Fifty milliliter of water was placed in a 100 ml graduated measuring cylinder and 5 g seeds were immersed in that water. Owing to the short duration of the experiment and the nature of the skin of the seed which did not allow water to be absorbed easily, the seeds were not coated to prevent moisture adsorption. The amount of displaced water was recorded from the graduated scale of the cylinder. The ratio of weight of seeds to the volume of displaced water gave the true density (Mohsenine, 1986).

$$True\ density\ = \frac{Weight\ of\ sample\ in\ air\ (g)}{Volume\ of\ displaced\ fluid\ (cm3)} \qquad \text{…. (3.2)}$$

3.2.1.3 Bulk density

The bulk density was determined by filling the samples into cylinder of known volume to overflowing and removing excess samples by rolling glass rod on the rim of the cylinder without compacting the seeds. To achieve uniform bulk density, the measuring cylinder was tapped to consolidate as reported by Mohsenin (1986). Ratio of mass and volume of the samples were recorded as bulk density.

$$Bulk\ density\ (kg/m3) = \frac{Weight\ of\ known\ volume\ of\ sample}{Volume\ of\ container} \qquad \text{... (3.3)}$$

3.2.1.4 Porosity

The porosity (ε) of bulk seeds was computed from the values of true density and bulk density using the relationship given by Mohsenin (1986).

$$Porosity\ (\varepsilon) = 1 - \frac{Bulk\ density}{True\ density}\ x\ 100 \qquad \text{…. (3.4)}$$

3.2.1.5 Determination of husk content

Husk content was estimated by dehulling 250 g of pumpkin seed manually. Husk content was calculated in percentage of weight of whole pumpkin seed as per the following expression:

$$Husk\ content\ (\%) = \frac{Weight\ of\ Husk}{Weight\ of\ whole\ pumpkin\ seed}\ x\ 100 \qquad \text{…. (3.5)}$$

3.2.1.6 1000 seed weight

1000 seed weight of both whole and dehulled pumpkin seeds were determined in triplicate by weighing 1000 seeds in an electronic balance (Mettler, Japan, p=0.001g).

3.2.2 Chemical Characteristics

3.2.2.1 Determination of moisture

Gravimetric method was used for determination of moisture (AOAC, 2012). Moisture was estimated by drying the weighed sample (5g) to a constant weight in hot air oven (Make: NOVA Instruments Pvt. Ltd., Ahmedabad) at 105°C. The dried sample was then cooled to room temperature in a desiccator prior to weighing. The percent moisture content was calculated as follows:

$$Moisture\ content\ (\%\ w.b.) = \frac{w1 - w2}{w1} x\ 100 \qquad \text{... (3.6)}$$

Where,

w1 = Initial weight of sample (g) and w2 = Weight of sample after drying (g)

3.2.2.2 Determination of crude protein

Crude protein content was estimated by Micro-Kjeldahl method (AOAC, 2012). About 0.2-0.3 g of sample was digested with 10 ml concentrated sulphuric acid (H_2SO_4) containing 3 g of catalyst mixture (K_2SO_4: $CuSO_4$, 2.5:0.5) at 400°C. The digested sample was distilled with 40% NaOH (35 ml for 45 second) and liberated ammonia was trapped in 4% boric acid solution (10 ml for 10 second), using mixed indicator (methyl red: bromocresol green, 1:5). The condensate was titrated with standard 0.1 N HCl until blue color disappeared. The percent nitrogen was estimated and the protein content was quantified by multiplying with the factor 6.25.

$$Nitrogen\ (\%) = \frac{14\ x\ (T - N)\ x\ Normality\ of\ HCl\ x\ 100}{W\ x\ 1000} \qquad \text{.... (3.7)}$$

$$\%\ Protein = \%\ Nitrogen\ x\ 6.25$$

Where, T = Titre value of sample, N = Titre value of blank sample and W = Weight of Sample

3.2.2.3 Determination of ash

Ash content was determined according to the procedure described by Rangana (1986). Sample weight of 10 g was taken and incinerated first on slow flame burner. Then it was ignited in a muffle furnace at 550°C until light grey ash was obtained (about 4 to 6 h). It was cooled in desiccator. The difference in weight was recorded. The percentage of total ash was calculated as follows:

$$\text{Ash}\ (\%) = \frac{\text{w2} - \text{w1}}{\text{w3}} x\ 100 \qquad \text{... (3.8)}$$

Where, w1 = weight of empty crucible (g), w2 = weight of crucible + Ash (g), w3 = weight of sample (g)

3.2.2.4 Determination of crude fibre

Fibra plus instrument (Make: Pelican Equipments, Chennai) as shown in plate 3.6 was used for estimation of crude fibre content. About 2 g of the sample was treated with 1.25 % H_2SO_4 (150 ml approx.) followed by 1.25 % NaOH (150 ml approx.) and washed thoroughly with distilled water (150 ml approx.) after each treatment. Neutral residue left over was dried and weighed and then

Plate 3.3: Hot Air Oven

Plate 3.4 Muffle Furnace

Plate 3.5 Kel-Plus Assembly

Plate 3.6 Fibra-Plus

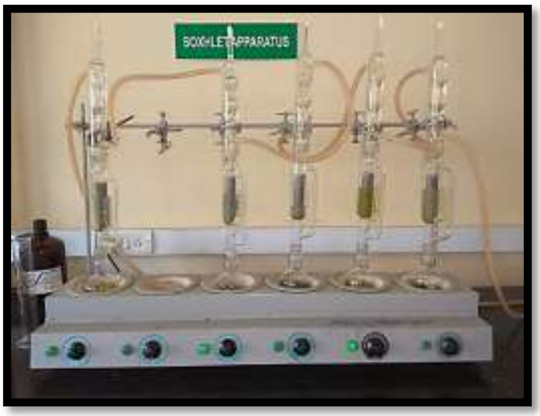

Plate 3.7 Soxhlet Apparatus

ignited into muffle furnace. From the loss in weight of the residue, the percentage of crude fibre was calculated using following formula given by Ranganna (1986).

$$\text{Crude fiber } (\%) = \frac{\text{w2} - \text{w3}}{\text{w1}} x\ 100 \qquad \text{…. (3.9)}$$

Where, w1 = weight of sample (g), w2 = weight of crucible + sample after washing and drying (g), w3 = weight of crucible + ash (g)

3.2.2.5 Determination of crude fat

Crude fat content of sample was determined using a Soxhlet apparatus (Make: Pelican Equipments, Chennai) as shown in Plate 3.7. About 2 g of sample was transferred to a thimble and plugged with cotton. The plugged thimble was placed into the fat extraction tube of the soxhlet apparatus. Approximately 125 ml n-Hexane was poured through the sample into the soxhlet flask attached at bottom of extraction tube. The condenser was attached at the top of the extraction tube. The sample was extracted for 5 h. At the end of extraction period, thimble was removed and most of the solvent was distilled off by allowing it to collect in the soxhlet tube. Remaining solvent was evaporated at low temperature. Then it was dried at 100°C for 1 h, cooled and weighed. The percentage of fat in the sample was calculated as follows:

$$Crude\ fat\ (\%) = \frac{Weight\ of\ the\ hexane\ soluble\ material\ (g)}{Weight\ of\ the\ sample\ (g)} x\ 100 \qquad \text{…(3.10)}$$

3.2.2.6 Determination of carbohydrate

Carbohydrate content was computed by difference. It was calculated using the formula below.

$$\%\ Carbohydrate = 100 - \%(moisture + crude\ protein + ash + crude\ fibre + crude\ fat) \qquad \text{...(3.11)}$$

3.2.2.7 Determination of phytic acid

The phytic acid content of the pumpkin seeds were analyzed according to the method given by Lolas and Markakis (1975). The 2.0 g of the finely ground sample was weighed into a 250 ml conical flask and 10 ml of 2% concentrated HCl was added into it. The content was kept for 3 h at room temperature with continuous stirring and then filtered with a Whatman No. 1 filter paper. 5 ml of the filtrate was transferred in 250 ml conical flask. 1 ml of the distilled water was added into the sample to give proper acidity. After that, 1 ml of 0.3% ammonium thiocynate solution was added which acted as an indicator. The content was titrated with standard Iron (II) chloride solution. End point was observed to be yellow colour. The phytic acid present in the sample was calculated using following formula.

$$\%\ Phytic\ acid = y\ x\ 1.19\ x\ 100 \qquad \text{......(3.12)}$$

Where, y = titre value x 0.00195

3.2.2.8 Estimation of fatty acid profile

To determine the fatty acid composition of the seeds, gas liquid chromatography (GC) was used. Fatty acid methyl esters (FAMES) were prepared as per the method of Christie (1992). Fatty acid profile analyzed at SICART Sardar Patel University, V. V. Nagar.

About 1-2 drops of extracted fat from seeds was taken in a clean screw capped tubes and 5ml of 0.5N methanolic sodium methoxide was added. The tube was capped and heated in a boiling water bath for 10 minutes. After cooling 0.5ml of boron trifluoride (14% BF3) was added, and was again heated in a similar manner for 5 minutes for complete methylation and tube was allowed to cool at room temperature.

Spectroscopic grade hexane (2ml) was added to the tube, mixed on cyclo mixer and 1µl of hexane containing extracted fatty acid methyl esters were used in Gas Chromatograph (GC) (MS Auto system XL, Perkin-Elmer) equipped with a flame ionization detector using a wax 30m (length) capillary column substrate with BP 225. Column was operated with programming from initial temperature of 65ºC which was increased to 220ºC at 10ºC per minute, the injection temperature was 250ºC while detector temperature was 300ºC, using split ratio 1:60 with a nitrogen carrier gas flow rate of 45ml/minutes while air flow rate was 450ml/minutes through the column. Total analysis time taken for all individual FAMES was about 48 minutes. Methyl esters were identified by comparing the retention time and peak area of the unknown with those of the fatty acid methyl ester standards.

Calculations

The fatty acid methyl esters were measured and identified by comparing retention time with the retention time of the standards. The area under the peak was calculated by the following formula:

Area of each fatty acid = Height of peak x width at half the height.

Per cent of individual fatty acid was calculated from the ratio of the area occupied by the individual fatty acid to total peak area.

3.2.2.9 Estimation of minerals

Mineral contents of sample was determined by using Inductive couple plasma-optical emission spectrometry, ICP-OES (Model Optima 7000 DV) at the micronutrient research centre, Anand Agricultural University, Anand. One g of sample was kept for overnight digestion adding 10 ml of concentrated nitric acid (HNO_3). Sample was heated inside the fumehood at 70-80^oC after adding 15 ml of diacid mixture (concentrated nitric acid: percholic acid, 2:1) until the solution become colourless. The solution was cooled, filtered through cotton cloth. Solution was made upto 50 ml in volumetric flask using ultrapure water. Finally sample was used for estimation of minerals.

Plate 3.8 Inductive couple plasma-optical emission spectrometry (ICP-OES)

3.2.2.10 Thermal characteristics

Thermal characteristics of pumpkin seed flour was analyzed at SICART, Sardar Patel University, V. V. Nagar using a differential scanning calorimeter (Make: Perkin Elmer, DSC-8000). A flow of nitrogen gas (20 ml/min) was used in the cell cooled by intra cooler.

The sample (4–5 mg) was weighed in open solid fat index (SFI) aluminium pans. An empty similar pan was used as reference. The sample and reference pans were then placed inside the calorimeter and kept at 0°C for 1 min. Samples were then kept at 0°C for 1 min, and then raised again at the same rate up to 250°C. Scans were performed at 10 °C/min. Thermal oxidation measurements were performed in duplicate.

3.3 STANDARDIZATION OF ROASTER TO DEVELOP VALUE ADDED PRODUCTS FROM PUMPKIN SEED

3.3.1 Preliminary Trials

During the preliminary trials with whole and dehulled seeds, the roasted whole pumpkin seeds were found to be unacceptable and this was due to the too much fibrous material on hull and organoleptically they were not acceptable in sensory evaluation. Hence, further studies were carried out from pumpkin seed kernels.

3.3.2 Standardization of Roaster for Pumpkin Seed Kernels

Roasting of pumpkin seeds is an important process parameter which promotes the flavour, desired colour, texture and ultimately increasing the palatability of the products. The important parameters involved in standardization of roasting were the temperature and time of roasting. Four different types of roasters (Plate 3.9) were used for the study, namely, halogen oven ($R_{1,}$ Model: Infiniti Cook^{TM} Halogen Oven 3513i, Voltage: 220-240 V AC, 50 Hz, Wattage: 130 W, Capacity: 12 L), hot air oven ($R_{2,}$ Make: NOVA Instruments Pvt. Ltd., Ahmedabad), microwave oven ($R_{3,}$ Model: 30SC3, 2450 MHz) and sand roasting (R_4). The process flow chart for the standardization of roaster for pumpkin seed kernels is given in Figure 3.1.

Based on the preliminary experiments conducted, the levels of roasting temperature and roasting time for different roasters were taken for standardization of pumpkin seed kernels. The independent parameters i, e, roasting temperature and roasting time were carried out to evaluate on dependable parameters i, e, sensory evaluation (colour and appearance, taste, odour, overall acceptability), texture profile analysis (hardness, fracturability) and phytic acid content for each of the roaster. Optimized sample of each of the four roasters were then compared and the best roaster was selected for roasting pumpkin seed kernels for further preparation of value added products.

3.3.3 Experimental Design

Completely randomized design (CRD) was adopted for experimental design and the optimization was carried out by using Design Expert 10.0.1 software. Based on the reviews and preliminary experiments conducted, the independent parameters namely roasting temperature (X_1) and roasting time (X_2) were selected for the study. The general factorial design with three levels were used. The process was optimized on the basis of two input variables whose interactions were studied on seven responses (colour and appearance, taste, odour, overall acceptability, hardness, fracturability and phytic acid). The levels of various input variables selected for different types of roasters were as follows: roasting temperature: 180, 190 and 200^oC, roasting time: 4, 6, 8 min for halogen oven. Similarly, for hot air oven, microwave oven and sand roasting, the roasting temperature and roasting time were 150, 160 and 170^oC for 10, 20 and 30 min; P-80 , P-90 and P-100 microwave power level (%) for 3, 4, and 5 min; 150, 160, 170^oC for 2, 3 and 4 min respectively. The independent parameters for different roasters with coded values are shown in Table 3.1. All the responses were analyzed in triplicates and the average values were reported. Twenty seven runs were carried out to select the best combination of input variables which could result in most desirable combination. The test factors were coded according to the following equation:

$$x_i = \frac{X_i - X_o}{\Delta X_i} \; X\,100 \qquad \text{... (3.13)}$$

Where, x_i = dimensionless value of an independent variable, X_i = level or value of controllable factor i in original units of measurement, X_0 = midpoint of the range of values for factor i and ΔX_i = range of values over the factor i will vary

Low and high levels of each factor were coded as –1 and +1 keeping 0 as midpoint. Since various responses were the result of various interactions of independent variables, the following second order polynomial regression equation was fitted to the experimental data of all responses

$$\boldsymbol{y = \beta_0 + \sum_{j=1}^{k} \beta_j X_j + \sum_{j=1}^{k} \beta_{jj} X_j^2 + \sum_{x-1}^{j=1} \sum_{j=2}^{k} \beta_{ij} X_i X_j + \in} \qquad \text{... (3.14)}$$

Where, y = predicted response, β_0 = a constant, β_i = linear coefficient, β_{ii}= squared coefficient, β_{ij}= interaction coefficient and X_i and X_j are the independent variables and $\in$ is noise or error

Full second order model was fitted in various responses and independent variables using least square regression analysis. Regression analysis and analysis of variance (ANOVA) was used for fitting the models represented by Equation (3.14) and to examine the statistical significance of the model terms. Testing the adequacy of the model at 1%, 5% and 10% level of significance were done based on coefficient of determination (R^2) and Fisher's F-test. If the model was adequate, then the effects of independent variables on responses were interpreted.

Fig. 3.1: Flow chart for the standardization of roaster for pumpkin seed kernels

(a) Halogen Oven **(b) Hot Air Oven**

(c) Microwave Oven **(d) Sand Roasting**

Plate 3.9 Different types of roasters used for roasting pumpkin seed kernels

3.3.4 Evaluation of Roasted Pumpkin Seed Kernels

For optimization of roaster for roasting pumpkin seed kernels, sensory evaluation, texture profile analysis and phytic acid content were determined. The phytic acid content of the roasted pumpkin seed kernels were determined by the method described in section 3.2.2.7. Sensory evaluation and texture profile analysis were conducted by using the methods described below.

3.3.4.1 Sensory evaluation

The sensory evaluation of roasted pumpkin seed kernels was conducted by a panel of 10 members comprising of staff and post graduate students. The judges were given a control sample and experimental samples. The samples were coded to avoid any biased judgement. The control sample and the test samples were prepared as per the experimental plan. Each product was evaluated and mean scores were calculated.

Table 3.1 Independent variables in optimization of roasting conditions for pumpkin seed kernels in different roasters

Variables \ Codes		Halogen oven (R_1)			Hot air oven (R_2)			Microwave oven (R_3)			Sand roasting (R_4)		
		-1	**0**	**+1**	**-1**	**0**	**+1**	**-1**	**0**	**+1**	**-1**	**0**	**+1**
Roasting temperature (ºC)	X_1	180	190	200	150	160	170	P-80	P-90	P-100	150	160	170
Roasting time (min)	X_2	4	6	8	10	20	30	3	4	5	2	3	4

Table 3.2 Actual and coded values of parameters for different roasters (Experimental runs)

Run	Halogen oven (R_1)		Hot air oven (R_2)		Microwave oven (R_3)		Sand roasting (R_4)	
	Roasting temperature (ºC)	Roasting time (min)	Roasting temperature (ºC)	Roasting time (min)	Roasting temperature (ºC)	Roasting time (min)	Roasting temperature (ºC)	Roasting time (min)
1	190 (0)	4 (-1)	150 (-1)	20 (0)	P-80 (-1)	4 (0)	160 (0)	2 (-1)
2	200 (1)	8 (1)	160 (0)	30 (1)	P-90 (0)	4 (0)	160 (0)	4 (1)
3	190 (0)	8 (1)	160 (0)	30 (1)	P-90 (0)	5 (1)	160 (0)	3 (0)
4	180 (-1)	8 (1)	150 (-1)	30 (1)	P-80 (-1)	5 (1)	150 (-1)	2 (-1)
5	190 (0)	6 (0)	150 (-1)	30 (1)	P-80 (-1)	5 (1)	150 (-1)	3 (0)
6	180 (-1)	4 (-1)	150 (-1)	10 (-1)	P-100 (1)	4 (0)	160 (0)	3 (0)
7	200 (1)	6 (0)	170 (1)	30 (1)	P-100 (1)	5 (1)	150 (-1)	4 (1)
8	180 (-1)	4 (-1)	170 (1)	10 (-1)	P-100 (1)	5 (1)	150 (-1)	2 (-1)

9	180 (-1)	6 (0)	160 (0)	30 (0)	P-90 (0)	5 (1)	150 (-1)	2 (-1)
10	180 (-1)	8 (1)	170 (1)	20 (0)	P-100 (1)	5 (1)	160 (0)	3 (0)
11	190 (0)	8 (1)	170 (1)	10 (-1)	P-80 (-1)	4 (0)	170 (1)	2 (-1)
12	180 (-1)	6 (0)	170 (1)	30 (1)	P-100 (1)	3 (-1)	170 (1)	2 (-1)
13	200 (1)	8 (1)	160 (0)	30 (1)	P-100 (1)	3 (-1)	170 (1)	4 (1)
14	200 (1)	4 (-1)	170 (1)	20 (0)	P-80 (-1)	4 (0)	160 (0)	2 (-1)
15	190 (0)	4 (-1)	160 (0)	20 (0)	P-90 (0)	3 (-1)	170 (1)	4 (1)
16	180 (-1)	8 (1)	160 (0)	10 (-1)	P-90 (0)	4 (0)	160 (0)	2 (-1)
17	190 (0)	6 (0)	150 (-1)	10 (-1)	P-80 (-1)	3 (-1)	170 (1)	2 (-1)
18	190 (0)	6 (0)	160 (0)	20 (0)	P-90 (0)	5 (1)	150 (-1)	3 (0)
19	200 (1)	4 (-1)	150 (-1)	10 (-1)	P-90 (0)	4 (0)	170 (1)	3 (0)
20	200 (1)	8 (1)	150 (-1)	20 (0)	P-80 (-1)	5 (1)	150 (-1)	4 (1)
21	190 (0)	8 (1)	160 (0)	10 (-1)	P-90 (0)	3 (-1)	150 (-1)	3 (0)
22	180 (-1)	4 (-1)	170 (1)	10 (-1)	P-90 (0)	3 (-1)	170 (1)	4 (1)
23	200 (1)	6 (0)	170 (1)	30 (1)	P-80 (-1)	3 (-1)	160 (0)	4 (1)
24	180 (-1)	6 (0)	170 (1)	20 (0)	P-100 (1)	4 (0)	170 (1)	3 (0)
25	200 (1)	4 (-1)	150 (-1)	20 (0)	P-100 (1)	5 (0)	160 (1)	4 (0)
26	190 (0)	4 (-1)	160 (0)	10 (-1)	P-100 (1)	5 (-1)	170 (-1)	2 (1)
27	200 (1)	6 (0)	150 (-1)	30 (1)	P-80 (-1)	3 (-1)	170 (0)	3 (1)

product was evaluated and mean scores were calculated. Panels were asked to score the samples for colour and appearance, flavor, taste, odour and overall acceptability based on 9-point hedonic scale. The organoleptic scorecard used for the evaluation has been given in Appendix–II.

Plate 3.10 Sensory evaluation of roasted salted pumpkin seed kernels by different panellists

Plate 3.11 Texture analyzer

3.3.4.2 Texture profile analysis

The textural quality of the roasted pumpkin seed kernels of each treatments were determined using Texture Analyzer (Stable Micro Systems, U.K.; Model: TA HD plus) as shown in the Plate 3.10. The sample were placed horizontally on the plate and double compression was applied using cylinder probe. The load cell used for this test was 100 kg, the test speed, probe diameter and penetration index of the probe are 0.2 mm/sec, 5 mm and 1.4 mm and 50% of the sample thickness respectively. The test was performed in three replications. Hardness (peak force of first compression cycle), cohesiveness (ratio of positive areas of second cycle to area of first cycle) were determined. The results were recorded in terms of TPA curve

The optimized parameters for each of the roaster was calculated and on the basis of sensory evaluation scores, texture profile analysis and phytic acid content, the best roaster was .considered for further studies.

3.4 DEVELOPMENT OF ROASTED SALTED PUMPKIN SEED KERNELS

3.4.1 Preparation of Roasted salted pumpkin seed kernels

Roasted salted pumpkin seed kernels were prepared using pumpkin seed kernels with different combinations of moisture conditioning and salt solution. The process of preparation of roasted salted pumpkin seed kernels is shown in Figure 3.2. Cleaning of seeds was done manually to remove unwanted particles like damaged seeds, light materials, undersized and immature seeds and other extraneous materials. Seeds were dehulled manually. Moisture conditioning and salt addition was done simultaneously. Initial moisture content of the pumpkin seed kernels was determined by drying 15 g of the sample, to a constant weight in hot air oven at 105°C. After determining initial moisture content, the samples were conditioned to 5, 10 and 15 % moisture content (w.b.) by adding measured amount of water (10, 15, 20% salt concentration). The following formula was used to calculate the amount of water to be added to the pumpkin seed kernels (Obi *et al.*, 2014).

$$Q = \frac{A\,(b - a)}{100 - b} \qquad \text{... (3.15)}$$

Where, Q = Mass of water to be added (g), A = Initial mass of sample (g), a = Initial moisture content of the sample (% w.b.), b = Final (desired) moisture content of the sample (% w.b.)

To ensure uniform moisture conditioning, each sample was thoroughly mixed and wrapped with muslin cloth and were tempered overnight in a refrigerator to enable the moisture to distribute uniformly throughout the samples. The conditioned samples were then subjected to roasting. Roasting of samples were done using the optimized roaster as explained in section 3.3. The roasted samples were cooled to room temperature before packing in aluminium laminated pouches and stored at ambient temperature (30±2^{o}C).

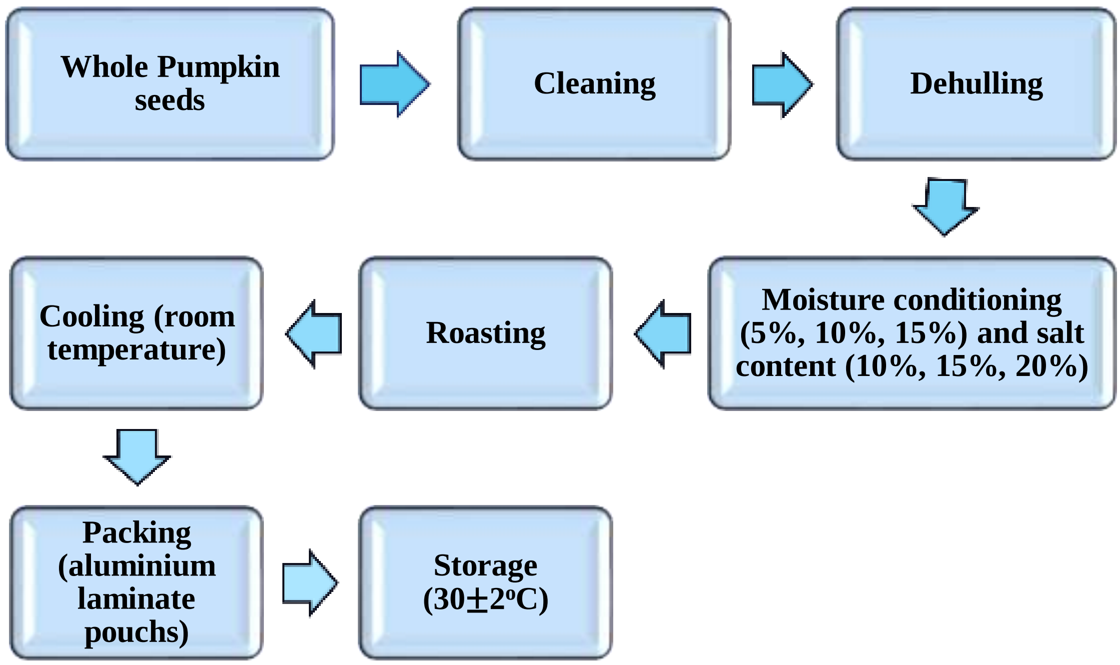

Fig. 3.2. Process flow chart for the preparation of roasted salted pumpkin seed kernels

3.4.2 Experimental Design

Completely randomized design (CRD) was adopted in experimental design and the optimization was carried out by using Design Expert 10.0.1 software. Based on the preliminary experiments conducted, the independent parameters namely moisture conditioning (X_1) and salt content (X_2) were selected for the study. The general factorial design with three levels were used. The process was optimized on the basis of two input variables whose interactions were studied on three responses (overall acceptability, hardness and fracturability). On the basis of preliminary single factor experiments, the levels of input variables were determined. The levels of various input variables selected were as follows: moisture conditioning: 5, 10 and 15%, salt solution: 10, 15 and 20%. The independent parameters with coded values are shown in table 3.3. All the responses were analyzed in triplicates and the average values were reported. Twenty seven runs (Table 3.4) were carried out to select the best combination of input variables which could result in most desirable combination for the preparation of roasted salted pumpkin seed kernels. The test factors were coded as per the equation explained above in 3.13 and the result of various interactions of independent variables were fitted to the experimental data of all responses, using second order polynomial regression equation 3.14.

3.4.3 Evaluation of Roasted salted pumpkin seed kernels

Moisture, crude protein, ash, fibre, carbohydrate, crude fat contents and fatty acid profile of roasted salted pumpkin seed kernels was determined using the methods

Table 3.3 Independent parameters of roasted salted pumpkin seed kernels

Variables \ Codes	-1	0	+1
Moisture conditioning, % (X_1)	5	10	15
Salt content, % (X_2)	10	15	20

Table 3.4 Actual and coded value of different parameters for experimentation for roasted salted pumpkin seed kernels

Expt. No	Uncoded values	
	Moisture conditioning (%)	Salt content (%)
1	10 (0)	10 (-1)
2	15 (1)	10 (-1)
3	5 (-1)	10 (-1)
4	10 (0)	10 (-1)
5	5 (-1)	10 (-1)
6	10 (0)	15 (0)
7	5 (-1)	10 (-1)
8	15 (1)	10 (-1)
9	15 (1)	15 (1)
10	15 (1)	10 (-1)
11	10 (0)	15 (0)
12	10 (0)	15 (0)
13	15 (1)	20 (1)
14	5 (-1)	15 (0)
15	15 (1)	15 (0)
16	5 (-1)	15 (0)
17	15 (1)	20 (1)
18	5 (-1)	15 (1)
19	10 (0)	10 (-1)
20	10 (0)	20 (1)
21	5 (-1)	20 (1)
22	5 (-1)	15 (0)
23	10 (0)	20 (1)
24	10 (0)	20 (1)
25	15 (1)	15 (0)
26	5 (-1)	20 (1)
27	15 (1)	15 (0)

described in section 3.2.2. The sensory evaluation (colour & appearance, taste, odour, overall acceptability) and textural profile analysis (hardness, fracturability) of roasted salted pumpkin seed kernels were done by using the methods described in section 3.3.4.1 and 3.3.4.2. The sensory evaluation by different panelists of roasted salted pumpkin seed kernels are shown in plate 3.12. Microbiological analysis was determined by using the method described below.

 

Plate 3.12 Sensory evaluation of roasted salted pumpkin seed kernels by panellists

3.4.3.1 Microbiological analysis

The samples were subjected to microbial analysis (BIS, 1984) for standard plate count using plate count agar, yeasts and molds count using freshly prepared acidified (pH adjusted to 3.5 by sterile 10 % tartaric acid solution) potato dextrose agar (PDA) and coliform counts using violet red bile agar (VRBA). Dehydrated media was procured from Hi-media Laboratories pvt. Ltd., Mumbai. Microbiological analysis was carried out in sterile environment at laminar air flow work station (Khera Instruments Pvt. Ltd., New Delhi).

(a) Standard plate count

Sample of 1.0 g was aseptically transferred to 9 ml sterile saline tube and mixed thoroughly and from this tube 1 ml was aseptically poured in sterile petri plates followed by pouring of 15 ml molten TPC agar. The contents were mixed gently and plates were cooled. The plates were inverted and incubated in incubator (Khera Instruments Pvt. Ltd., New Delhi) maintained at 37±0.5°C for 24 h. Colonies were counted and reported into number of colony forming unit per g (cfu/g).

(b) Yeast and mold count

Sample of 1 g was aseptically transferred to 9 ml sterile saline tube and mixed thoroughly and from this tube 1 ml was aseptically poured in sterile petri plates followed by pouring of 15 ml molten PDA agar. The contents were mixed gently and plates were cooled. The plates were incubated at 25±0.5°C for 3-5 days and colonies were counted using colony counter. Colonies were noted and recorded into number of colony forming unit per g (cfu/g).

(c) Coliform count

Sample of 1 g was aseptically transferred to 9 ml sterile saline tube and mixed thoroughly and from this tube 1 ml was aseptically poured in sterile petri plates followed by pouring of 15 ml molten VRBA agar, mixed gently and content were cooled. A second additional layer of VRBA was poured over the solidified content @ 5 ml. The plates were inverted, incubated at 37±0.5°C for 48 h and colonies were counted using colony counter. Counted colonies were recorded and converted into numbers of colony forming unit per g (cfu/g).

3.5 DEVELOPMENT OF PUMPKIN SEED SPREAD

3.5.1 Production of Pumpkin Seed Spread

The ingredients used in the preparation were soy lecithin (Astron Chemicals India Ltd., Ahmedabad), hydrogenated vegetable oil (Zaika vanspati), salt, sugar and spices viz. cinnamon, nutmeg, ginger powders (Local market) as shown in Plate 3.13. The pumpkin seeds spread was prepared with varying levels of stabilizer (HVO) and emulsifier (soy lecithin) at the rate of 10, 15, 20 percent and 0.5, 1.0 and 1.5 percent respectively. The sugar, salt and spices (1:1:1 ratio of cinnamon, nutmeq and ginger powder) were added at the rate of 7, 1.5 and 2 percent in all experiments. Optimization was done based on sensory evaluation, textural characteristics and L*, a*, b* colour values.

The process for the production of pumpkin seed spread involved are cleaning of pumpkin seeds, dehulling, roasting, cooling, addition of dry ingredients and mixing, grinding, addition of wet ingredients, grinding, filling, cooling, storage and quality evaluation. The flow chart depicting experimental procedure is shown in Figure 3.3.

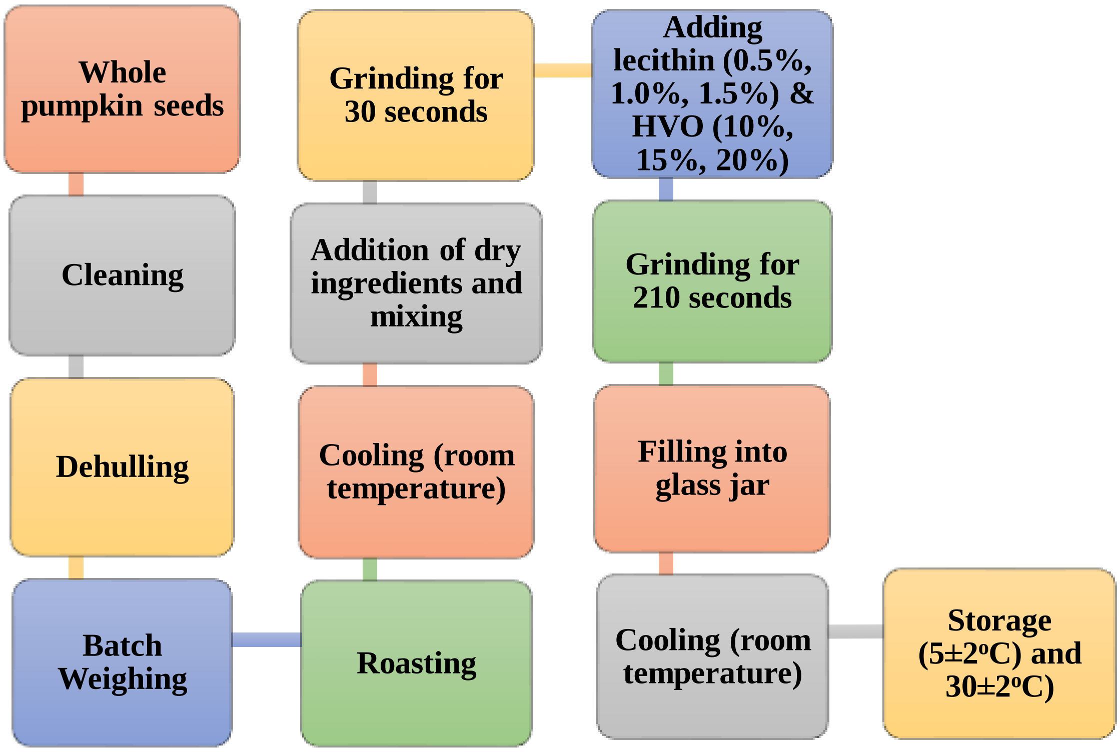

Fig. 3.3 Process flow chart for production of pumpkin seed spread

The pumpkin seed kernels were roasted using the optimized roaster as described in section 3.3. After cooling the roasted seeds to room temperature, the seeds were ground in grinder (Crompton Greaves ltd.,) for a total of four minutes at low speed. Roasted pumpkin seed kernels were initially ground for 30 seconds with dry ingredients (salt, sugar and spices) and then after adding wet ingredients (soya lecithin and hydrogenated vegetable oil) it was again ground for 210 seconds till a smooth and spreadable texture of pumpkin seed spread was obtained (Plate 3.14).

3.5.2 Experimental Design

Completely randomized design (CRD) was adopted in experimental design and the optimization was carried out by using Design Expert 10.0.1 software. Based on the preliminary experiments conducted, the two independent parameters, hydrogenated vegetable oil (X_1) and lecithin (X_2) were selected for the study. The general factorial designs with two levels were used. The process was optimized on the basis of two input variables whose interactions were studied as seven responses (overall acceptability hardness, adhesiveness, cohesiveness, L*, a*, b* colour values). On the basis of preliminary single factor experiments, the levels of input variables were determined.

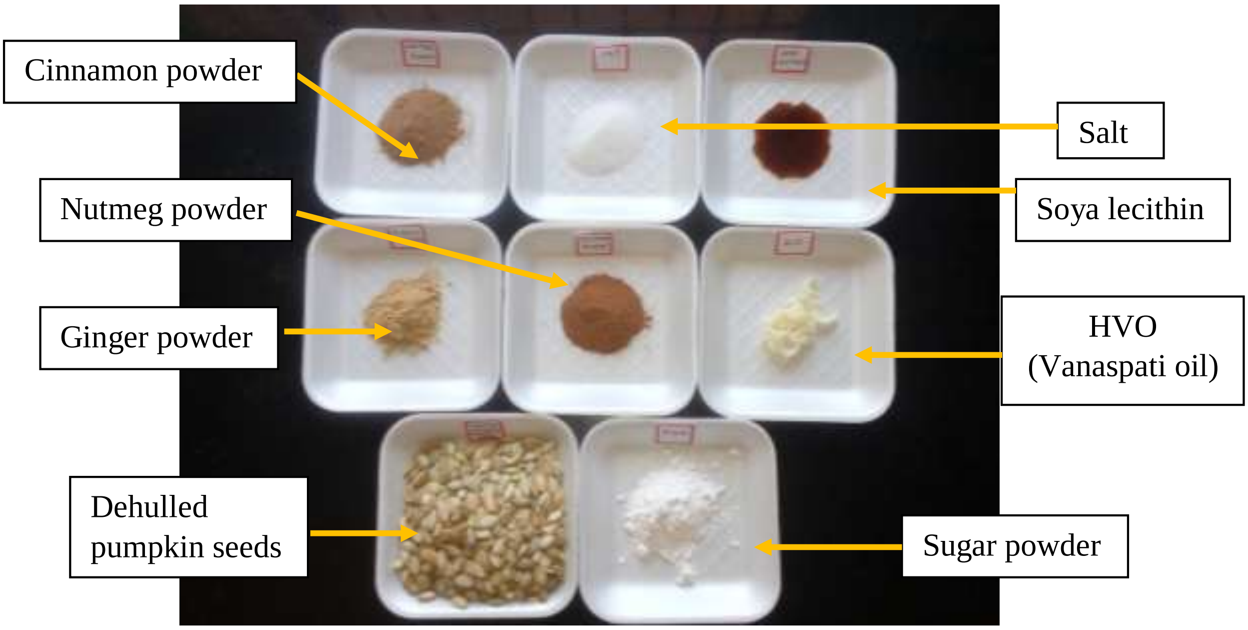

Plate 3.13. Raw ingredients for pumpkin seed spread

(a) **Roasted dehulled pumpkin seeds**

(b) **Grinder**

(c) **Grinding to smooth paste**

(d) **Pumpkin seed spread**

Plate 3.14: Preparation of pumpkin seed spread

The levels of various input variables selected were as follows: Hydrogenated vegetable oil: 10, 15 and 20%, lecithin: 0.5, 1.0, and 1.5%. The independent parameters with coded values are shown in table 3.5. All the responses were analyzed in triplicates and the average value were reported. Twenty seven runs (Table 3.6) were carried out to select the best combination of input variables which could result in most desirable combination for the preparation of pumpkin seed spread. The test factors were coded as per the equation explained previously in 3.13 and the results of various interactions of independent variables was fitted to the experimental data of all responses, using second order polynomial regression equation 3.14.

Table 3.5 Independent parameters of pumpkin seed spread

Codes / Variables	-1	0	+1
Hydrogenated vegetable oil, % (X_1)	10	15	20
Lecithin, % (X_2)	0.5	1.0	1.5

Table 3.6 Actual and coded values of different parameters for pumpkin seed spread

Expt. No	Actual/coded values	
	Hydrogenated vegetable oil (%)	Lecithin (%)
1	15 (0)	1.0 (0)
2	15 (0)	1.0 (0)
3	15 (0)	0.5 (-1)
4	10 (-1)	0.5 (-1)
5	10 (-1)	1.5 (1)
6	15 (0)	1.5 (1)
7	10 (-1)	1.5 (1)
8	10 (-1)	1.5 (1)
9	15 (0)	0.5 (-1)
10	20 (1)	1.0 (0)
11	20 (1)	1.0 (0)
12	10 (-1)	1.0 (0)
13	10 (-1)	0.5 (-1)
14	20 (1)	1.0 (1)
15	15 (0)	1.5 (1)
16	20 (1)	0.5 (-1)
17	15 (0)	0.5 (-1)
18	15 (0)	1.5 (1)
19	15 (0)	1.0 (0)
20	20 (1)	1.5 (1)
21	10 (-1)	1.0 (0)
22	10 (-1)	0.5 (-1)
23	20 (1)	1.0 (0)
24	20 (1)	0.5 (-1)
25	10 (-1)	1.0 (0)
26	20 (1)	0.5 (-1)
27	20 (1)	1.5 (1)

3.5.3 Evaluation of Pumpkin Seed Spread

Moisture, crude protein, ash, crude fiber, carbohydrate and fat contents of pumpkin seed spread was determined as per the methods described at section 3.2.2. The sensory evaluation (colour & appearance, flavour, body and texture, overall acceptability) and microbiological analysis was carried out using the methods described in section 3.3.4.1. The sensory evaluation of pumpkin seed spread by different panelists were shown in plate 3.15. The texture profile analysis (hardness, adhesiveness, cohesiveness), colour, particle size distribution, peroxide value, sugar content (reducing sugar, non-reducing sugar, total sugar), viscosity, free fatty acid and pH of pumpkin seed spread was carried out as per the methods described below.

3.5.3.1 Textural profile analysis

The textural quality of the pumpkin seed spread during experiments as well as during storage study was determined using Texture Analyzer (Stable Micro Systems, U.K.; Model: TA HD plus) as shown in the Plate 3.16. Double compression was applied using cylinder probe. Pumpkin seed spread samples were placed in a conical sample holder and applied with a load cell of 4.5 kg .The crosshead was set to move downward and penetrate the pumpkin seed spread sample. Conical perspex probe (code: HDP/SR) having 45 degree cone angle was penetrated into the sample up to a distance of 8 mm. The conditions were: pre-test speed of cone: 1 mm/s, speed of cone while penetrating into pumpkin seed spread: 2 mm/s, speed of cone while withdrawal from pumpkin seed spread: 2 mm/s. Hardness (peak force of first compression cycle), cohesiveness (ratio of positive areas of second cycle to area of first cycle) and adhesiveness (negative force area of the first byte represented the work necessary to pull the compressing plunger away from the sample) were determined. The results were recorded in terms of TPA curve of pumpkin seed spread.

3.5.3.2 Colour

Colour parameter of pumpkin seed spread samples was determined using Tintometre (Lovibond, Model RT850i) as shown in plate 3.17. The instrument was standardized with a white and a black ceramic plate. In this coordinated system, the L* value is a measure of lightness, ranging from 0 (black) to 100 (white), the a* value ranges from -100 (greenness) to +100 (redness) and the b* value ranges from – 100 (being blue) to +100 (yellowness).

Plate 3.15 Sensory analysis of pumpkin seed spread by different panelists

Plate 3.16 Texture analyser for pumpkin seed spread

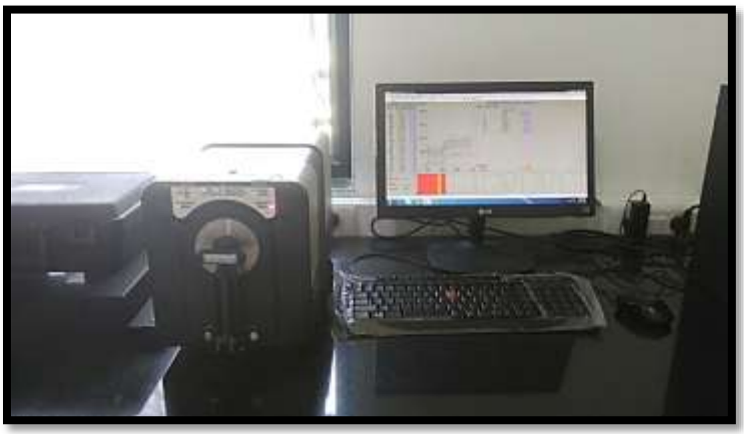

Plate 3.17 Lovibond tinometer

3.5.3.3 Particle size distribution

The particle diameter and size distribution of pumpkin seed spread was measured using a laserscattering particle size distribution analyzer (Sympatec, Helos BF,Germany). The experiments were carried out using water to dilute the samples. The data were obtained and analyzed using the program WINDOX 5. Particle size calculations were based on the Mie Scattering theory the mean, median, mode and diameter on cumulative (10% and 90%) were obtained. Particle size analyses were applied to determine particle size of optimized pumpkin seed spread.

3.5.3.4 Peroxide value

Peroxide value of pumpkin seed spread was determined by using the AOAC method. One gram fat extracted from sample of pumpkin seed spread was dissolved into 30 ml of the solvent (3/2 mixture of glacial acetic acid/chloroform) and 0.2 ml of potassium iodide. Mixture obtained was left to stand in the dark for about 1 min, thereafter 20 ml of distilled water and 2-3 drops of the diluted starch solution were added, prior to titration with 0.1 N sodium thiosulphate solution. The volume of the sodium thiosulphate used was recorded. A blank was also prepared in the same conditions. The peroxide value was expressed as milliequivalent per kilogramme of pumpkin seed spread.

$$Peroxide\ value\ (meq/kg\ oil) = \frac{A\ x\ N\ x\ 1000}{Weight\ of\ the\ sample} \qquad ...(3.16)$$

Where

A= ml of sodium thiosulphate (Test-Blank),

N= Normality of sodium thiosulphate solution

3.5.3.6 Estimation of sugars

The titrimetric method of Lane and Eynon method described by Ranganna (1986) was adopted for estimation of sugars, which is given below.

(a) Sample preparation

25 g of sample was blended with 200 ml distilled water. The solution was neutralized with 1 N NaOH using phenolphthalein indicator. The solution was boiled for 1 h with occasional stirring and boiling water was added to maintain the original level. It was then cooled, volume made up to 250 ml and filtered through No. 4 Whatman paper. 50 ml of aliquot was transferred to 250 ml volumetric flask and 2 ml

of neutral lead acetate and about 100 ml distilled water was added to it. The solution was allowed to stand for 10 min and then 2 ml of potassium oxalate solution was added. The volume was made up to mark and filtered.

(b) Estimation of reducing sugars

5 ml Fehling A + 5 ml Fehling B + 25 ml distilled water was taken in conical flask and placed on a hot plate. When the solution started boiling, methylene blue indicator was added. It was quickly titrated against the sample already prepared. The end point was indicated by change in colour of the solution from blue to brick red. The amount of sample solution required was noted down in the burette reading (B. R.) for further calculations.

Reducing sugar (%) = Dilution factor x Fehling factor B.R (ml) x sample weight (g) x 100 … (3.17)

(c) Estimation of total sugars

50 ml of clarified solution was taken in 250 ml conical flask, 5 g citric acid and 50 ml distilled water was added to it. The solution was boiled for 10 min and then cooled. Then it was transferred to 250 ml volumetric flask and neutralized with 1 N NaOH with phenolphthalein indicator till the pink colour appeared. The volume was made up 250 ml with distilled water.

5 ml Fehling A + 5 ml Fehling B + 25 ml distilled water was taken in conical flask and placed on a hot plate. When the solution started boiling, methylene blue indicator was added. It was quickly titrated against the sample already prepared. The end point was indicated by change in colour of the solution from blue to brick red. The amount of sample solution required was noted down from burette reading (B. R.) for further calculations.

Total sugar (%) = Dilution factor x Fehling factor B.R (ml) x sample weight (g) x 100 … (3.18)

(d) Estimation of non-reducing sugars

The amount of non-reducing sugar present in the sample was calculated using the following equation.

Non-reducing sugar (%) = Total sugar (%) – Reducing sugar (%) … (3.19)

3.5.3.7 Viscosity

Viscosity measurements were carried out using Brookfield viscometer (model DV-II+ Pro, Plate 3.22). The measurements were carried out at ambient temperature 30± 2 ºC. The Brookfield viscometer was leveled on the platform and the spindle S64 was attached to the viscometer by screwing them onto the lower shaft.

The spindle was dipped into the sample and the rheological data were recorded at the speeds 12 rpm by pressing the enter key on the equipment. Viscosity was displayed in centipoise (cP) and torque was displayed in percentage. This viscosity was converted into pa.s. Temperature of sample during experiment was measured by dipping the temperature probe in the sample which was coupled to the viscometer (Swami *et al.,* 2013).

Plate 3.18 Viscometer

3.5.3.8 Free fatty acids

Free fatty acids of the sample was determined according to AOCS test method. About 10 g of sample was weighed into an erlenmeyer flask and 100 ml. neutral alcohol was added in a flask and 2-3 drops of phenolphthalein was added and sample was neutralized by drop wise addition of 0.1 N potassium hydroxide till a faint pink color which persisted for 15 seconds. FFA % as Oleic acid was calculated as

$$FFA\,\%\,Oleic\ acid = \frac{(28.2\ x\ N\ x\ V)}{W} \quad \text{…. (3.20)}$$

Where: N = normality of KOH solution; V = volume of KOH solution used in ml;
W = weigh of sample.

3.5.3.9 pH

The pH value of the sample was determined using a digital pH meter. The pH meter was standardized with double distilled water of 7.0 pH and standard buffer solution of 4.0 and 9.0 pH before analysis. The homogenate prepared by diluting 20 g of sample in 20 ml of glass distilled water was subjected to pH measurement.

3.6 DEVELOPMENT OF DEFATTED PUMPKIN SEED FLOUR

3.6.1 Preparation of Defatted Pumpkin seed flour

The pumpkin seed flour was prepared from unroasted, roasted and sprouted pumpkin seeds. The flow chart presented in Figure 3.4 explains preparation of Defatted pumpkin seed flour. The process consists of different unit operations such as roasting, sprouting, grinding, defatting, drying, sieving and storage. Plate 3.19 depicts the preparation process for pumpkin seed flour. The process for roasting of pumpkin seed kernels was done by using the roaster optimized in section 3.3. Grinding was done using the domestic grinder (Crompton Greaves ltd.). Sprouting was done using the seed germinator. Soxhlet apparatus was used for defatting of the pumpkin seed kernels.

3.6.1.1 Sprouting process

The pumpkin seeds were sprouted using seed germinator (Seed Germinator Double Chamber, 67094, Indosaw) using between paper method (International seed testing Association, ISTA, 1985). The pumpkin seeds were washed thoroughly with tap water to remove the dirt and dust particles present on the seeds. The washed and cleaned seeds were placed in between the wet paper in layers like sandwich, and are placed inside the seed germinator in plastic tray maintained at RH-90%, temperature-25ºC for 4 days. Plate 3:20 shows the sprouting process of pumpkin seeds by using in between paper method inside seed germinator. After sprouting the pumpkin seeds were dried at 60˚C till the moisture content reached to 15-16 percent. The rootlets of dried seeds were removed by scrubbing manually and then the seeds were dehulled manually.

3.6.1.2 Defatting of pumpkin seed flour

The unroasted, roasted and sprouted pumpkin seeds were subjected to grinding using domestic grinder (Crompton Greaves ltd.) to facilitate oil extraction. Defatting of pumpkin seeds was done in soxhlet apparatus as shown in plate 3.21 by using n-hexane as solvent for 9 h. The deffated grounded pumpkin seeds were dried at in hot air oven

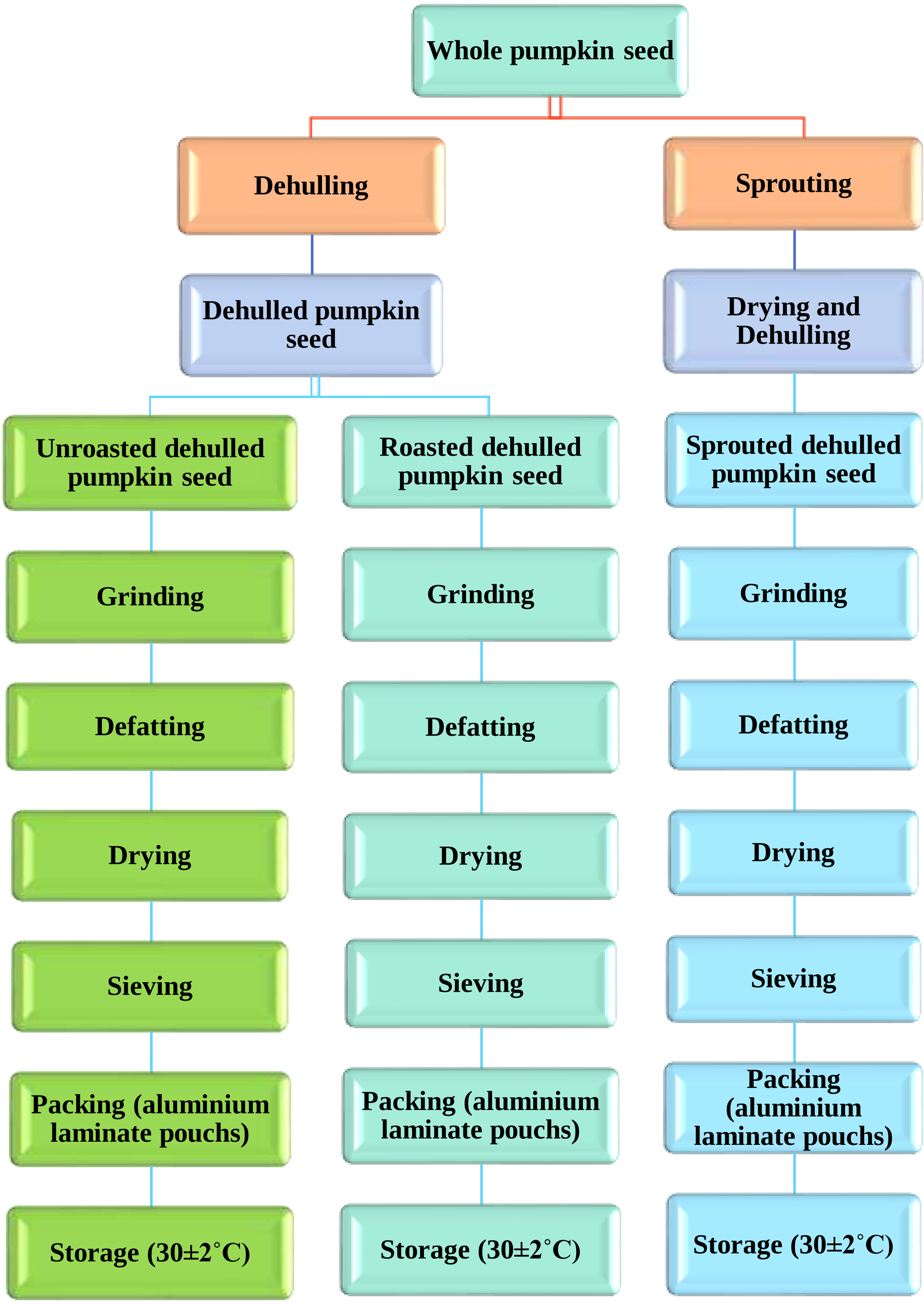

Fig. 3.4 Process flow chart for the preparation of pumpkin seed flour

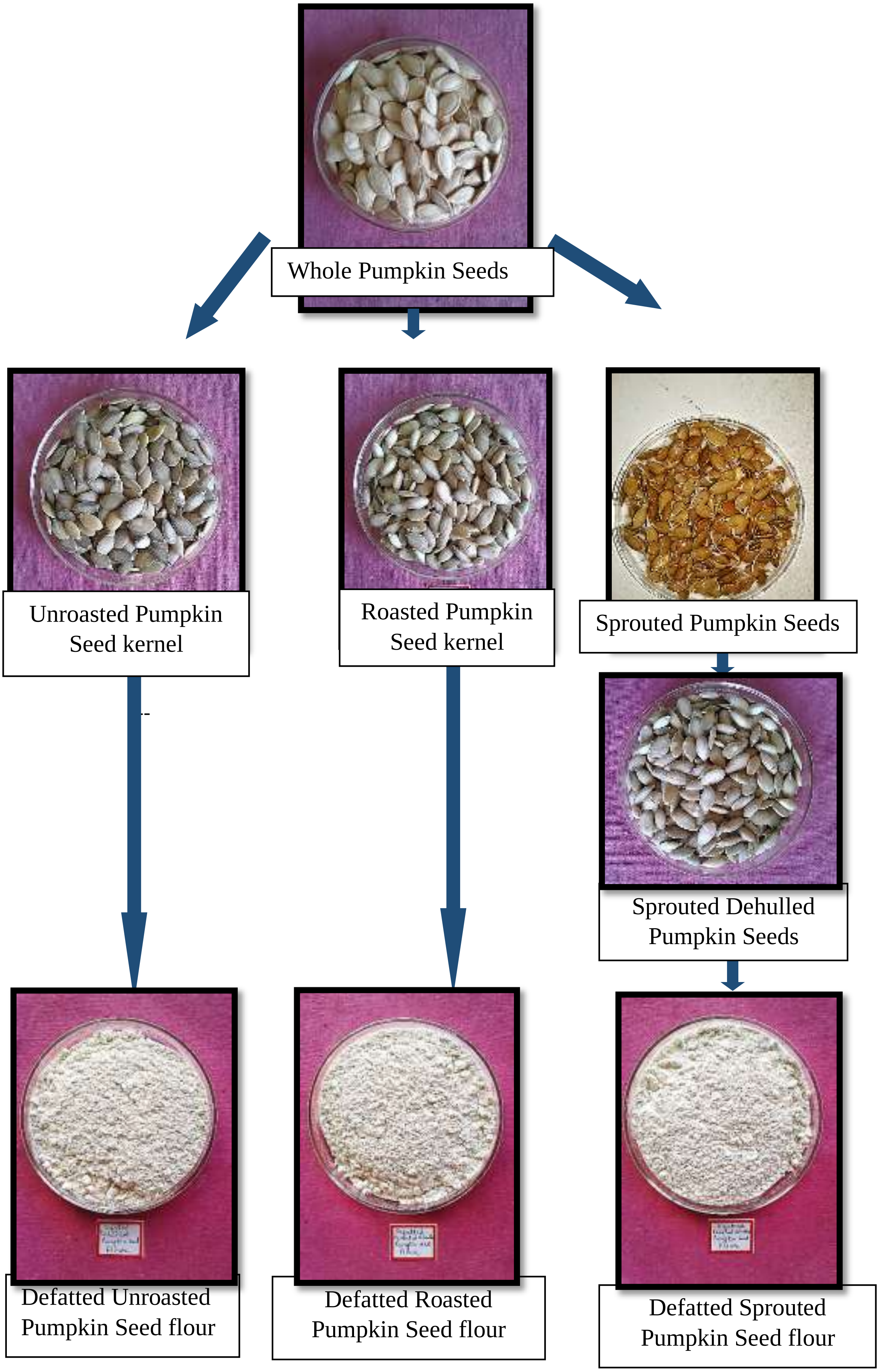

Plate 3.19 Preparation of Defatted pumpkin seed flour

Plate 3.20 Sprouting of pumpkin seeds in seed germinator

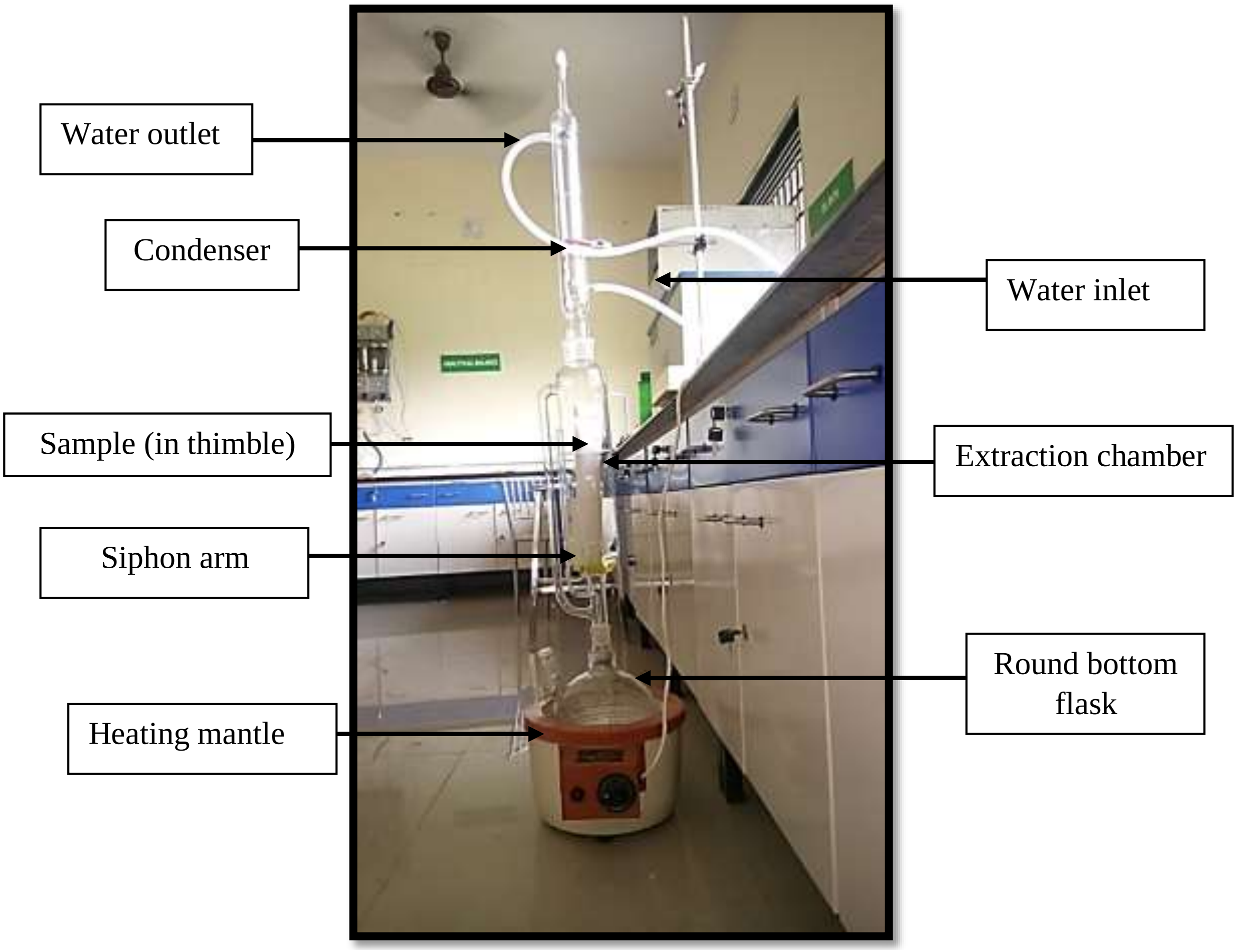

Plate 3.21 Soxhlet apparatus

at 50^{o}C to remove n-hexane residues for 1 h. The dried pumpkin seed flour was then sieved using 0.4 mm mesh sieved size and packed in aluminium laminated pouches and stored at ambient temperature (30±2^{o}C) condition.

3.6.2 Experimental Design

Table 3.7 Independent parameters of pumpkin seed flour

Codes / Variables	1	2	3
Types of pumpkin seeds (X)	UPSF	RPSF	SPSF

Table 3.8 Actual and coded values for pumpkin seed flour (experimental runs)

Expt. No	Coded values	Uncoded values
	Types of seeds	Type of seeds
1	3	Sprouted pumpkin seed flour (SPSF)
2	1	Unroasted pumpkin seed flour (UPSF)
3	3	Sprouted pumpkin seed flour (SPSF)
4	2	Roasted pumpkin seed flour (RPSF)
5	3	Sprouted pumpkin seed flour (SPSF)
6	1	Unroasted pumpkin seed flour (UPSF)
7	2	Roasted pumpkin seed flour (RPSF)
8	2	Roasted pumpkin seed flour (RPSF)
9	1	Unroasted pumpkin seed flour (UPSF)
10	2	Roasted pumpkin seed flour (RPSF)
11	3	Sprouted pumpkin seed flour (SPSF)
12	1	Unroasted pumpkin seed flour (UPSF)

Completely randomized design (CRD) was adopted in experimental design and the optimization was carried out by using Design Expert 10.0.1 software. Based on preliminary experiment conducted, one independent parameter i,e, types of seed (X) was selected for the study. The factorial designs with three levels used for the study. The process was optimized on the basis of one input variables whose interactions were studied at three responses (protein content, fat content and water absorption capacity). On the basis of preliminary single factor experiments, the levels of input variables were determined. The levels of the input variables selected were as follows: types of seed: defatted unroasted pumpkin seed flour (UPSF), defatted roasted pumpkin seed flour (RPSF) and defatted sprouted pumpkin seed flour (SPSF). The independent parameters with coded values are shown in Table 3.7. All the responses were analyzed in four replicates and the average values were reported. Twelve runs (Table 3.8) were carried out to select the best combination of input variables which could result in most desirable combinations for the preparation of Defatted pumpkin seed flour. The test factors were coded as per the equation explained above in 3.13 and the results of various interactions of independent variables was fitted to the experimental data of all responses, using second order polynomial regression equation 3.14.

3.6.3 Evaluation of Defatted Pumpkin seed flour

Moisture, crude protein, ash, crude fiber, carbohydrate, crude fat, phytic acid, mineral contents and thermal characteristics of Defatted pumpkin seed flour was determined as per the methods described at section 3.2.2. Colour (L*, a* and b* values), peroxide value and bulk density were determined as per the method described in section 3.5.2.2, 3.5.2.5 and 3.2.1.3. Water absorption capacity (WAC), *Invitro* protein digestibility was determined by using the method described below.

3.6.3.1 Water absorption capacity (WAC)

One gram (1 g), of the sample was weighed into pre-weighed centrifuge tube. This was followed by the addition of 10 ml of distilled water and then stirred with a glass rod to completely dissolve lumps. The solution was then centrifuged at 3500 rpm for 15 min and the supernatant was discarded (Adelekan Aminat *et al*., 2013).

$$\% \, Water\ absorption\ capacity, WAC\ (\%) = [(Weight\ of\ tube + wet\ sample) - (Weight\ of\ tube + Dry\ sample)]\ X\ 100 \quad \text{... (3.21)}$$

3.6.3.2 *Invitro* protein digestibility

For determination of *Invitro* protein digestibility procedure standardized by Hooi (2012) was followed. The sample was weighed by using following formula.

$$Weight\ of\ sample\ (mg) = \frac{62.5}{p}\, x\ 100 \quad \text{…. (3.22)}$$

Where, p = Protein content of the sample (%)

The sample was mixed with 10 ml of distilled water and incubated in water bath at 37 °C for 1 h with intermittent stirring. Simultaneously, multienzyme solution having

1.6 mg of trypsin, 3.1 mg of chymotrypsin and 1.3 mg of protease per ml in distilled water was prepared. After incubation, the sample from water bath was removed and the pH of the sample was adjusted to 8.0 by using 0.1 N NaOH and/or 0.1 N HCl. 10 ml of freshly prepared multienzyme solution was added to the sample. The pH was recorded after every 30 sec for 10 minutes. The change in pH at 10 min ($\triangle pH_{10min}$) was used for calculation of protein digestibility.

$$\text{IVPD (\%)} = 65.66 + 18.1 \; x \; 0.95 \triangle pH_{10min} \qquad \text{.... (3.23)}$$

3.7 OPTIMIZATION OF INDEPENDENT VARIABLES OF VALUE ADDED PRODUCTS FROM PUMPKIN SEEDS

For the optimization of value added products from pumpkin seeds viz. roasted salted pumpkin seed kernels, pumpkin seed spread and pumpkin seed flour, full second order model was fitted in various responses and independent variables using least square regression analysis. Data analysis was done by using Design expert 10.0.1. Software. Effect of independent variables on the responses for different value added products were interpreted using the models.

3.8 SHELF LIFE EVALUATION OF VALUE ADDED PRODUCTS FROM PUMPKIN SEEDS

The optimized value added pumpkin seed products viz. roasted salted dehulled pumpkin seeds, pumpkin seed spread and defatted pumpkin seed flour were stored at different storage conditions and evaluated at regular intervals.

3.8.1 Roasted salted pumpkin seed kernels

The roasted salted pumpkin seed kernels were stored in aluminium laminate pouches (110 micron) at ambient temperature (30±2ºC) and different parameters viz. moisture, peroxide value, sensory evaluation and microbiological analysis were determined by using the method described in 3.2.2.1, 3.5.2.4, 3.3.4.1 and . The analysis was done at an interval of 15 days.

3.8.2 Pumpkin Seed Spread

The pumpkin seed spread were stored in glass jar at two different storages conditions of 30±2°C and 5±2°C and the analysis was done at an interval of 15 days and 30 days respectively. The texture profile analysis, pH, free fatty acid, sensory analysis and microbiological analysis were determined by using the method as described in section 3.3.4.2, 3.5.2.9, 3.5.2.8, 3.3.4.1 and 3.4.2.1.

3.8.3 Defatted Pumpkin seed flour

The moisture, free fatty acids, water absorption capacity and microbiological analysis was determined by using the methods described in section 3.2.2.1, 3.5.2.8, 3.6.4.1 and 3.4.2.1 respectively. The defatted pumpkin seed flour were stored in aluminium laminate pouches (110 micron) at room temperature (30±2°C) and the analysis was done at an interval of 15 days.

CHAPTER IV

RESULTS AND DISCUSSION

This chapter deals with the results obtained from various experiments carried out during investigation. The data obtained was statistically analysed and the results are discussed and interpreted under different sections.

4.1 PHYSICOCHEMICAL CHARACTERIZATION OF PUMPKIN SEEDS

Pumpkin seeds were analysed for its physical and chemical characteristics. The results of length, width, thickness, true density, bulk density, geometric mean diameter, porosity, 1000 seed weight, husk content, moisture, protein, ash, crude fiber, fat, carbohydrate, phytic acid, fatty acid profile, mineral content and thermal properties were analysed as per the methods explained in the previous chapter and results are tabulated in Tables 4.1- 4.4.

4.1.1 Physical Properties of Pumpkin Seeds

Table 4.1 Physical properties of pumpkin seeds

Sl.no.	Parameters	Whole pumpkin seed	Kernel
1	Length (mm)	16.81±0.91	11.65±0.69
2	Width (mm)	8.87±0.61	5.80±0.26
3	Thickness (mm)	2.75±0.18	2.52±0.29
4	True density (kg/m^3)	1157±1.02	1068±0.94
5	Bulk density (kg/m^3)	398±0.80	475±0.95
6	Geometric mean diameter, Dg (mm)	7.42±0.35	5.54±0.29
7	Porosity (%)	65.60±0.47	55.52±0.55
8	1000 seed weight (g)	202.2±0.75	148.1±0.87
9	Husk content (%)	26.75±0.98	-

*length, width and thickness =average of 100 seeds; true density, bulk density, 1000 seed weight= average of 3 replications.

Physical properties of foods are important for designing storage systems as well as processing and handling/conveying systems (Mohsenin, 1986). The mean length (L), width (W) and thickness (T) values of whole pumpkin seed and kernel were 16.81±0.91mm, 8.87±0.61mm, 2.75±0.18mm and 11.65±0.69mm, 5.80±0.26mm, 2.52±0.29mm, respectively at a moisture content of 5.53±0.26% (d.b) for whole pumpkin seed and 4.43±0.44% (d.b) for kernel. The results obtained are in good accordance with the results reported by Joshi *et al.,* (1993) and Altuntas (2008).

The mean value obtained for bulk density and true density are 398±0.80 kg/m^3 and 1157±1.02 kg/m^3 for whole pumpkin seed whereas for kernel, it was found to be 475±0.95 kg/m^3 and 1068±0.94 kg/m^3. These results were in agreement with the ranges reported by Milani *et al*., (2007) and Altuntas, (2008). The 1000 seed weight, geometric mean diameter and porosity values for whole pumpkin seed and dehulled pumpkin seed are 202.2±0.75g, 7.42±0.35mm, 65.60±0.47% and 148.1±0.87g, 5.54±0.29mm, 55.52±0.55% respectively. 1000 seed weight of pumpkin seed was found to be within the range as reported by Turkmen *et al*., 2006. Husk content of pumpkin seed was found to be 26.75±0.98%. The results obtained were found to be similar with the earlier findings reported by Yildiz *et al*., (2013).

4.1.2 Chemical Properties of Pumpkin Seed

Chemical evaluation of pumpkin seeds (whole and kernel) was carried out as per the methods cited in Chapter III, section 3.2.2. The data obtained for the chemical composition of pumpkin seeds i.e. moisture, protein, ash, crude fiber, fat, carbohydrate and phytic acid content are presented in Table 4.2. All determinations were carried out on the wet basis in triplicate and average values are reported.

Table 4.2: Chemical composition of whole pumpkin seed and kernels

Parameter	**Mean value ± S.D.**	
	Whole pumpkin seed	**Kernel**
Moisture, (%)	5.53±0.26	4.43±0.44
Crude protein (%)	28.90±1.36	31.98±1.18
Crude fat (%)	31.75±0.45	38.29±1.51
Crude fiber (%)	4.59±1.01	4.26±0.43
Ash (%)	6.90±0.14	2.36±0.10
Total Carbohydrates, % (by difference)	27.86±1.50	33.11±2.94
Phytic acid (%)	1.867±0.01	1.547±0.03

The moisture content of whole pumpkin seed (5.53±0.26%) was higher than the kernels (4.43±0.44%). The results of moisture content were found similar with the earlier findings reported by Elinge *et al.,* (2012), Steiner-Asiedu *et al.*, (2014) and Al-Anoos *et al.,* (2015). The kernel has high protein content, crude fat content and total carbohydrate than whole pumpkin seed. The results of protein, crude fat, ash and carbohydrate observed during the present study are in good accordance with the results reported by Gohari Ardabili *et al*., (2011) for pumpkin seeds (*C. pepo* subsp. *pepo* var.

Styriaca), Elinge *et al*., (2012) for pumpkin seeds varieties (*cucurbita pepo* L) from Tudunwada area, Kaduna Nigeria and Steiner-Asiedu *et al*., (2014). Crude protein content was found to be higher than the result reported by Sharma and Lakhawat (2017). Fat content was moderately less compared to the result reported by Alfawaz (2004) and Achu *et al*., (2005) for different species of pumpkin seeds (*Cucumeropsis mannii, Cucurbita maxima*, *Cucurbita moschata*, *Lagenaria siceraria* and *Cucumis sativus*) grown in different regions of cameroon. Crude fibre was in accordance with the findings reported by Al-Anoos *et al.*, (2015) and Alfawaz (2004) but moderately less compared to the result reported by Karanja *et al*., (2013). The phytic acid content of whole pumpkin seeds were found to be higher than the kernels. The phytic acid of whole pumpkin seed and kernel was found to be 1.867±0.01% and 1.547±0.03%, which are slightly lower than the value reported by Giami (2003) for fluted pumpkin (*Telfairia occidentalis* Hook) seeds. However, some differences in the composition may be due to environmental stress, climatic conditions, geographical, cultivation and harvesting practices.

Table 4.3: Fatty acid composition of pumpkin seed kernels

Sl.no.	Fatty acid	Mean value (%)
1	Palmitic Acid	17.63
2	Palmitolic Acid	0.33
3	Stearic Acid	14.96
4	Oleic Acid	27.75
5	Linoleic Acid	37.89
6	Linolinic Acid	0.18
7	Arachidic Acid	0.30
8	Behenic Acid	0.21
9	Eursic acid	0.21

Table 4.3, shows the fatty acid composition of pumpkin seed kernels. The oil mainly consisted of linoleic acid, oleic acid, palmitic acid, stearic acid, palmitolic acid, arachidic acid, eursic acid, behenic acid and linolenic acid. Major free fatty acid compounds of pumpkin seeds are linolenic acid, oleic acid, palmitic acid and stearic acid. Rodriguez-Miranda *et al*., (2013) and Quattara *et al.*, (2015) also reported linolenic acid, oleic acid, palmitic acid and stearic acid as the major free fatty acid compounds in pumpkin seed oil. Similarly, Gohari *et al*., (2011) reported the major free fatty acids of pumpkin seeds as linoleic acid, oleic acid, palmitic acid and stearic acid with slightly higher values of linoleic acid (39.84±0.08%) and oleic acid

(38.84±0.37%) and lower values of palmitic acid (10.68±0.42%) and stearic acid (8.67±0.27%). The results obtained in the present study was found to be in similar with the findings of Elinge *et al.*, (2012). The differences in free fatty acids composition might be attributed due to the factors such as variety, origin, and drying conditions, among others. The gas chromatograph graph of fatty acid profile of pumpkin seed oil is shown in appendix III (a).

Table 4.4: Mineral composition of pumpkin seed kernels

Sl.no.	Minerals	Mean value (mg/100g)
1	Iron (Fe)	16.1
2	Manganese (Mn)	487.0
3	Zinc (Zn)	907.0
4	Copper (Cu)	124.0
5	Phosphorus (P)	848.6
6	Potassium (K)	404.9
7	Calcium (Ca)	25.7
8	Magnesium (Mg)	335.6
9	Sodium (Na)	2.2
10	Cobalt (Co)	0.6

The mineral contents in pumpkin seed kernel were found to be Zinc (907 mg), Phosphorus (848.6 mg), manganese (487 mg), potassium (404.9 mg), magnesium (335.6 mg), copper (124 mg), calcium (25.7 mg), iron (16.1 mg), sodium (2.2 mg) and cobalt (0.6 mg). Table 4.4 shows the mineral composition of pumpkin seed kernels. Elinge *et al*., (2012) and Rezig *et al*., (2012) also reported that pumpkin seeds are rich source of minerals comprising of potassium, sodium, calcium, magnesium, phosphorus, iron, cobalt, manganese and zinc and recommended that pumpkin seeds could be used for food enrichment and against malnutrition.

4.1.3 Thermal Properties

The thermal properties viz. onset temperature (T_o), peak temperature (T_p) and enthalpy, (ΔH) of pumpkin seed kernel were found to be 124.47°C, 115.57°C and 104.26 J/g. The results obtained were found to be higher than the values reported by Rodriguez-Miranda *et al*., (2013) for pumpkin seed, Normand *et al*. (1989) for whole grain milled rice and milled rice flour. Thermal properties graph is shown in appendix IV (a).

4.2 STANDARDIZATION OF ROASTER FOR DEVELOPMENT OF VALUE ADDED PRODUCTS FROM PUMPKIN SEED KERNELS

Roasting is one of the important processing step to enhance the flavour, colour, texture and overall acceptability of food products. Development of flavour and aroma depends upon the temperature and time of roasting besides the type of materials and techniques applied. Experiments for standardizing roaster for the development of value added products from pumpkin seed kernels were conducted as discussed in chapter III section 3.3. Most suitable roaster with optimum roasting temperature and roasting time was selected among the four different roasters viz. halogen oven (R_1), hot air oven (R_2), microwave oven (R_3) and sand roasting (R_4) based on their response variables. The pumpkin seeds kernel were roasted at 180, 190 and 200°C for 4, 6 and 8 min in halogen oven (R_1). Similarly, the roasting temperature and roasting time for the hot air oven (R_2), microwave oven (R_3) and sand roasting (R_4) were 150, 160 and 170°C for 10, 20 and 30 min; P-80, P-90 and P-100 microwave power level (%) for 3, 4 and 5 min and 150, 160 and 170°C for 2, 3 and 4 min respectively. The optimal conditions of each roaster were then compared to select the best roaster for further studies on development of products from pumpkin seeds.

Full second order model was fitted in various responses and independent variables using least square regression analysis. The coefficient of determination (R^2) and Fisher's F- test were used to test the adequacy of the model. If the model was adequate, then the effect of independent variables on responses were interpreted. Design-Expert 10.0.1 software was used for optimization of variables from each of the roaster based on the roasted pumpkin seed kernels properties. The results obtained are discussed below.

4.2.1 Optimization of Roasting Conditions of Pumpkin Seed Kernels in Halogen Oven

Effect of roasting temperature and roasting time on the responses i.e. sensory evaluation (colour and appearance, taste, odour, overall acceptability), texture profile analysis (hardness, fracturability), and phytic acid was determined and statistically analyzed by using Design Expert 10.0.1 software. Experimental data is shown in Table 4.5.

4.2.1.1 Effect of roasting temperature and roasting time on colour and appearance

Effect of process variables on colour and appearance is depicted in Table 4.5. The colour and appearance score ranged from 5.5 to 9.0. The maximum score (9.0) of colour and appearance was observed for experimental combination of 190°C roasting temperature and 6 min roasting time. The minimum score (5.5) was observed for experimental combinations of 180°C and 200°C roasting temperature and 4 min and 8 min roasting time.

Table 4.5: Variables and responses of pumpkin seed kernels roasted in halogen oven (R_1)

Expt No.	Roasting temperature (ºC)	Roasting time (min)	Colour & Appearance (1-9)	Taste (1-9)	Odour (1-9)	Overall acceptability (OAA) (1-9)	Hardness (g)	Fracturability (g)	Phytic acid (%)
1.	190 (0)	4 (-1)	7.5	7.2	7.0	7.5	50.38	4.31	0.1926
2.	200 (1)	8 (1)	5.5**	5.8	6.5	6.0**	26.72	3.11**	0.1439
3.	190 (0)	8 (1)	8.0	8.2	8.0	8.2	40.69	3.60	0.1841
4.	180 (-1)	8 (1)	6.0	7.0	6.6	7.0	52.16	5.21	0.2149
5.	190 (0)	6 (0)	8.5	9.0*	8.3	8.8*	45.42	3.99	0.1946
6.	180 (-1)	4 (-1)	6.0	5.5	5.5	6.1	59.96	6.69	0.2552*
7.	200 (1)	6 (0)	6.0	5.5	6.0	6.2	35.71	3.39	0.1508
8.	180 (-1)	4 (-1)	5.5**	5.9	5.0**	6.1	62.11	6.41	0.232
9.	180 (-1)	6 (0)	6.0	6.2	6.0	6.3	58.65	5.21	0.2145
10.	180 (-1)	8 (1)	6.5	6.8	6.0	7.0	50.12	5.60	0.2072
11.	190 (0)	8 (1)	7.8	8.0	8.0	7.6	42.12	3.80	0.1740

12.	180 (-1)	6 (0)	6.0	6.2	6.0	6.0**	56.698	5.96	0.2265
13.	200 (1)	8 (1)	5.8	5.1	5.6	6.0**	27.12	3.28	0.1552
14.	200 (1)	4 (-1)	8.0	6.5	8.0	8.0	38.91	3.57	0.1624
15.	190 (0)	4 (-1)	8.5	7.4	8.0	8.0	48.31	3.91	0.2080
16.	180 (-1)	8 (1)	6.5	6.5	6.0	7.0	52.28	4.92	0.1879
17.	190 (0)	6 (0)	9.0*	8.5	8.0	8.5	43.92	4.28	0.1856
18.	190 (0)	6 (0)	9.0*	9.0*	8.0	8.8*	48.21	3.98	0.2003
19.	200 (1)	4 (-1)	6.5	6.8	8.8*	7.5	35.99	3.45	0.1508
20.	200 (1)	8 (1)	5.8	5.0**	5.8	6.0**	24.92**	3.19	0.1468
21.	190 (0)	8 (1)	7.5	8.5	7.3	7.5	39.91	3.70	0.1717
22.	180 (-1)	4 (-1)	5.7	5.0**	6.0	6.5	62.91*	6.90*	0.2510
23.	200 (1)	6 (0)	6.0	6.5	6.0	6.0**	32.17	3.55	0.1724
24.	180 (-1)	6 (0)	6.0	6.0	6.0	6.5	56.98	6.23	0.2065
25.	200 (1)	4 (-1)	6.0	6.5	7.0	7.0	37.21	3.69	0.1385**
26.	190 (0)	4 (-1)	7.4	7.5	7.0	7.0	50.28	4.10	0.1880
27.	200 (1)	6 (0)	7.0	7.0	6.5	7.0	38.12	3.29	0.1578

*Maximum, ** Minimum

Table 4.6: Regression analysis of roasted pumpkin seed kernels in halogen oven (R_1)

Cons.	Colour & Appearance		Taste		Odour		Overall acceptability		Hardness		Fracturability		Phytic acid	
	Coeff.	P (%)	Coeff.	P (%)	Coeff.	P (%)	Coeff.	P (%)	Coeff.	P (%)	Coeff.	P (%)	Coeff.	P (%)
	0.12	0.01*	0.12	0.01*	0.13	0.01*	8.21	0.05*	46.57	0.01*	3.98	0.01*	5.20	0.01*
X_1	-0.0028	2379	0.00032	89.13	-0.0084	49.00	-0.11	41.95	-11.94	0.01*	-1.26	0.01*	1.00	0.01*
X_2	0.0027	25.52	-0.00269	25.20	0.0032	23.72	-0.15	27.88	-5.00	0.01*	-0.37	0.01*	0.25	0.34*
X_1X_2	0.011	0.08*	0.020	0.01*	0.014	2.00**	-0.38	3.39**	-0.24	63.21	0.26	0.29*	-0.20	4.22**
X_1^2	0.042	0.01*	0.043	0.01*	0.033	0.01*	-1.21	0.01*	-0.54	45.48	0.68	0.01*	0.24	8.56***
X_2^2	0.0053	19.63	0.011	1.23**	0.0021	65.10	-0.33	17.53	-1.65	3.06**	-0.019	86.68	0.17	19.60
R^2	86.27		89.64		79.47		63.09		97.95		95.79		90.41	
Adj.R^2	83.00		87.17		74.58		54.30		97.46		94.79		88.13	
F	26.38 (1% 4.042)		36.34 (1% 4.042)		16.26 (1% 4.042)		7.18 (1% 4.042)		200.39 (1% 4.042)		95.62 (1% 4.042)		39.59 (1% 4.042)	
LOF	NS		NS		NS		NS		NS		NS		NS	

*, ** and *** Significant at 1, 5 and 10% level of significance respectively, Coeff. = Coefficient, NS= Non significant, Cons.= Constant, LOF= Lack of Fit, X_1= Roasting temperature and X_2 = Roasting time

The analysis was done by means of Fisher's 'F'-test and the results of the regression analysis on colour and appearance is given in Table 4.6. The model was found highly significant with F-value 26.38 which is greater than F_{tab} (4.042) at 1%. Second order regression was fitted into the colour and appearance data obtained from experimental conditions. The model was checked using a numerical method employing the coefficient of determination (R^2) and adjusted R^2. R^2 indicates how much of the observed variability in the data was accounted by the model while R^2 –adj modifies R^2 by taking into account the number of covariate or predictors in the model. Regression analysis revealed that the coefficient of determination (R^2) for the regression model of colour and appearance was 0.8627, which implies that the model could account for 86.27% variability in data. R^2 -adj (0.8300) value was observed to be relatively close to R^2 (0.8627) value, it ensures a relatively satisfactory adjustment of the quadratic model to the experimental data. The lack of fit was found non-significant for the model hence the model can be used to navigate the design. The result of regression coefficient shows the effect of roasting temperature has significant effect ($p<0.01$) at quadratic level. At interactive level, roasting temperature and roasting time significantly affected the colour and appearance ($p<0.01$). Second order predictive quadratic equation for colour and appearance is given below

$$Y= 0.12- 0.0028X_1+ 0.0027X_2+ 0.011X_1X_2+ 0.042X_1^2+ 0.0053X_2^2$$

Where, Y is colour and appearance and X_1 and X_2 are roasting temperature and roasting time

In Equation, the coefficient with one factor i.e. the one in front of X_1, and X_2 represent the effect of that particular factor, while the interaction between two factors was represented by coefficients with two factors i.e. the one in front of X_1X_2 and those with second order terms i.e. X_1^2 and X_2^2 indicate the quadratic effects, the positive sign in front of the terms indicates a synergistic effect while the negative sign shows the antagonistic effect. Table 4.6 also shows the regression coefficients in the model and the significance of each term. Positive coefficient of the model at the linear level indicate an increase in responses with increase in regressor of its influencing factors and vice versa. Positive quadratic terms give the minimum response at the centre. While negative quadratic terms give the maximum response at the centre. The negative interaction suggested that the regressor of one variable of the interaction can be increased while the other decreased to get the same response.

Table 4.7: ANOVA for colour and appearance (halogen oven)

SOURCE	DF	SS	MS	F-Value
Model	5	0.0120	4.5440	26.38*
Linear	2	0.0003	0.0002	1.597
Quadratic	2	0.0112	0.0056	59.42*
Interactive	1	0.0014	0.0014	15.15*
Error	21	0.0020	0.0001	
Total	26	0.0140		

***, **, * Significant at 10, 5 and 1% level

Table 4.7 shows the effect of roasting temperature and roasting time at linear, quadratic and interaction levels. It can be seen from the table that quadratic and interactive levels were highly significant at 1% level, as their F_{cal} values 59.42 and 15.15 were greater than their F_{tab}. (5.780 and 8.017), while for linear it was found to be non-significant, as their F_{cal} 1.597 value was lesser than F_{tab} (2575) value.

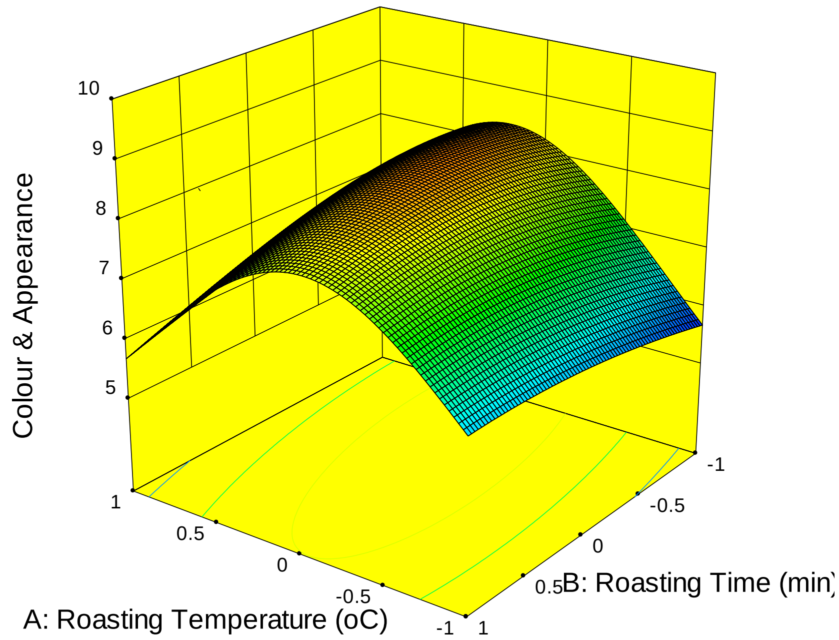

Fig.4.1: Effect of roasting temperature and roasting time on colour and appearance for halogen oven

Influence of roasting temperature and roasting time on colour and appearance is shown in Figure 4.1. It was observed that colour and appearance increases up to 190°C roasting temperature and 6 min roasting time but had minimum score at lower (180°C for 4 min) and higher (200°C for 8 min) roasting temperature and roasting time.

This may be due to the under and over roasting of pumpkin seed kernels at low and high roasting temperatures and time.

4.2.1.2 Effect of roasting temperature and roasting time on taste

Effect of process variables on taste are depicted in Table 4.5. The score ranged from 5.0 to 9.0. The maximum score (9.0) of taste was observed for experimental combination of 190ºC roasting temperature and 6 min roasting time. The minimum score (5.0) was observed for experimental combination of 180 and 200ºC roasting temperature and 4 and 8 min roasting time. Table 4.8 shows the effect of roasting temperature and roasting time at linear, quadratic and interaction levels. It can be seen from the table that quadratic and interactive levels were highly significant at 1% level, as their F_{cal} values 62.555 and 52.706 was greater than F_{tab}.(5.780 and 8.017), while for linear it was found to be non-significant, as their F_{cal} 0.7034 value was lesser than F_{tab}(2.575) value.

Table 4.8: ANOVA for taste (halogen oven)

SOURCE	DF	SS	MS	F-Value
Model	5	0.0170	0.0034	36.340*
Linear	2	0.0001	0.0001	0.7035
Quadratic	2	0.0117	0.0059	62.555*
Interactive	1	0.0048	0.0048	52.706*
Error	21	0.0020	0.0001	
Total	26	0.0190		

***, **, * Significant at 10, 5 and 1% level

The regression analysis on taste is shown in Table 4.6. The model was found highly significant with F-value 36.34 which is greater than F_{tab} (4.042) at 1%. The values of R^2, adj-R^2 were found to be 0.8964 and 0.8717 respectively. R^2 -adj value was observed to be relatively close to R^2 value, it ensures a relatively satisfactory adjustment of the quadratic model to the experimental data. The lack of fit was found to be non-significant for the model hence the model can be used to navigate the design. The result of regression coefficient shows the effect of roasting temperature and roasting time had non-significant effect at linear. At quadratic level, roasting temperature has ($p<0.01$) and roasting time ($p<0.05$) significance. Roasting temperature and roasting time was significant ($p<0.01$) at interactive level. Second order predictive quadratic equation for taste is given below

$$Y= 0.12+ 0.0003152X_1- 0.002685X_2+0.020X_1X_2+0.043X_1^2+0.011X_2^2$$

Where, Y is taste and X_1 and X_2 are roasting temperature and roasting time

Influence of roasting temperature and roasting time on taste is shown in Figure 4.2. It was observed that taste score increased up to 190°C roasting temperature and 6 min roasting time but had minimum value at lower (180°C for 4 min) and higher (200°C for 8 min) roasting temperature and roasting time. This indicates that the pumpkin seed kernels roasted at 190°C for 6 min were superior in taste as compare to the remaining samples.

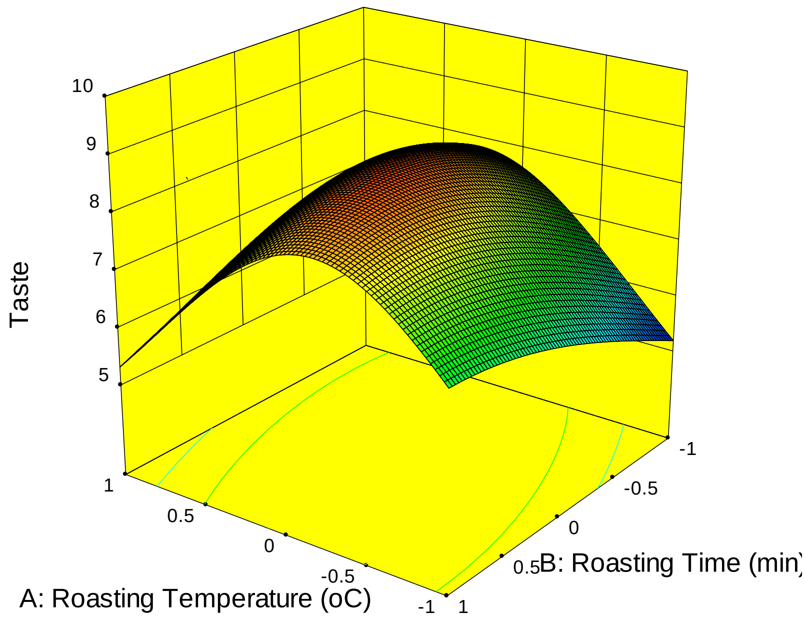

Fig.4.2: Effect of roasting temperature and roasting time on taste for halogen oven

4.2.1.3 Effect of roasting temperature and roasting time on odour

Effect of process variables on odour are depicted in Table 4.5. The score ranged from 5.0 to 8.8. The maximum score (8.8) of odour was observed for experimental combination of 200°C and 4 min. The minimum score (5.0) of odour was observed for experimental combination of 180°C and 4 min roasting time. Table 4.9 shows the effect of roasting temperature and roasting time at linear, quadratic and interaction levels. It can be seen from the table that quadratic and interactive levels were highly significant at 1% level, as their F_{cal} values 25.20 and 19.54 was greater than F_{tab}. (5.780 and 8.017), followed by linear which is significant at 5% level, as their F_{cal} 5.678 value was greater than F_{tab} (3.467) value.

Table 4.9: ANOVA for odour (halogen oven)

SOURCE	DF	SS	MS	F-Value
Model	5	0.01000	0.002000	16.26*
Linear	2	0.00145	0.000727	5.678**
Quadratic	2	0.00645	0.003225	25.20*
Interactive	1	0.00250	0.002501	19.54*
Error	21	0.00269	0.000128	
Total	26	0.01300		

***, **, * Significant at 10, 5 and 1% level

The regression analysis on odour is given in Table 4.6. The model was found highly significant with F-value 16.26 which is greater than F_{tab} (4.042) at 1%. The values of R^2, adj. R^2 were found to be 0.7947 and 0.7458 respectively. R^2 -adj value was observed to be relatively close to R^2 value, it ensures a relatively satisfactory adjustment of the quadratic model to the experimental data. The lack of fit was found non-significant for the model hence the model can be used to navigate the design. The result of regression coefficient shows the effect of roasting temperature and roasting time has significant effect ($p<0.05$) at interactive level. Roasting temperature was significant ($p<0.01$) at quadratic level. Second order predictive quadratic equation for odour is given below

$$Y= 0.13- 0.00838X_1+ 0.003245X_2+ 0.014X_1X_2+ 0.033X_1^2+ 0.00212X_2^2$$

Where, Y is odour and X_1 and X_2 are roasting temperature and roasting time

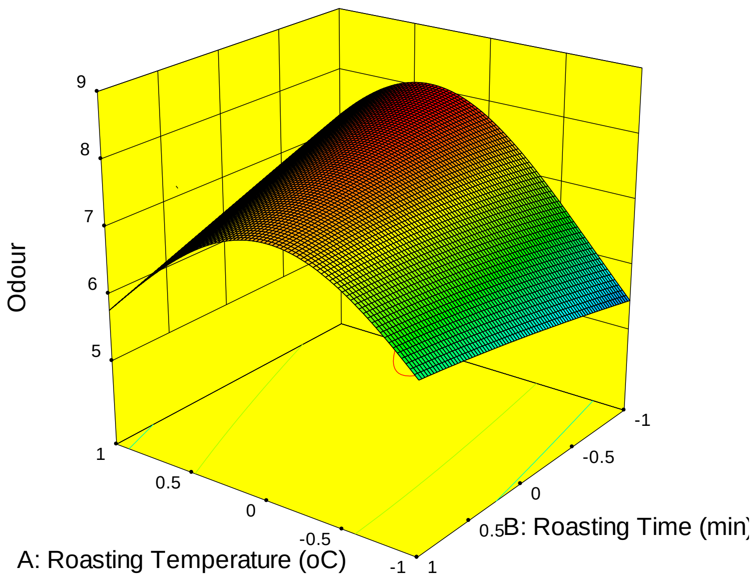

Fig. 4.3: Effect of roasting temperature and roasting time on odour for halogen oven

Influence of roasting temperature and roasting time on odour is shown in Figure 4.3. It was observed that odour scores increased upto certain roasting temperature and roasting time but decreased at low and high roasting temperature and roasting time. It revealed that the variation in roasting temperature and roasting time effected the odour of roasted pumpkin seeds. Sample roasted at 200ºC for 4 min exhibited better odour than other sample.

4.2.1.4 Effect of roasting temperature and roasting time on overall acceptability

Effect of process variables on overall acceptability is depicted in Table 4.5. The score ranged from 6.0 to 8.8. The maximum score (8.8) of overall acceptability was observed for experimental combination of 190ºC roasting temperature and 6 min roasting time. The minimum score (6.0) of overall acceptability was observed for experimental combinations of 180ºC for 6 min and 200ºC for 6 and 8 min roasting temperature roasting time. Table 4.10 shows the effect of roasting temperature and roasting time at linear, quadratic and interaction levels. It can be seen from the table that quadratic and interactive levels were significant at 1% and 5% levels, as their F_{cal} (14.39 and 5.152) was greater than F_{tab} (5.780 and 4.325) while for linear it found to be non-significant, as their F_{cal} (0.945) value was lesser than F_{tab} (2.575) value.

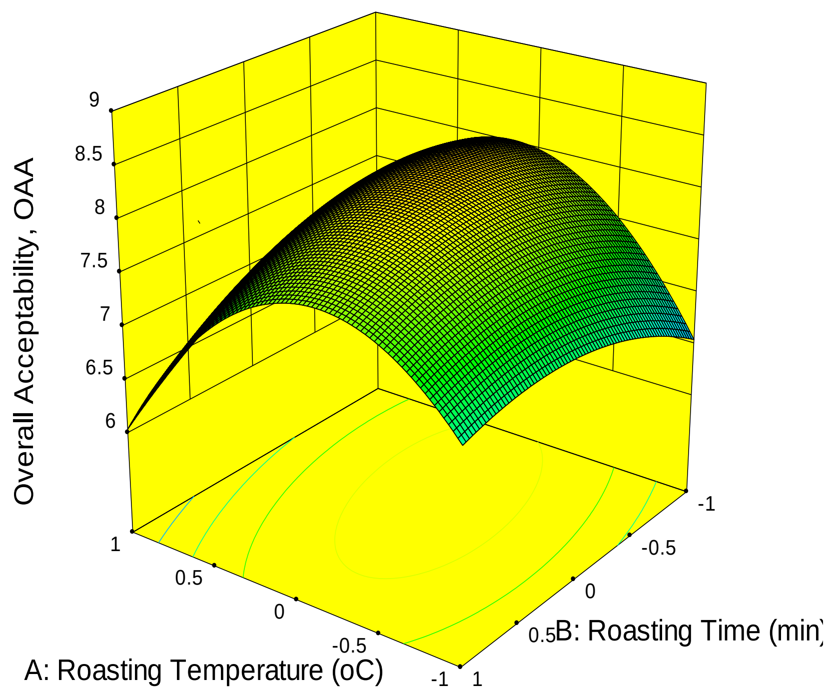

Fig. 4.4: Effect of roasting temperature and roasting time on overall acceptability for halogen oven

Table 4.10: ANOVA for overall acceptability (halogen oven)

SOURCE	DF	SS	MS	F-Value
Model	5	11.76	2.352	7.18*
Linear	2	0.620	0.310	0.945
Quadratic	2	9.440	4.720	14.39*
Interactive	1	1.690	1.690	5.152**
Error	21	6.88	0.328	
Total	26	18.64		

***, **, * Significant at 10, 5 and 1% level

The regression analysis on overall acceptability is given in Table 4.6. The model was found highly significant with F-value 7.18 which is greater than F_{tab} (4.042) at 1%. The values of R^2, adj. R^2 were found to be 0.6309 and 0.5430 respectively. R^2 -adj value was observed to be relatively close to R^2 value, it ensures a relatively satisfactory adjustment of the quadratic model to the experimental data. The lack of fit was found non-significant for the model hence the model can be used to navigate the design. The result of regression coefficient shows that the effect of roasting temperature has significant effect ($p<0.01$) at quadratic level. At interactive level, roasting temperature and roasting time significantly affected the overall acceptability ($p<0.05$). Second order predictive quadratic equation for overall acceptability is given below

$$Y= 8.21-0.11X_1- 0.15X_2- 0.38X_1X_2- 1.21X_1^2- 0.33X_2^2$$

Where, Y is overall acceptability and X_1 and X_2 are roasting temperature and roasting time

Influence of roasting temperature and roasting time on overall acceptability is shown in Figure 4.4. It was observed that overall acceptability increased up to roasting temperature and roasting time of 190ºC for 6 min but decreased at lower and higher roasting temperature and roasting time. This may be due to the under and over roasting of pumpkin seed kernel at lower and higher roasting temperature and time. Ozdemir and Sedaghat (2001) also stated that very light roasted and very dark roasted hazelnuts were not preferred by the consumers. Medium roasted hazelnuts obtained the highest score.

4.2.1.5 Effect of roasting temperature and roasting time on hardness

Effect of process variables on hardness is depicted in Table 4.5. It ranged from 24.92 g to 62.91 g. The maximum value (62.91g) of hardness was observed for experimental combination of 180ºC roasting temperature and 4 min roasting time. The minimum value (24.92g) of hardness was observed for experimental combination of 200ºC roasting temperature and 8 min roasting time. Table 4.11 shows the effect of roasting temperature and roasting time at linear, quadratic and interaction levels. It can be seen from the table that linear and quadratic levels had significant effect at 1% and 10% level, as their F_{cal} values 497.90 and 2.9776 were greater than F_{tab}.(5.780 and 2.575), while for interactive level it was found to be non-significant, as their F_{cal} 0.2375 value was lesser than F_{tab}(2.169) value.

The regression analysis on hardness is given in Table 4.6. The model was found highly significant with F-value 200.39 which is greater than F_{tab} (4.042) at 1%. The values of R^2, adj. R^2 were found to be 0.9795 and 0.9746 respectively. R^2–adj. value was observed to be relatively close to R^2 value, it ensures a relatively satisfactory adjustment of the quadratic model to the experimental data. The lack of fit was found non-significant for the model hence the model can be used to navigate the design. The result of regression coefficient shows the effect of roasting temperature and roasting time has significant effect ($p<0.1$) at linear level. Roasting time was significant ($p<0.05$) at quadratic level. Second order predictive quadratic equation for hardness is given below

$$Y= 46.57-11.94X_1- 5.00X_2-0.24X_1X_2- 0.54X_1^2- 1.65X_2^2$$

Where, Y is hardness and X_1 and X_2 are roasting temperature and roasting time

Table 4.11: ANOVA for hardness (halogen oven)

SOURCE	DF	SS	MS	F-Value
Model	5	3036.97	607.394	200.39*
Linear	2	3018.21	1509.11	497.90*
Quadratic	2	18.0500	9.02500	2.9776***
Interactive	1	0.72000	0.72000	0.2375
Error	21	63.6500	3.03095	
Total	26	3100.62		

***, **, * Significant at 10, 5 and 1% level

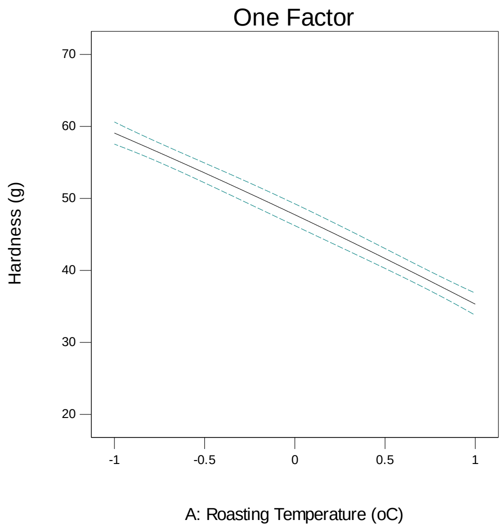

Fig. 4.5: Effect of roasting temperature on hardness for halogen oven

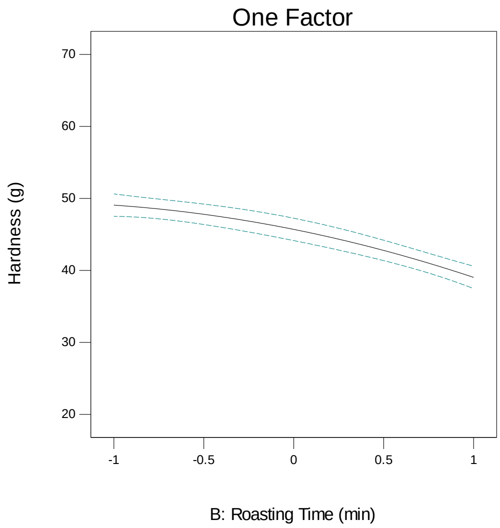

Fig. 4.6: Effect of roasting time on hardness for halogen oven

Influence of roasting temperature and roasting time on hardness is shown in Figures 4.5-4.6. There was a reverse relation between roasting temperature and roasting time on hardness, with the increasing temperature and time of roasting, hardness decreases, indicating a reduction in the strength of the kernel due to decrease in moisture content. The decrease in hardness showed the same deformation trend and force required to break the kernels was lower as roasting temperature and time were increased. Decreasing in hardness due to use of higher roasting temperature and time were also reported by Shakerardekani *et al.,* (2011) and Moghaddam *et al*., (2016) for pistachio kernels, Kita and Figiel (2006) for walnuts, Maridula *et al*., (2007) for soyabean respectively.

4.2.1.6 Effect of roasting temperature and roasting time on fracturability

Effect of process variables on fracturability is depicted in Table 4.5. The values ranged from 3.11g to 6.90g. The maximum value (6.90g) of fracturability was observed for experimental combination of 180ºC roasting temperature at 4 min roasting time. The minimum value (3.11g) of fracturability was observed for experimental combination of 200ºC roasting temperature and 8 min roasting time. Table 4.12 shows the effect of roasting temperature and roasting time at linear, quadratic and interaction levels. It can be seen from the table that linear, quadratic and interactive levels were highly significant at 1% level, as their F_{cal} values 214.186, 19.5549 and 11.4047 was greater than their F_{tab}.(5.780 and 8.017) values.

Table 4.12: ANOVA for fracturability (halogen oven)

SOURCE	DF	SS	MS	F-Value
Model	5	34.45	6.890	95.6200*
Linear	2	30.81	15.40	214.186*
Quadratic	2	2.812	1.406	19.5549*
Interactive	1	0.820	0.820	11.4047*
Error	21	1.510	0.072	
Total	26	35.96		

***, **, * Significant at 10, 5 and 1% level

The regression analysis on fracturability is given in Table 4.6. The model was found highly significant with F-value 95.62 which is greater than F_{tab} (4.042) at 1%. The values of R^2 and adj. R^2 were found to be 0.9579 and 0.9479 respectively. R^2 -adj value was observed to be relatively close to R^2 value, it ensures a relatively satisfactory adjustment of the quadratic model to the experimental data. The lack of fit was found non-significant for the model hence the model can be used to navigate the design. The result of regression coefficient shows the effect of roasting temperature and roasting time has significant effect ($p<0.1$) at linear and interactive level. Roasting temperature was significant ($p<0.01$) at quadratic level. Second order predictive quadratic equation for fracturability is given below

$$Y= 3.98- 1.26X_1- 0.37X_2- 0.26X_1X_2+ 0.68X_1^2- 0.019X_2^2$$

Where, Y is fracturability and X_1 and X_2 are roasting temperature and roasting time

Influence of roasting temperature and roasting time on fracturability is shown in Figure 4.7. It was observed that fracturability decreased with increase in roasting temperature and roasting time. Moghaddam *et al.*, (2016) reported that increasing the roasting temperature led to decrease the fracture force because during the roasting, moisture content decreased and the pistachio nuts and kernels become more crumble and fragile that cause to break easily. The results are also in agreement with those found by Saklar *et al*., (1999) and Dogan and Cronin *et al*., (2004) for roasting hazelnuts, Nikzadeh and Sedaghat (2008) for roasting pistachio nuts and Kahyaoglu and Kaya *et al*., (2006) for roasting sesame seeds.

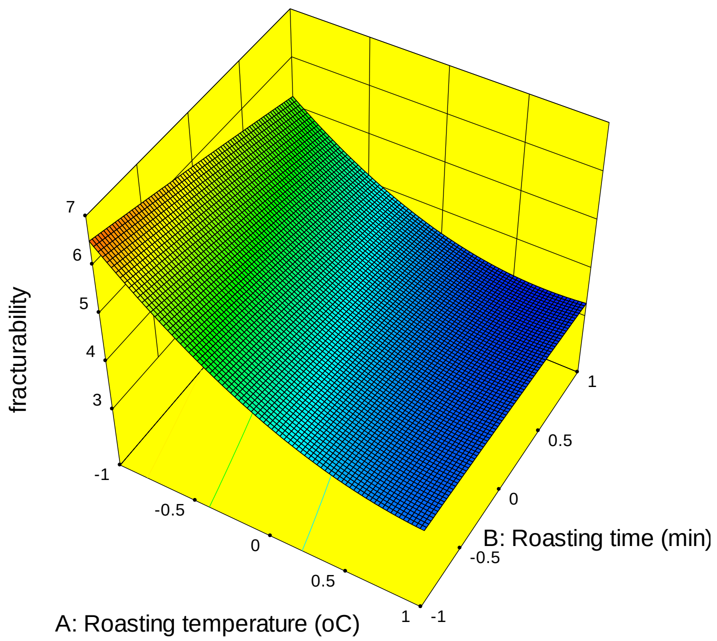

Fig. 4.7: Effect of roasting temperature and roasting time on fracturability for halogen oven

4.2.1.7 Effect of roasting temperature and roasting time on phytic acid

Effect of process variables on phytic acid is depicted in Table 4.5. The values ranged from 0.1385% to 0.2552%. The maximum value (0.2552%) of phytic acid was observed for experimental combination of 180ºC roasting temperature and 4 min roasting time. The minimum value (0.1385%) of phytic acid was observed for experimental combination of 200ºC roasting temperature and 4 min roasting time. Table 4.13 shows the effect of roasting temperature and roasting time at linear, quadratic and interaction levels. It can be seen from the table that linear and interactive levels were significant at 1% and 5% level, as their F_{cal} values 94.26 and 4.710 was greater than F_{tab}. (5.780 and 4.325), while for quadratic level it was found to be non-significant, as their F_{cal} 2.502 value was lesser than F_{tab} (2.575) value.

Table 4.13: ANOVA for phytic acid (halogen oven)

SOURCE	DF	SS	MS	F-Value
Model	5	20.20	4.040	39.59*
Linear	2	19.21	9.605	94.26*
Quadratic	2	0.510	0.255	2.502
Interactive	1	0.480	0.480	4.710**
Error	21	2.140	0.102	
Total	26	22.34		

***, **, * Significant at 10, 5 and 1% level

The regression analysis on phytic acid is given in Table 4.6. The model was found highly significant with F-value 39.59 which is greater than F_{tab} (4.042) at 1%. The values of R^2 and adj. R^2 were found to be 0.9041 and 0.8813 respectively. R^2 -adj value was observed to be relatively close to R^2 value, it ensures a relatively satisfactory adjustment of the quadratic model to the experimental data. The lack of fit was found non-significant for the model hence the model can be used to navigate the design. The result of regression coefficient shows the effect of roasting temperature and roasting time has significant effect ($p<0.01$) at linear level. Roasting temperature was significant ($p<0.1$) at quadratic level. The effect of roasting temperature and roasting time has significant effect ($p<0.05$) at interactive level. Second order predictive quadratic equation for phytic acid is given below

$$Y= 5.20+ 1.00X_1+ 0.25X_2- 0.20X_1X_2+ 0.24X_1^2+ 0.17X_2^2$$

Where, Y is phytic acid and X_1 and X_2 are roasting temperature and roasting time

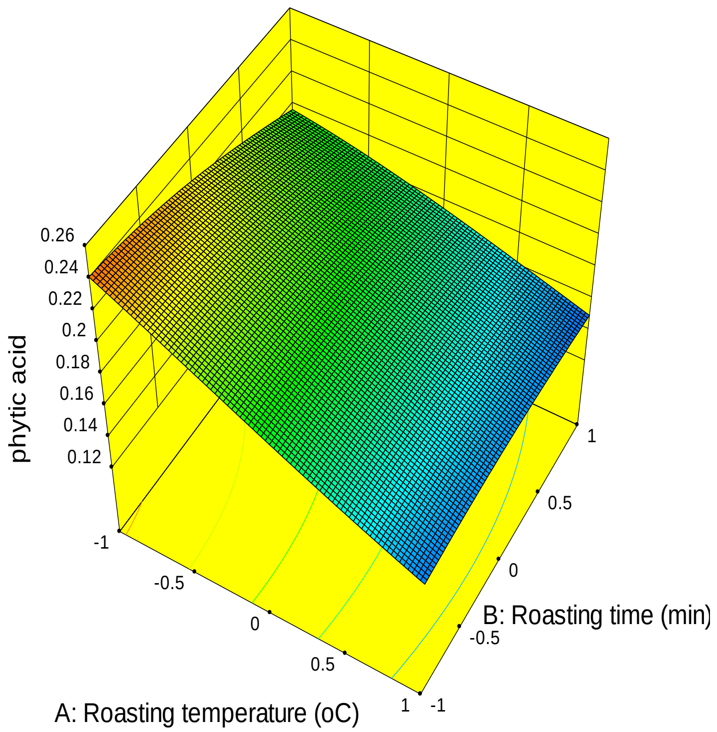

Fig.4.8: Effect of roasting temperature and roasting time on phytic acid for halogen oven

Influence of roasting temperature and roasting time on phytic acid is shown in Figure 4.8. It was observed that phytic acid decreased with increase in roasting temperature and roasting time. Phytic acid is relatively heat-labile, therefore its value might have decrease with higher roasting temperature and roasting time. Garcia *et al*., (2012) also reported the lower phytic acid content in roasted samples than unroasted samples of rice bran. Similarly, a significant reduction of phytic acid contents by thermal processing (boiling, microwave, autoclaving, roasting) were also observed by Fagbemi *et al*., (2006), Frontela *et al*., (2008) and Wang *et al*.,(2008) in pumpkin seeds and peas.

4.2.1.8 Optimization of variables

Table 4.14: Optimum levels of roasting conditions for pumpkin seed kernels

Independent variables	Coded levels	Predicted levels	Actual levels
Roasting Temperature (X_1)	0.073	190.73ºC	190ºC
Roasting time (X_2)	-0.257	5.486 min	5.00 min
Responses		**Values**	**Values**
Colour & appearance (1-9)		8.547	8.5
Taste (1-9)		8.56	8.3
Odour (1-9)		7.865	8.0
Overall acceptability (1-9)		8.217	8.3
Hardness (g)		46.88	44.62
Fracturability (g)		3.976	4.531
Phytic acid (%)		0.192	0.157

For the optimization of different variables, a numerical optimization was carried out using Design Expert 10.0.1 statistical software, where all the responses were given similar importance. The desired results for each factor and response were chosen and assigned as per the ultimate aim. The ultimate aims were as follows, maximum colour and appearance, maximum taste, maximum odour, maximum overall acceptability, minimum hardness, maximum fracturability and minimum phytic acid. The best solution with a single formulation with different levels of variables was obtained which is presented in Table 4.14, along with the actual values of the optimized product.

4.2.2 Optimization of Roasting Conditions of Pumpkin Seed Kernels in Hot Air Oven

Effect of roasting temperature and roasting time on the responses i.e. sensory evaluation (colour and appearance, taste, odour, overall acceptability), texture profile analysis (hardness, fracturability), and phytic acid was determined and statistically analysed. Experimental data is shown in Table 4.15.

4.2.2.1 Effect of roasting temperature and roasting time on colour and appearance

Effect of process variables on colour and appearance are depicted in Table 4.15. The colour and appearance score ranged from 5.0 to 7.8. The maximum score (7.8) of colour and appearance was observed for experimental combination of 160ºC roasting temperature and 30 min roasting time. The minimum score (5.5) was observed for experimental combinations of 150ºC and 170ºC roasting temperature and 20 min and 30 min roasting time. It can be seen from the Table 4.17 that quadratic and interactive levels were significant at 1% and 10% levels, as their F_{cal} values 23.679 and 2.261 was greater than their F_{tab}. (5.780 and 2.169), while for linear level it was found to be non-significant, as their F_{cal} 2.413 value was lesser than F_{tab} (2.575) value.

The regression analysis on colour and appearance is shown in Table 4.16. The model was found highly significant with F-value 10.69 which is greater than $F_{tab.}$ (4.042) at 1%. The values of R^2, adj.-R^2 were found to be 0.7179 and 0.6507 respectively. R^2 –adj value was observed to be relatively close to R^2 value, it ensures a relatively satisfactory adjustment of the quadratic model to the experimental data. The lack of fit was found non-significant for the model hence the model can be used to navigate the design. The result of regression coefficient shows the effect of roasting temperature has significant effect ($p<0.1$) at linear level. At quadratic level, roasting temperature was significantly affected the colour and appearance ($p<0.01$). Second order predictive quadratic equation for colour and appearance is given below

$$Y= 7.19- 0.22X_1+ 0.11X_2- 0.21X_1X_2- 1.32X_1^2- 0.31X_2^2$$

Where, Y is colour and appearance and

X_1 and X_2 are roasting temperature and roasting time

Table 4.15: Variables and responses of pumpkin seed kernels roasted in hot air oven (R_2)

Expt No.	Roasting temperature (°C)	Roasting time (min)	Colour & Appearance (1-9)	Taste (1-9)	Odour (1-9)	Overall acceptability (OAA) (1-9)	Hardness (g)	Fracturability (g)	Phytic acid (%)
1.	150 (-1)	20 (0)	6.0	6.0	6.0	6.5	61.22	5.16	0.2088
2.	160 (0)	30 (1)	7.0	8.0	7.8	7.8	40.10	3.50	0.1508
3.	160 (0)	30 (1)	7.0	7.5	8.0	7.5	39.70	3.80	0.1508
4.	150 (-1)	30 (1)	6.0	7.0	7.0	7.0	50.29	4.73	0.1996
5.	150 (-1)	30 (1)	6.5	7.0	7.5	7.0	50.11	4.84	0.1972
6.	150 (-1)	10 (-1)	6.0	7.0	6.5	6.5	65.50	6.21*	0.2320*
7.	170 (1)	30 (1)	5.0**	6.0	6.0	6.0	26.90**	3.32	0.0789**
8.	170 (1)	10 (-1)	6.0	5.5	6.0	6.5	35.47	3.78	0.1044
9.	160 (0)	30 (1)	7.8*	8.5*	8.5*	8.2	45.51	3.90	0.1740
10.	170 (1)	20 (0)	5.0**	6.0	5.7	5.0**	33.70	3.38	0.1081
11.	170 (1)	10 (-1)	5.5	6.0	7.0	7.0	34.33	3.57	0.1044
12.	170 (1)	30 (1)	5.5	5.5	5.5**	5.0**	29.30	3.09**	0.0812

13.	160 (0)	30 (1)	7.5	7.8	7.0	7.5	39.90	3.90	0.1485
14.	170 (1)	20 (0)	5.5	7.0	6.0	6.0	30.80	3.27	0.0858
15.	160 (0)	20 (0)	7.0	8.0	8.0	8.2	48.43	3.94	0.1763
16.	160 (0)	10 (-1)	6.0	6.5	7.5	7.2	47.10	4.26	0.1856
17.	150 (-1)	10 (-1)	5.0**	6.0	6.0	6.0	66.10*	6.00	0.2320*
18.	160 (0)	20 (0)	7.5	7.8	7.5	8.5*	41.35	3.89	0.1740
19.	150 (-1)	10 (-1)	6.0	6.5	6.5	6.0	65.20	6.01	0.2297
20.	150 (-1)	20 (0)	6.5	6.5	6.5	6.0	61.12	5.34	0.2088
21.	160 (0)	10 (-1)	6.0	7.0	7.0	7.0	50.20	4.35	0.1880
22.	170 (1)	10 (-1)	5.5	7.5	7.5	6.0	35.45	3.69	0.1021
23.	170 (1)	30 (1)	5.0**	5.0**	5.7	5.0**	28.70	3.16	0.1020
24.	170 (1)	20 (0)	5.2	5.3	5.6	5.0**	33.80	3.49	0.0882
25.	150 (-1)	20 (0)	5.5	6.5	6.5	7.0	61.32	5.28	0.2042
26.	160 (0)	10 (-1)	7.0	7.0	7.0	7.0	48.30	4.47	0.1856
27.	150 (-1)	30 (1)	6.5	6.0	7.0	7.0	50.17	4.95	0.1903

*Maximum, ** Minimum

Table 4.16: Regression analysis of roasted pumpkin seed kernels in hot air oven (R_2)

Cons.	Colour & Appearance		Taste		Odour		Overall acceptability		Hardness		Fracturability		Phytic acid	
	Coeff.	P (%)	Coeff.	P (%)	Coeff.	P (%)	Coeff.	P (%)	Coeff.	P (%)	Coeff.	P (%)	Coeff.	P (%)
	7.19	0.01*	7.78	0.09*	7.67	0.02*	7.58	0.01*	45.68	0.01*	0.25	0.01*	0.17	0.01*
X_1	-0.22	6.50***	-0.22	14.05	-0.11	34.03	-0.43	0.35*	-13.48	0.01*	0.053	0.01*	-0.058	0.01*
X_2	0.11	34.13	0.044	76.23	0.044	70.02	0.028	83.51	-5.14	0.01*	0.020	0.01*	-0.015	0.01*
X_1X_2	-0.21	15.09	-0.25	17.40	-0.46	0.35*	-0.75	0.01*	2.16	0.01*	-0.00002	99.13	0.0048	2.34**
X_1^2	-1.31	0.01*	-1.29	0.01*	-1.09	0.01*	-1.40	0.01*	1.02	13.53	-0.011	0.25*	-0.017	0.01*
X_2^2	-0.31	13.04	-0.32	21.36	-0.12	54.21	0.050	82.88	-1.76	1.37**	-0.0048	13.42	0.00037	89.50
R^2	71.79		60.66		67.07		76.94		98.61		98		98.56	
Adj.R^2	65.07		51.29		59.23		71.45		98.23		97.52		98.22	
F	10.69 (1% 4.042)		6.48 (1% 4.042)		8.56 (1% 4.042)		14.02 (1% 4.042)		297.63 (1% 4.042)		205.85 (1% 4.042)		287.32 (1% 4.042)	
LOF	NS		NS		NS		NS		NS		NS		NS	

*, ** and *** Significant at 1, 5 and 10% level of significance respectively, Coeff. = Coefficient, NS= Non significant, Cons.= Constant, LOF= Lack of Fit, X_1= Roasting temperature and X_2 = Roasting time

Table 4.17: ANOVA for colour and appearance (hot air oven)

SOURCE	DF	SS	MS	F-Value
Model	5	12.53	2.510	10.69*
Linear	2	1.110	0.555	2.413
Quadratic	2	10.89	5.445	23.674*
Interactive	1	0.520	0.520	2.261***
Error	21	4.920	0.230	
Total	26	17.45		

***, **, * Significant at 10, 5 and 1% level

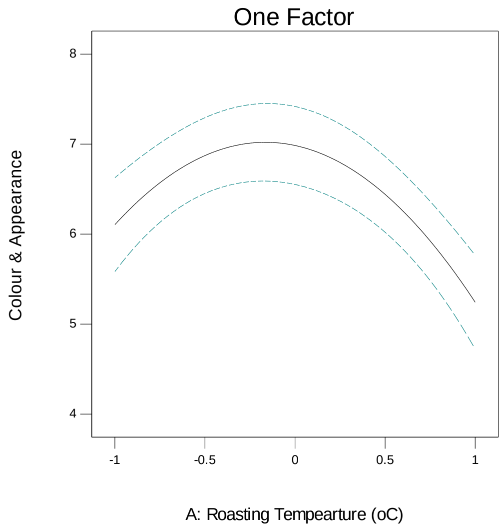

Fig.4.9: Effect of roasting temperature on colour and appearance for hot air oven

Influence of roasting temperature and roasting time on colour and appearance is shown in Figure 4.9. It was observed that colour and appearance increased up to roasting temperature and roasting time of 160ºC for 6 min but the score reduced at lower and higher roasting temperature and roasting time.

4.2.2.2 Effect of roasting temperature and roasting time on taste

Effect of process variables on taste is depicted in Table 4.15. The score ranged from 5.0 to 8.5. The maximum score (8.5) of taste was observed for experimental combination of 160ºC roasting temperature and 30 min roasting time. The minimum score (5.0) was observed for experimental combination of 170ºC roasting temperature 30 min roasting time. It can be seen from the Table 4.18 that quadratic level was highly significant at 1% level, as their F_{cal} values 13.934 was greater than F_{tab}.(5.780), while for linear and interactive levels were found to be non-significant, as their F_{cal} (1.218 and 1.974) values were lesser than F_{tab} (2.575 and 2.169) values.

Table 4.18: ANOVA for taste (hot air oven)

SOURCE	DF	SS	MS	F-Value
Model	5	12.26	2.450	6.480*
Linear	2	0.926	0.463	1.218
Quadratic	2	10.59	5.295	13.934*
Interactive	1	0.750	0.750	1.974
Error	21	7.950	0.380	
Total	26	20.21		

***, **, * Significant at 10, 5 and 1% level

The regression analysis on taste is shown in Table 4.16. The model was found highly significant with F-value 6.48 which is greater than F_{tab} (4.042) at 1%. The values of R^2, adj-R^2 were found to be 0.6066 and 0.5129 respectively. R^2 -adj value was observed to be relatively close to R^2 value, it ensures a relatively satisfactory adjustment of the quadratic model to the experimental data. The lack of fit was found to be non-significant for the model hence the model can be used to navigate the design. The result of regression coefficient shows the effect of roasting temperature and roasting time has non-significant effect at linear and interactive levels. At quadratic level, roasting temperature has ($p<0.01$) significance. Second order predictive quadratic equation for taste is given below

$$Y= 7.78- 0.22X_1+ 0.044X_2- 0.25X_1X_2- 1.29X_1^2- 0.32X_2^2$$

Where, Y is taste and X_1 and X_2 are roasting temperature and roasting time

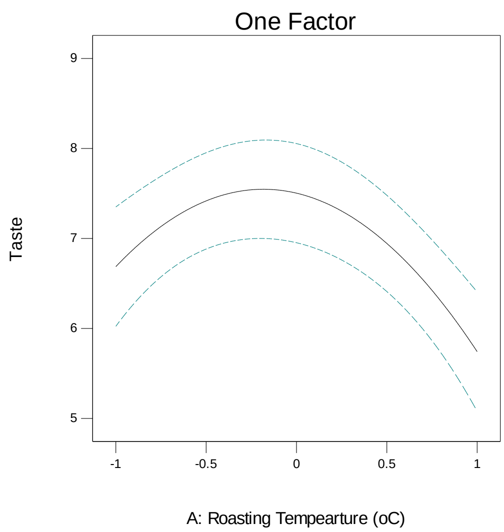

Fig.4.10: Effect of roasting temperature on taste for hot air oven

Influence of roasting temperature and roasting time on taste is shown in Figure 4.10. It was observed that taste score increased up to 160°C roasting temperature and 30 min roasting time but reduced at lower and higher roasting temperature and roasting time.

4.2.2.3 Effect of roasting temperature and roasting time on odour

Effect of process variables on odour is depicted in Table 4.15. The score ranged from 5.5 to 8.5. The maximum score (8.5) of odour was observed for experimental combination of 160°C and 30 min. The minimum score (5.5) of odour was observed for experimental combination of 170°C and 30 min roasting time. It can be seen from the Table 4.19 that quadratic and interactive levels were highly significant at 1% level, as their F_{cal} values 25.598 and 29.348 was greater than F_{tab}. (5.780 and 8.017), while linear level was found to be non-significant as their F_{cal} 0.557 value was lesser than F_{tab} (2.575) value.

Table 4.19: ANOVA for odour (hot air oven)

SOURCE	DF	SS	MS	F-Value
Model	5	9.980	2.000	8.560*
Linear	2	0.256	0.128	0.557
Quadratic	2	11.775	5.888	25.598*
Interactive	1	6.750	6.750	29.348*
Error	21	4.900	0.230	
Total	26	14.880		

***, **, * Significant at 10, 5 and 1% level

The regression analysis on odour is given in Table 4.16. The model was found highly significant with F-value 8.56 which is greater than F_{tab} (4.042) at 1%. The values of R^2, adj. R^2 were found to be 0.6707 and 0.5923 respectively. R^2 -adj value was observed to be relatively close to R^2 value, it ensures a relatively satisfactory adjustment of the quadratic model to the experimental data. The lack of fit was found non-significant for the model hence the model can be used to navigate the design. The result of regression coefficient shows the effect of roasting temperature and roasting time has significant effect ($p<0.01$) at interactive level. Roasting temperature was significant ($p<0.01$) at quadratic level. Second order predictive quadratic equation for hardness is given below

$$Y = 7.67 - 0.11X_1 + 0.044X_2 - 0.46X_1X_2 - 1.09X_1^2 - 0.12X_2^2$$

Where, Y is odour and X_1 and X_2 are roasting temperature and roasting time

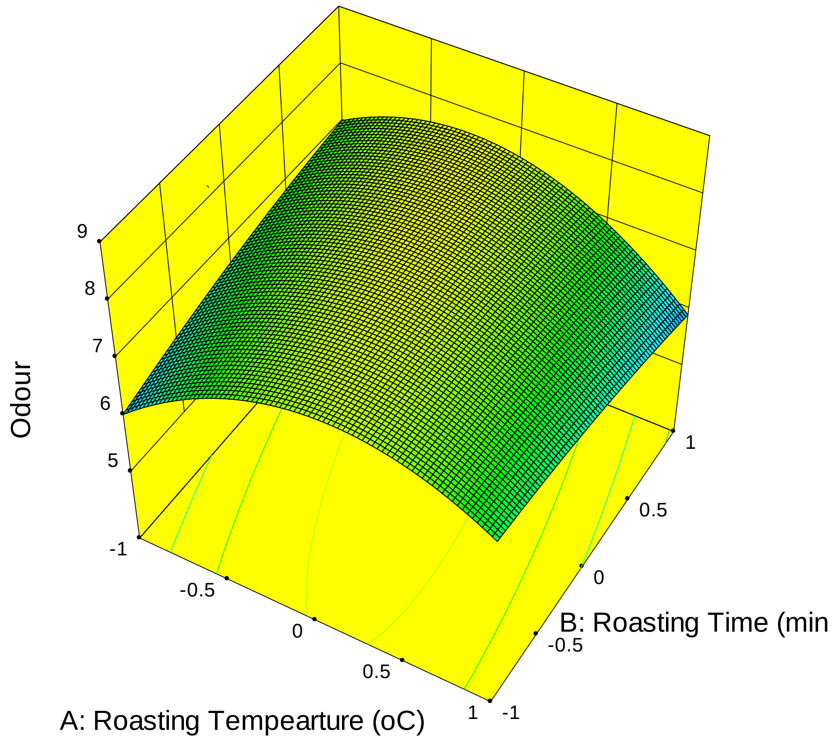

Fig. 4.11: Effect of roasting temperature and roasting time on odour for hot air oven

Influence of roasting temperature and roasting time on odour is shown in Figure 4.11. It was observed that odour scores were low at lower and higher level of roasting temperature and roasting time.

4.2.2.4 Effect of roasting temperature and roasting time on overall acceptability

Effect of process variables on overall acceptability is depicted in Table 4.15. The score ranged from 5.0 to 8.5. The maximum score (8.5) of overall acceptability was observed for experimental combination of 160°C roasting temperature and 20 min roasting time. The minimum score (5.0) of overall acceptability was observed for experimental combinations of 170°C for 20 min and 30 min roasting temperature roasting time. It can be seen from the Table 4.20 that linear, quadratic and interactive levels were significant at 10%, 1% level and 1%, as their F_{cal} 5.474, 18.992 and 21.774 values was greater than F_{tab} (3.467, 5.780 and 8.017) values.

The regression analysis on overall acceptability is given in Table 4.16. The model was found highly significant with F-value 14.02 which is greater than F_{tab} (4.042) at 1%. The values of R^2, adj. R^2 were found to be 0.7694 and 0.7145 respectively. R^2 –

adj. value was observed to be relatively close to R^2 value, it ensures a relatively satisfactory adjustment of the quadratic model to the experimental data. The lack of fit was found non-significant for the model hence the model can be used to navigate the design. The result of regression coefficient shows that the effect of roasting temperature has significant effect ($p<0.1$) at linear and quadratic levels. At interactive level, roasting temperature and roasting time significantly affected the overall acceptability ($p<0.01$). Second order predictive quadratic equation for overall acceptability is given below

$$Y= 7.58- 0.43X_1+ 0.028X_2- 0.75X_1X_2- 1.40X_1^2+ 0.050X_2^2$$

Where, Y is overall acceptability and X_1 and X_2 are roasting temperature and roasting time

Table 4.20: ANOVA for overall acceptability (hot air oven)

SOURCE	DF	SS	MS	F-Value
Model	5	21.920	4.380	14.020*
Linear	2	3.394	1.697	5.474**
Quadratic	2	11.775	5.888	18.992*
Interactive	1	6.750	6.750	21.774*
Error	21	6.570	0.310	
Total	26	28.490		

***, **, * Significant at 10, 5 and 1% level

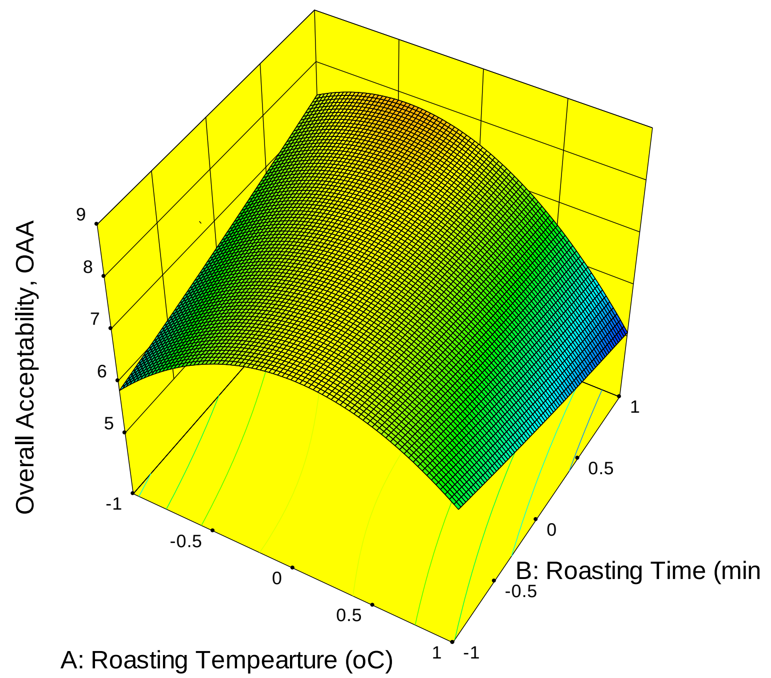

Fig. 4.12: Effect of roasting temperature and roasting time on overall acceptability for hot air oven

Influence of roasting temperature and roasting time on overall acceptability is shown in Figure 4.12. It was observed that overall acceptability increased up to 160ºC for 20 min roasting temperature and roasting time but reduced at low and high roasting temperature and roasting time.

4.2.2.5 Effect of roasting temperature and roasting time on hardness

Effect of process variables on hardness is depicted in Table 4.15. It ranged from 26.90 g to 66.10 g. The maximum value (66.10 g) of hardness was observed for experimental combination of 150ºC roasting temperature and 10 min roasting time. The minimum value (26.90 g) of hardness was observed for experimental combination of 170ºC roasting temperature and 30 min roasting time. It can be seen from the Table 4.21 that linear, quadratic and interactive levels has significant at 1%, 5% and 1% levels, as their F_{cal} values 728.46, 4.823 and 21.716 were greater than F_{tab}.(5.780, 3.467 and 8.017) values.

Table 4.21: ANOVA for hardness (hot air oven)

SOURCE	DF	SS	MS	F-Value
Model	5	3824.91	764.980	297.63*
Linear	2	3744.31	1872.155	728.46*
Quadratic	2	24.79	12.395	4.823**
Interactive	1	55.81	55.810	21.716*
Error	21	53.97	2.570	
Total	26	3878.88		

***, **, * Significant at 10, 5 and 1% level

The regression analysis on hardness is given in Table 4.16. The model was found highly significant with F-value 297.63 which is greater than F_{tab} (4.042) at 1%. The values of R^2, adj. R^2 were found to be 0.9861 and 0.9823 respectively. R^2–adj. value was observed to be relatively close to R^2 value, it ensures a relatively satisfactory adjustment of the quadratic model to the experimental data. The lack of fit was found non-significant for the model hence the model can be used to navigate the design. The result of regression coefficient shows the effect of roasting temperature and roasting time has significant effect ($p<0.01$) at linear and interactive levels. Roasting time has significant ($p<0.05$) at quadratic level. Second order predictive quadratic equation for hardness is given below

$$Y= 45.58-13.48X_1- 5.14X_2+ 2.16X_1X_2+ 1.02X_1^2- 1.76X_2^2$$

Where, Y is hardness and X_1 and X_2 are roasting temperature and roasting time

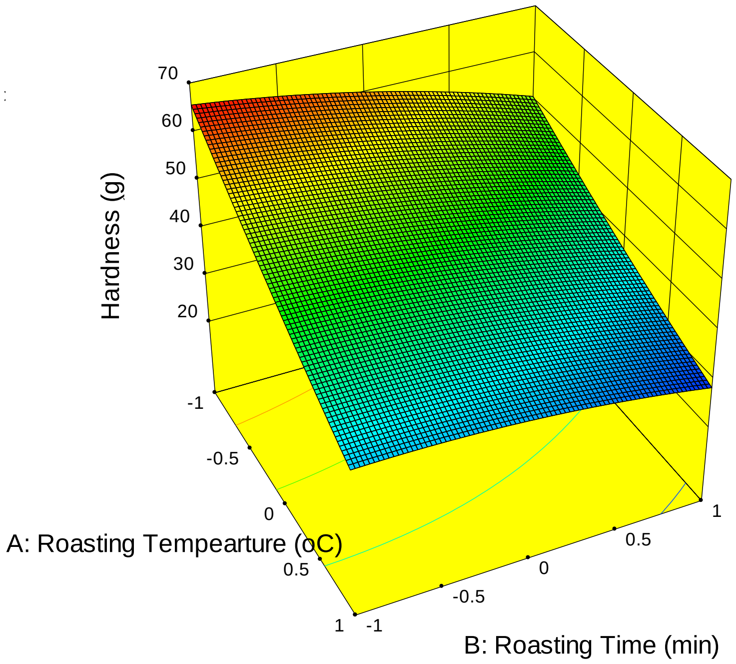

Fig. 4.13: Effect of roasting temperature and roasting time on hardness for hot air oven

Influence of roasting temperature and roasting time on hardness is shown in Figure 4.13. It was observed that hardness decreased with increasing in roasting temperature (150ºC-170ºC) and roasting time (10 min -30 min). The results are in accordance with the results reported by Kahyaoglu and Kaya (2006) for sesame seed and Nikzadeh and Sedaghat (2008) for pistachio nuts for decreased in hardness at higher roasting temperature and roasting time.

4.2.2.6 Effect of roasting temperature and roasting time on fracturability

Effect of process variables on fracturability is depicted in Table 4.15. The values ranged from 3.09 g to 6.21 g. The maximum value (6.21 g) of fracturability was observed for experimental combination of 150ºC roasting temperature at 10 min roasting time. The minimum value (3.09 g) of fracturability was observed for experimental combination of 170ºC roasting temperature and 30 min roasting time. It can be seen from the Table 4.22 that linear and quadratic were significant at 1% and 5% levels, as their F_{cal} values 504.68 and 7.098 was greater than their F_{tab}.(5.780 and 3.467) values while the interactive level was found to be non-significant as their F_{cal} value 0.0002 was lesser than their F_{tab}.(2.169) value.

Table 4.22: ANOVA for fracturability (hot air oven)

SOURCE	DF	SS	MS	F-Value
Model	5	0.060	0.0120	205.85*
Linear	2	0.059	0.0293	504.68*
Quadratic	2	0.0008	0.0004	7.098**
Interactive	1	0.0000	0.0000	0.0002
Error	21	0.0012	0.0001	
Total	26	0.0612		

***, **, * Significant at 10, 5 and 1% level

The regression analysis on fracturability is given in Table 4.16. The model was found highly significant with F-value 205.85 which is greater than F_{tab} (4.042) at 1%. The values of R^2 and adj. R^2 were found to be 0.9800 and 0.9752 respectively. R^2 -adj value was observed to be relatively close to R^2 value, it ensures a relatively satisfactory adjustment of the quadratic model to the experimental data. The lack of fit was found non-significant for the model hence the model can be used to navigate the design. The result of regression coefficient shows the effect of roasting temperature and roasting time has significant effect ($p<0.1$) at linear level. Roasting temperature was significant ($p<0.01$) at quadratic level. Second order predictive quadratic equation for fracturability is given below

$$Y= 0.25+ 0.053X_1- 0.020X_2- 0.000024X_1X_2- 0.011X_1^2- 0.0048X_2^2$$

Where, Y is fracturability and X_1 and X_2 are roasting temperature and roasting time

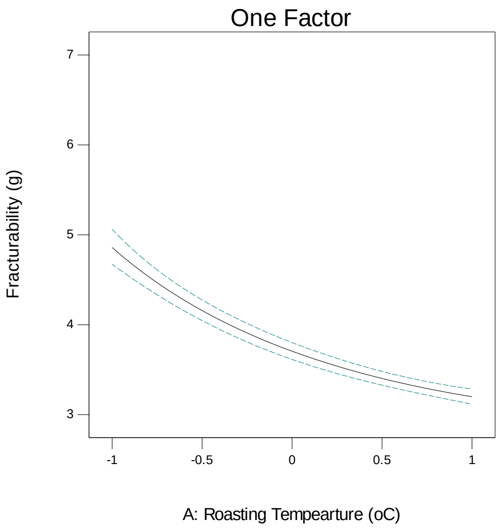

Fig. 4.14: Effect of roasting temperature on fracturability for hot air oven

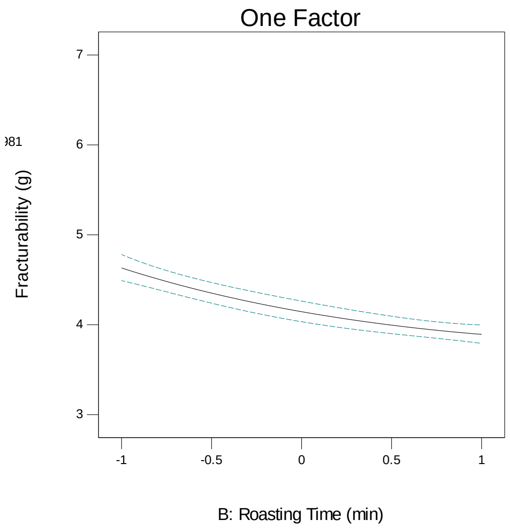

Fig. 4.15: Effect of roasting time on fracturability for hot air oven

Influence of roasting temperature and roasting time on fracturability is shown in Figures 4.14-4.15. It was observed that fracturability decreased with increase in roasting temperature and roasting time similar to the results reported by Saklar *et al.*, (1999) and Dogan and Cronin (2004) for roasting hazelnuts, Nikzadeh and Sedaghat (2008) for roasting pistachio nuts and Kahyaoglu and kaya (2006) for roasting sesame seeds.

4.2.2.7 Effect of roasting temperature and roasting time on phytic acid

Effect of process variables on phytic acid is depicted in Table 4.15. The values ranged from 0.0789% to 0.2320%. The maximum value (0.2320%) of phytic acid was observed for experimental combination of 150ºC roasting temperature and 10 min roasting time. The minimum value (0.0789%) of phytic acid was observed for experimental combination of 170ºC roasting temperature and 30 min roasting time.

Table 4.23: ANOVA for phytic acid (hot air oven)

SOURCE	DF	SS	MS	F-Value
Model	5	0.0670	0.01300	287.320*
Linear	2	0.0649	0.03240	690.319*
Quadratic	2	0.0018	0.00089	18.945*
Interactive	1	0.0003	0.00028	5.915**
Error	21	0.0009	0.00005	
Total	26	0.0679		

***, **, * Significant at 10, 5 and 1% level

It can be seen from the Table 4.23 that linear and quadratic levels were highly significant at 1% level, as their F_{cal} values 690.319 and 18.945 were greater than F_{tab}. (5.780), followed by interactive level which is significant at 5%, as their F_{cal} 5.915 value was greater than F_{tab} (4.325) value.

The regression analysis on phytic acid is given in Table 4.16. The model was found highly significant with F-value 287.32 which is greater than F_{tab} (4.042) at 1%. The values of R^2 and adj. R^2 were found to be 0.9856 and 0.9822 respectively. R^2 -adj value was observed to be relatively close to R^2 value, it ensures a relatively satisfactory adjustment of the quadratic model to the experimental data. The lack of fit was found non-significant for the model hence the model can be used to navigate the design. The result of regression coefficient shows the effect of roasting temperature and roasting time has highly significant effect ($p<0.01$) at linear level. Roasting temperature and roasting time has significant effect ($p<0.05$) at interactive level. The effect of roasting temperature has significant effect ($p<0.01$) at quadratic level. Second order predictive quadratic equation for phytic acid is given below

$$Y= 0.17- 0.058X_1- 0.015X_2+ 0.0048X_1X_2- 0.017X_1^2+ 0.00037X_2^2$$

Where, Y is phytic acid and X_1 and X_2 are roasting temperature and roasting time

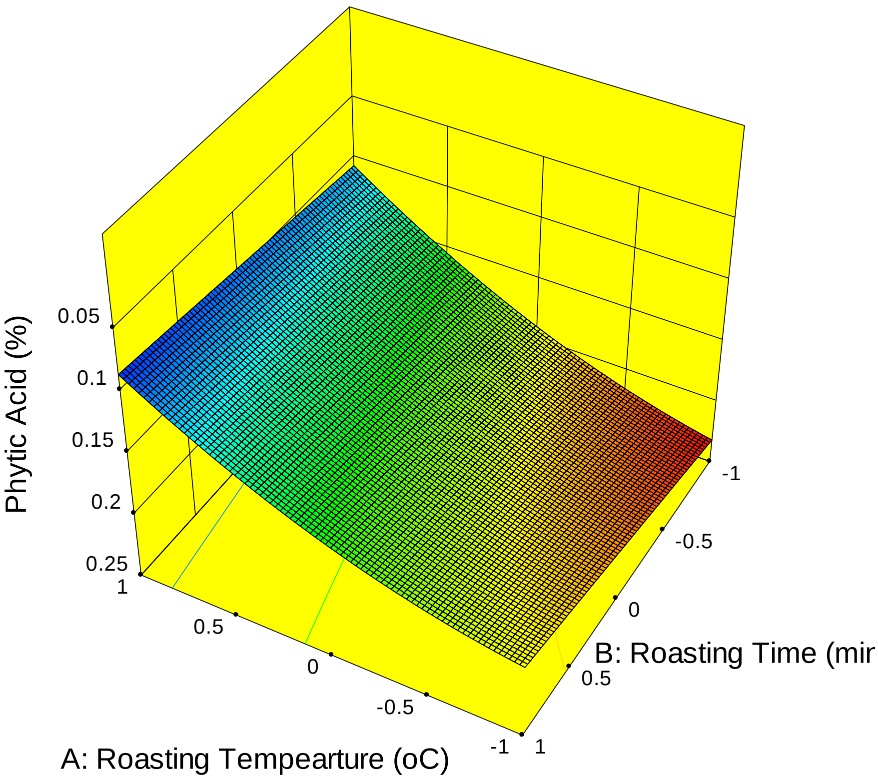

Fig.4.16: Effect of roasting temperature and roasting time on phytic acid for hot air oven

Influence of roasting temperature and roasting time on phytic acid is shown in Figure 4.16. It was observed that phytic acid decreased with roasting temperature and roasting time which is also in accordance with the results reported by Embaby (2010) for peanuts seeds and Habiba, (2002), Fagbemi *et al*., (2005), Frontela *et al*., (2008) and Wang *et al*., (2008) for other plant foods.

4.2.2.8 Optimization of variables

For the optimization of different variables, a numerical optimization was carried out using Design Expert 10.0.1 statistical software, where all the responses were given similar importance. The desired results for each factor and response were chosen and assigned as per the ultimate aim. The best solution with a single formulation with different levels of variables was obtained which is presented in Table 4.24, along with the actual values of the optimized product.

Table 4.24: Optimum levels of roasting conditions for pumpkin seed kernels for hot air oven

Independent variables	Coded levels	Predicted levels	Actual levels
Roasting Temperature (X_1)	-0.232	157.68ºC	160ºC
Roasting time (X_2)	1	30 min	30 min
Responses		**Values**	**Values**
Colour & appearance (1-9)		7.014	7.5
Flavour (1-9)		7.544	7.7
Odour (1-9)		7.666	7.8
Overall acceptability (1-9)		7.855	7.8
Hardness (g)		41.469	44.35
Fracturability (g)		3.893	3.912
Phytic acid (%)		0.167	0.159

4.2.3 Optimization of Roasting Conditions of Pumpkin Seed Kernels in Microwave oven

Effect of roasting temperature and roasting time on the responses i.e. sensory evaluation (colour and appearance, taste, odour, overall acceptability), texture profile analysis (hardness, fracturability), and phytic acid was determined and statistically analysed. Experimental data is shown in Table 4.25.

4.2.3.1 Effect of roasting temperature and roasting time on colour and appearance

The colour and appearance score ranged from 5.0 to 8.2. The maximum score (8.2) of colour and appearance was observed for experimental combination of P-90 roasting temperature and 3 min roasting time. The minimum score (5.0) was observed for experimental combinations of P-80 and P-100 roasting temperature and 3 min and 5 min roasting time. Table 4.27 shows the effect of roasting temperature and roasting time at linear, quadratic and interaction levels. It can be seen from the table that quadratic and interactive levels were significant at 1% level, as their F_{cal} values 13.35 and 28.79 was greater than their F_{tab}. (5.780 and 8.017), while for linear level it was found to be non-significant, as their F_{cal} 0.06 value was lesser than F_{tab} (2.575) value.

Table 4.25: Variables and responses of pumpkin seed kernels roasted in microwave oven (R_3)

*Maximum, ** Minimum

Table 4.26: Regression analysis of roasted pumpkin seed kernels in microwave oven (R_3)

Expt No.	Roasting temperature (°C)	Roasting time (min)	Colour & Appearance (1-9)	Taste (1-9)	Odour (1-9)	Overall acceptability (OAA) (1-9)	Hardness (g)	Fracturability (g)	Phytic acid (%)
1.	P-80 (-1)	4 (0)	6.7	7.0	6.0	7.0	64.32	6.16	0.2158
2.	P-90 (0)	4 (0)	7.8	8.0	7.6	7.5	50.31	4.90	0.1787
3.	P-90 (0)	5 (1)	7.8	6.0	7.0	7.0	50.12	4.59	0.1508
4.	P-80 (-1)	5 (1)	7.0	7.5	6.0	7.5	56.39	5.78	0.2542
5.	P-80 (-1)	5 (1)	7.5	7.5	8.0	7.8	52.31	5.74	0.2219
6.	P-100 (1)	4 (0)	7.0	7.0	6.0	6.5	40.71	3.75	0.1091
7.	P-100 (1)	5 (1)	5.0**	5.0**	5.5	5.0**	37.29	3.62**	0.1021**
8.	P-100 (1)	5 (1)	5.8	5.0**	5.0**	5.2	38.33	3.69	0.1044
9.	P-90 (0)	5 (1)	7.0	6.0	7.0	6.8	49.87	4.80	0.1508
10.	P-100 (1)	5 (1)	6.2	5.3	5.5	5.0**	36.27**	3.66	0.1044
11.	P-80 (-1)	4 (0)	6.9	7.0	7.0	6.6	62.22	6.24	0.2083

12.	P-100 (1)	3 (-1)	7.0	6.5	6.0	6.8	48.67	3.88	0.1276
13.	P-100 (1)	3 (-1)	6.5	7.0	6.5	7.2	45.73	3.92	0.1276
14.	P-80 (-1)	4 (0)	7.0	6.5	7.0	6.8	63.12	6.23	0.2358
15.	P-90 (0)	3 (-1)	8.2*	8.2*	8.0	8.2*	55.13	5.36	0.1972
16.	P-90 (0)	4 (0)	7.2	7.8	7.0	7.0	52.04	4.92	0.1763
17.	P-80 (-1)	3 (-1)	5.5	5.3	6.1	6.0	66.21*	7.28*	0.2297
18.	P-90 (0)	5 (1)	6.8	6.0	7.0	6.5	45.91	4.69	0.1508
19.	P-90 (0)	4 (0)	7.3	7.7	8.5*	7.5	52.25	4.89	0.174
20.	P-80 (-1)	5 (1)	7.0	6.0	7.5	7.8	50.27	5.75	0.2019
21.	P-90 (0)	3 (-1)	8.0	7.0	7.5	7.8	63.12	5.35	0.1819
22.	P-90 (0)	3 (-1)	7.8	7.6	7.0	7.8	54.03	5.37	0.1949
23.	P-80 (-1)	3 (-1)	5.0**	5.0**	5.8	6.0	66.18	7.14	0.2479
24.	P-100 (1)	4 (0)	6.0	7.0	7.0	6.8	44.80	3.74	0.1091
25.	P-100 (1)	5 (1)	7.0	7.0	7.0	6.8	40.93	3.72	0.1114
26.	P-100 (1)	5 (1)	6.8	7.0	6.0	6.5	44.95	3.93	0.1253
27.	P-80 (-1)	3 (-1)	6.4	5.6	5.5	6.4	65.16	7.16	0.2797*

Cons.	Colour & Appearance		Taste		Odour		Overall acceptability		Hardness		Fracturability		Phytic acid	
	Coeff.	P (%)	Coeff.	P (%)	Coeff.	P (%)	Coeff.	P (%)	Coeff.	P (%)	Coeff.	P (%)	Coeff.	P (%)
	0.13	0.01*	0.13	0.01*	0.12	0.01*	0.14	0.01*	0.19	0.01*	0.20	0.01*	5.94	0.01*
X_1	-0.00062	83.99	-0.00021	94.08	0.00697	2.78**	0.011	0.01*	0.00371	0.01*	0.054	0.01*	2.27	0.01*
X_2	-0.00084	78.42	0.00526	7.88***	0.00059	84.26	0.006827	0.12*	0.00202	0.01*	0.013	0.01*	0.61	0.01*
X_1X_2	0.020	0.01*	0.022	0.01*	0.014	0.08*	0.021	0.01*	0.00039	18.02	-0.00424	0.01*	0.32	0.08*
$X_1{}^2$	0.024	0.01*	0.023	0.01*	0.026	0.01*	0.023	0.01*	0.00118	0.70*	0.011	0.01*	0.76	0.01*
$X_2{}^2$	0.011	4.02**	0.021	0.03*	0.017	0.36*	-0.002919	36.59	0.00043	29.0	0.003917	0.01*	-0.14	25.94
R^2	72.62		79.69		73.47		89.88		94.43		99.86		98.37	
Adj.R^2	66.10		74.85		67.15		87.48		93.10		99.83		97.98	
F	11.14 (1% 4.042)		16.48(1% 4.042)		11.63(1% 4.042)		37.32(1% 4.042)		71.22 (1% 4.042)		2979.08 (1% 4.042)		253.64 (1% 4.042)	
LOF	NS		NS		NS		NS		NS		NS		NS	

*, ** and *** Significant at 1, 5 and 10% level of significance respectively, Coeff. = Coefficient, NS= Non significant, Cons.= Constant, LOF= Lack of Fit, X_1= Roasting temperature and X_2 = Roasting time

Table 4.27: ANOVA for colour and appearance (microwave oven)

SOURCE	DF	SS	MS	F-Value
Model	5	0.009109	0.0018218	11.14*
Linear	2	0.000019	0.0000097	0.06
Quadratic	2	0.004373	0.0021900	13.35*
Interactive	1	0.004716	0.0047160	28.79*
Error	21	0.003435	0.0001640	
Total	26	0.013000		

***, **, * Significant at 10, 5 and 1% level

The regression analysis on colour and appearance is shown in Table 4.26. The model was found highly significant with F-value 11.14 which is greater than $F_{tab.}$ (4.042) at 1%. The values of R^2, adj.-R^2 were found to be 0.7262 and 0.6610 respectively. R^2 –adj value was observed to be relatively close to R^2 value, it ensures a relatively satisfactory adjustment of the quadratic model to the experimental data. The lack of fit was found non-significant for the model hence the model can be used to navigate the design. The result of regression coefficient shows the effect of roasting temperature has significant effect ($p<0.01$) at interactive level. At quadratic level, roasting temperature was significant at ($p<0.01$) and roasting time at ($p<0.05$). Second order predictive quadratic equation for colour and appearance is given below

$$Y= 0.13- 0.00062X_1- 0.00084X_2+ 0.020X_1X_2+ 0.024X_1^2+ 0.011X_2^2$$

Where, Y is colour and appearance and X_1 and X_2 are roasting temperature and roasting time.

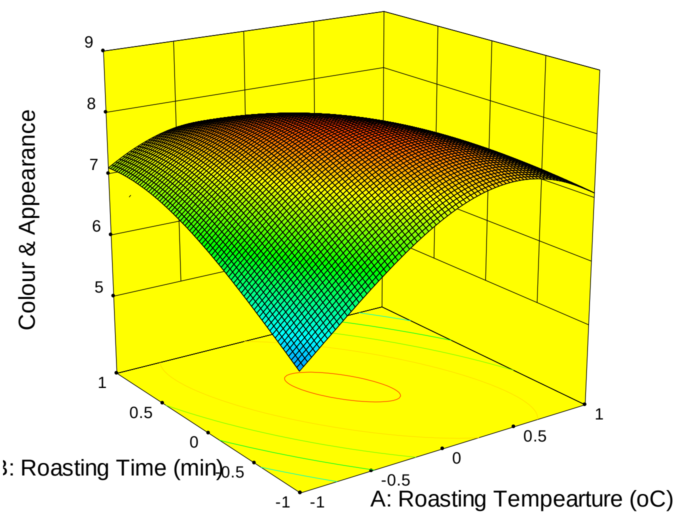

Fig.4.17: Effect of roasting temperature on colour and appearance for microwave oven

Influence of roasting temperature and roasting time on colour and appearance is shown in Figure 4.17. It was observed that colour and appearance increases up to P-90 for 30 min roasting temperature and roasting time but had reduced at lower and higher roasting temperature and roasting time.

4.2.3.2 Effect of roasting temperature and roasting time on taste

Effect of process variables on taste is presented in Table 4.25. The score ranged from 5.0 to 8.2. The maximum score (8.2) of taste was observed for experimental combinations of P-90 roasting temperature and 3 min roasting time. The minimum score (5.0) was observed for experimental combination of P-80 and P-100 roasting temperature and 3 and 5 min roasting time. Table 4.28 shows the effect of roasting temperature and roasting time at linear, quadratic and interaction levels. It can be seen from the table that quadratic and interactive levels were highly significant at 1% level, as their F_{cal} values 19.75 and 39.34 was greater than F_{tab}.(5.780 and 8.017), while for linear level was found to be non-significant, as their F_{cal} (1.71) value were lesser than F_{tab} (2.142) values.

Table 4.28: ANOVA for taste (microwave oven)

SOURCE	DF	SS	MS	F-Value
Model	5	0.012000	0.00240	16.48*
Linear	2	0.000498	0.00025	1.71
Quadratic	2	0.005766	0.00288	19.75*
Interactive	1	0.005743	0.00574	39.34*
Error	21	0.003060	0.00015	
Total	26	0.015000		

***, **, * Significant at 10, 5 and 1% level

The regression analysis on taste is shown in Table 4.26. The model was found highly significant with F-value 16.48 which is greater than F_{tab} (4.042) at 1%. The values of R^2, adj-R^2 were found to be 0.7969 and 0.7485 respectively. R^2 -adj value was observed to be relatively close to R^2 value, it ensures a relatively satisfactory adjustment of the quadratic model to the experimental data. The lack of fit was found to be non-significant for the model hence the model can be used to navigate the design. The result of regression coefficient shows the effect of roasting time has significant effect ($p<0.1$) at linear level. At quadratic and interactive levels, roasting temperature and roasting time has highly significant effect at ($p<0.01$) significance. Second order predictive quadratic equation for taste is given below

$$Y= 0.13- 0.00021X_1+ 0.00526X_2+0.022X_1X_2+0.023X_1^2+0.021X_2^2$$

Where, Y is taste and X_1 and X_2 are roasting temperature and roasting time

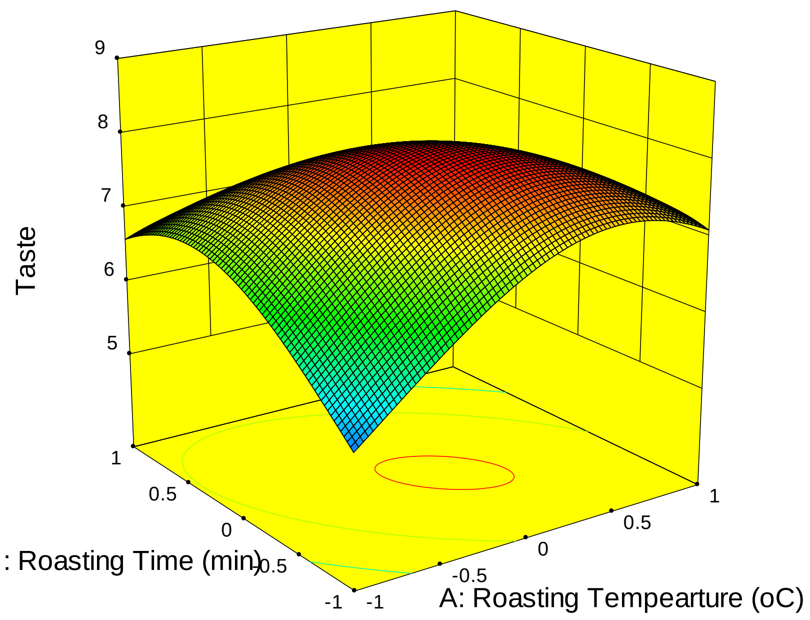

Fig.4.18: Effect of roasting temperature on taste for microwave oven

Influence of roasting temperature and roasting time on taste is shown in Figure 4.18. It was observed that taste score increased up to P-90 for 3 min roasting temperature and roasting time but reduced at low and high roasting temperature and roasting time.

4.2.3.3 Effect of roasting temperature and roasting time on odour

Effect of process variables on odour is presented in Table 4.25. The score ranged from 5.0 to 8.5. The maximum score (8.5) of odour was observed for experimental combination of P-90 and 4 min. The minimum score (5.0) of odour was observed for experimental combination of P-100 and 5 min roasting time. Table 4.29 shows the effect of roasting temperature and roasting time at linear, quadratic and interaction levels. It can be seen from the table that quadratic and interactive levels were highly significant at 1% level, as their F_{cal} values 18.61 and 15.32 was greater than F_{tab}. (5.780

and 8.017), followed by linear level which is significant at 10% as their F_{cal} 2.82 value was greater than F_{tab} (2.575) value.

Table 4.29: ANOVA for odour (microwave oven)

SOURCE	DF	SS	MS	F-Value
Model	5	0.009104	0.0018208	11.63*
Linear	2	0.000881	0.0004407	2.82***
Quadratic	2	0.005825	0.0029125	18.61*
Interactive	1	0.002398	0.0023980	15.32*
Error	21	0.003287	0.0001565	
Total	26	0.012000		

***, **, * Significant at 10, 5 and 1% level

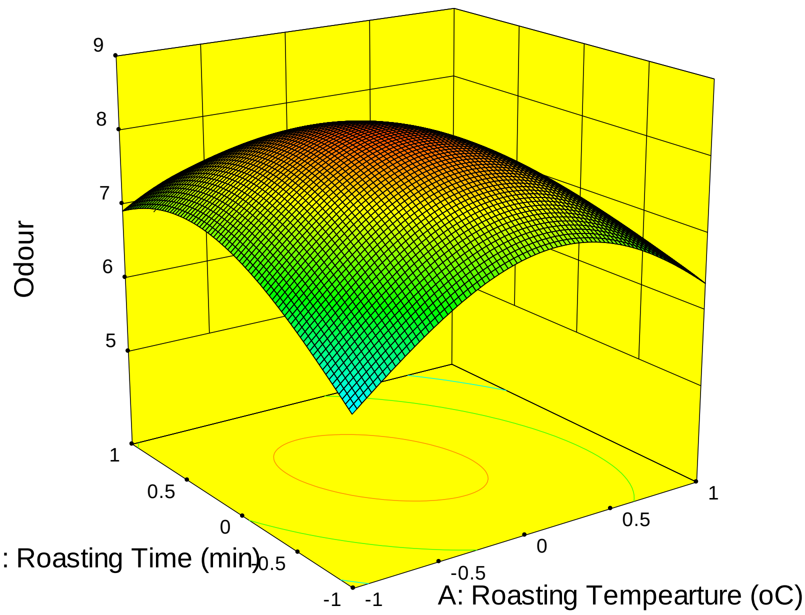

Fig. 4.19: Effect of roasting temperature and roasting time on odour

The regression analysis on odour is given in Table 4.26. The model was found highly significant with F-value 11.63 which is greater than F_{tab} (4.042) at 1%. The values of R^2, adj. R^2 were found to be 0.7347 and 0.6715 respectively. R^2 -adj value was observed to be relatively close to R^2 value, it ensures a relatively satisfactory adjustment of the quadratic model to the experimental data. The lack of fit was found non-significant for the model hence the model can be used to navigate the design. The result of regression coefficient shows the effect of roasting temperature and roasting time has significant effect ($p<0.01$) at interactive and quadratic levels. Roasting temperature was significant ($p<0.05$) at linear level. Second order predictive quadratic equation for odour is given below

$$Y= 0.12+ 0.00697X_1+ 0.00059X_2+0.014X_1X_2+0.026X_1^2+0.017X_2^2$$

Where, Y is odour and X_1 and X_2 are roasting temperature and roasting time

Influence of roasting temperature and roasting time on odour is shown in Figure 4.19. It was observed that odour score were low at lower and higher value of roasting temperature and roasting time.

4.2.3.4 Effect of roasting temperature and roasting time on overall acceptability

Effect of process variables on overall acceptability is presented in Table 4.25. The score ranged from 5.0 to 8.2. The maximum score (8.2) of overall acceptability was observed for experimental combination of P-90 roasting temperature and 3 min roasting time. The minimum score (5.0) of overall acceptability was observed for experimental combinations of P-100 for 5 min roasting temperature roasting time. Table 4.30 shows the effect of roasting temperature and roasting time at linear, quadratic and interaction levels. It can be seen from the table that linear, quadratic and interactive levels were highly significant at 1%, as their F_{cal} 5.474, 18.992 and 21.774 values was greater than F_{tab} (5.780 and 8.017) values.

Table 4.30: ANOVA for overall acceptability (microwave oven)

SOURCE	DF	SS	MS	F-Value
Model	5	0.011000	0.002200	37.32*
Linear	2	0.002847	0.001423	23.76*
Quadratic	2	0.003130	0.001043	17.42*
Interactive	1	0.005193	0.005193	86.69*
Error	21	0.001257	0.000059	
Total	26	0.012		

***, **, * Significant at 10, 5 and 1% level

The regression analysis on overall acceptability is given in Table 4.26. The model was found highly significant with F-value 37.32 which is greater than F_{tab} (4.042) at 1%. The values of R^2, adj. R^2 were found to be 0.8988 and 0.8748 respectively. R^2 – adj. value was observed to be relatively close to R^2 value, it ensures a relatively satisfactory adjustment of the quadratic model to the experimental data. The lack of fit was found non-significant for the model hence the model can be used to navigate the design. The result of regression coefficient shows that the effect of roasting temperature and roasting time was highly significant at ($p<0.01$) at linear and interactive levels. At quadrative level, roasting temperature was significant at ($p<0.01$). Second order predictive quadratic equation for overall acceptability is given below

$$Y= 0.14+0.011X_1+ 0.006827X_2+ 0.021X_1X_2+ 0.023X_1^2- 0.002919X_2^2$$

Where, Y is overall acceptability and X_1 and X_2 are roasting temperature and roasting time

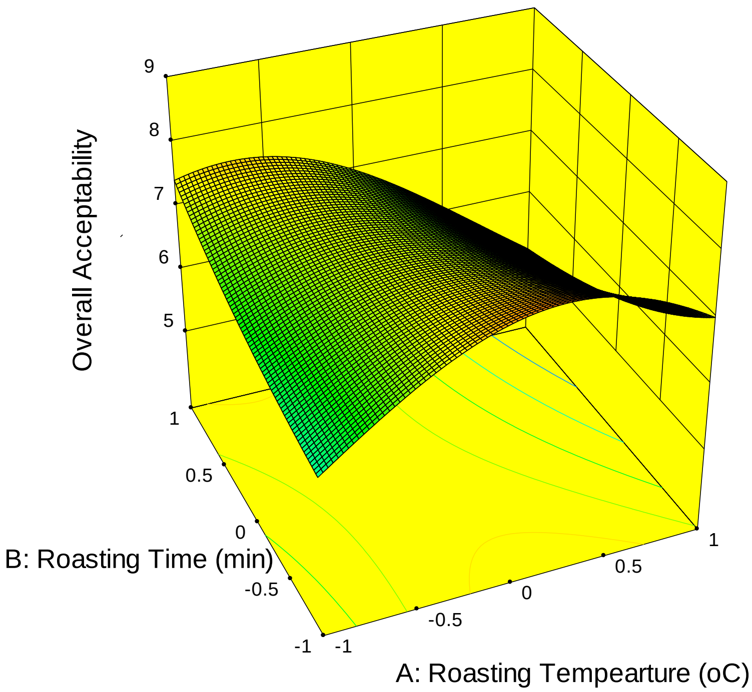

Fig. 4.20: Effect of roasting temperature and roasting time on overall acceptability

Influence of roasting temperature and roasting time on overall acceptability is shown in Figure 4.20. It was observed that overall acceptability increased up to P-90 roasting temperature and 3 min roasting time and reduced at lower and higher roasting temperature and roasting time.

4.2.3.5 Effect of roasting temperature and roasting time on hardness

Effect of process variables on hardness is presented in Table 4.25. It range from 36.27 g to 66.21 g. The maximum value (66.21 g) of hardness was observed for experimental combination of P-80 roasting temperature and 3 min roasting time. The minimum value (36.27 g) of hardness was observed for experimental combination of P-100 roasting temperature and 5 min roasting time. Table 4.31 shows the effect of roasting temperature and roasting time at linear, quadratic and interaction levels. It can be seen from the table that linear and quadratic levels has significant effect at 1% and 5% levels, as their F_{cal} values 172.01 and 5.06 were greater than F_{tab}.(5.780 and 3.467) values while the interactive level was found to be non-significant, as their F_{cal} value 1.92 were lesser than F_{tab}.(2.169) value.

Table 4.31: ANOVA for hardness (microwave oven)

SOURCE	DF	SS	MS	F-Value
Model	5	0.003315	0.000663	71.22*
Linear	2	0.000320	0.000160	172.01*
Quadratic	2	0.000009	0.000005	5.06**
Interactive	1	0.000002	0.000002	1.92
Error	21	0.000019	0.000001	
Total	26	0.000351		

***, **, * Significant at 10, 5 and 1% level

The regression analysis on hardness is given in Table 4.26. The model was found highly significant with F-value 71.22 which is greater than F_{tab} (4.042) at 1%. The values of R^2, adj. R^2 were found to be 0.9443 and 0.9310 respectively. R^2–adj. value was observed to be relatively close to R^2 value, it ensures a relatively satisfactory adjustment of the quadratic model to the experimental data. The lack of fit was found non-significant for the model hence the model can be used to navigate the design. The result of regression coefficient shows the effect of roasting temperature and roasting time has significant effect ($p<0.01$) at linear level. Roasting temperature has significant ($p<0.01$) at quadratic level. Second order predictive quadratic equation for hardness is given below

$$Y= 0.19+ 0.00371X_1+ 0.00202X_2+ 0.00039X_1X_2+ 0.00118X_1^2+ 0.00043X_2^2$$

Where, Y is hardness and X_1 and X_2 are roasting temperature and roasting time

Influence of roasting temperature and roasting time on hardness is shown in Figures 4.21-4.22. In both the cases, it was also observed that hardness decreased with increase in roasting temperature and roasting time similar to the results obtained for halogen oven and hot air oven.

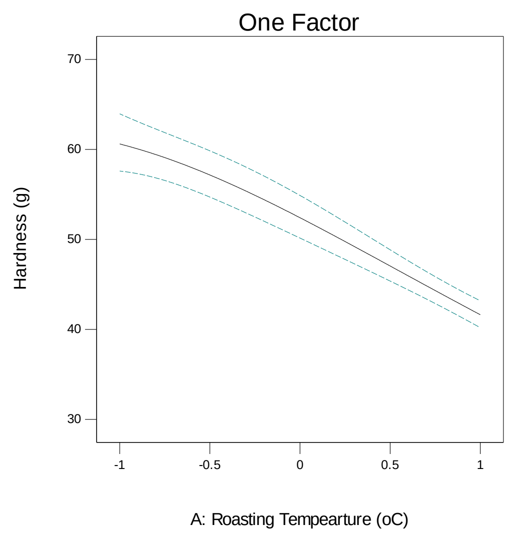	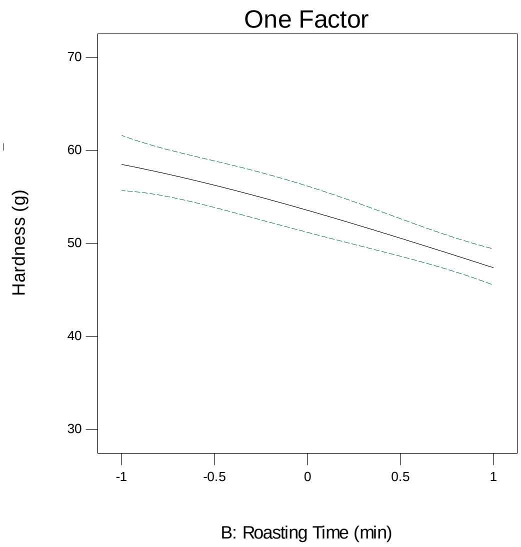
Fig. 4.21: Effect of roasting temperature on hardness for microwave oven	**Fig. 4.22: Effect of roasting time on hardness for microwave oven**

4.2.3.6 Effect of roasting temperature and roasting time on fracturability

Effect of process variables on fracturability is presented in Table 4.25. The values ranged from 3.62 g to 7.28 g. The maximum value (7.28 g) of fracturability was observed for experimental combination of P-80 roasting temperature at 3 min roasting time. The minimum value (3.62 g) of fracturability was observed for experimental combination of P-100 roasting temperature and 5 min roasting time. Table 4.31 shows the effect of roasting temperature and roasting time at linear, quadratic and interaction levels. It can be seen from the table that linear, quadratic and interactive were significant at 1% level, as their F_{cal} values 7292.80, 100.66 and 57.079 was greater than their F_{tab}.(5.780 and 8.017) values.

Table 4.31: ANOVA for fracturability (microwave oven)

SOURCE	DF	SS	MS	F-Value
Model	5	0.058000	0.1160000	2979.08*
Linear	2	0.055119	0.0275595	7292.80*
Quadratic	2	0.0007608	0.0003804	100.66*
Interactive	1	0.0002157	0.0002157	57.079*
Error	21	0.00007936	0.000003779	
Total	26	0.056		

***, **, * Significant at 10, 5 and 1% level

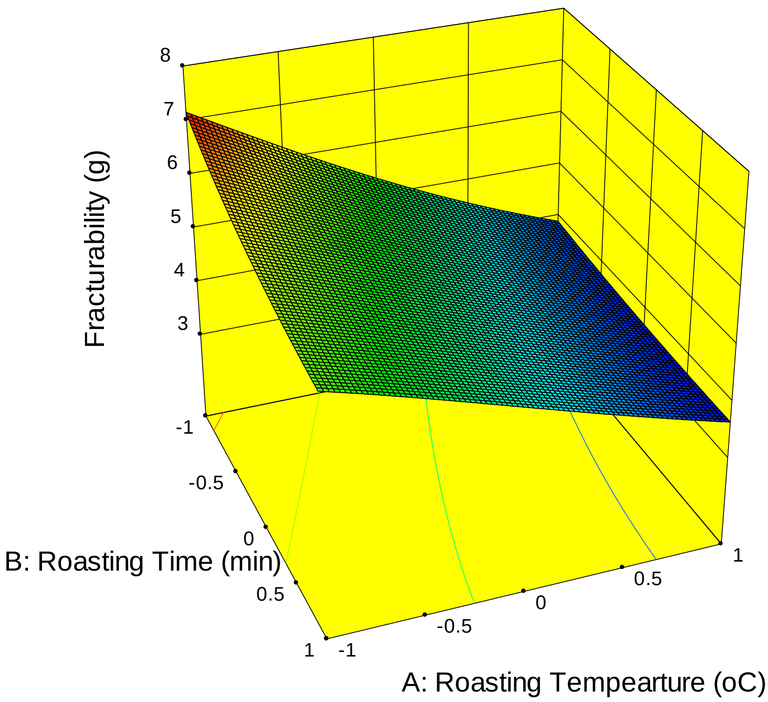

Fig.4.23: Effect of roasting temperature and roasting time on fracturability for microwave oven

The regression analysis on fracturability is given in Table 4.26. The model was found highly significant with F-value 2979.08 which is greater than F_{tab} (4.042) at 1%. The values of R^2 and adj. R^2 were found to be 0.9986 and 0.9983 respectively. R^2 -adj value was observed to be relatively close to R^2 value, it ensures a relatively satisfactory adjustment of the quadratic model to the experimental data. The lack of fit was found non-significant for the model hence the model can be used to navigate the design. The result of regression coefficient shows the effect of roasting temperature and roasting time has significant effect ($p<0.01$) at linear, quadratic and interactive levels. Second order predictive quadratic equation for fracturability is given below

$$Y= 3.98- 1.26X_1- 0.37X_2- 0.26X_1X_2+ 0.68X_1^2- 0.019X_2^2$$

Where, Y is fracturability and X_1 and X_2 are roasting temperature and roasting time

Influence of roasting temperature and roasting time on fracturability is shown in Figure 4.23. In both the cases, it was observed that fracturability decreased with increase in roasting temperature and roasting time.

4.2.3.7 Effect of roasting temperature and roasting time on phytic acid

Effect of process variables on phytic acid is presented in Table 4.25. The values ranged from 0.1021% to 0.2797%. The maximum value (0.2797%) of phytic acid was observed for experimental combination of P-80 roasting temperature and 3 min roasting time. The minimum value (0.1021%) of phytic acid was observed for experimental combination of P-100 roasting temperature and 5 min roasting time. Table 4.32 shows the effect of roasting temperature and roasting time at linear, quadratic and interaction levels. It can be seen from the table that linear, quadratic and interactive levels were highly significant at 1% level, as their F_{cal} values 1004.02, 36.33 and 25.23 were greater than F_{tab}. (5.780 and 8.017) values.

Table 4.32: ANOVA for phytic acid (microwave oven)

SOURCE	DF	SS	MS	F-Value
Model	5	104.33	0.411	253.64*
Linear	2	99.49	49.745	1004.02*
Quadratic	2	3.60	1.800	36.33*
Interactive	1	1.25	1.250	25.23*
Error	21	1.73	0.049	
Total	26	106.06		

***, **, * Significant at 10, 5 and 1% level

The regression analysis on phytic acid is given in Table 4.26. The model was found highly significant with F-value 253.64 which is greater than F_{tab} (4.042) at 1%. The values of R^2 and adj. R^2 were found to be 0.9837 and 0.9798 respectively. R^2 -adj value was observed to be relatively close to R^2 value, it ensures a relatively satisfactory adjustment of the quadratic model to the experimental data. The lack of fit was found non-significant for the model hence the model can be used to navigate the design. The result of regression coefficient shows the effect of roasting temperature and roasting time has highly significant effect ($p<0.01$) at linear and interactive levels. The effect of roasting temperature has significant effect ($p<0.01$) at quadratic level. Second order predictive quadratic equation for phytic acid is given below

$$Y= 5.94+ 2.27X_1+ 0.61X_2+ 0.32X_1X_2+ 0.76X_1^2- 0.14X_2^2$$

Where, Y is phytic acid and X_1 and X_2 are roasting temperature and roasting time

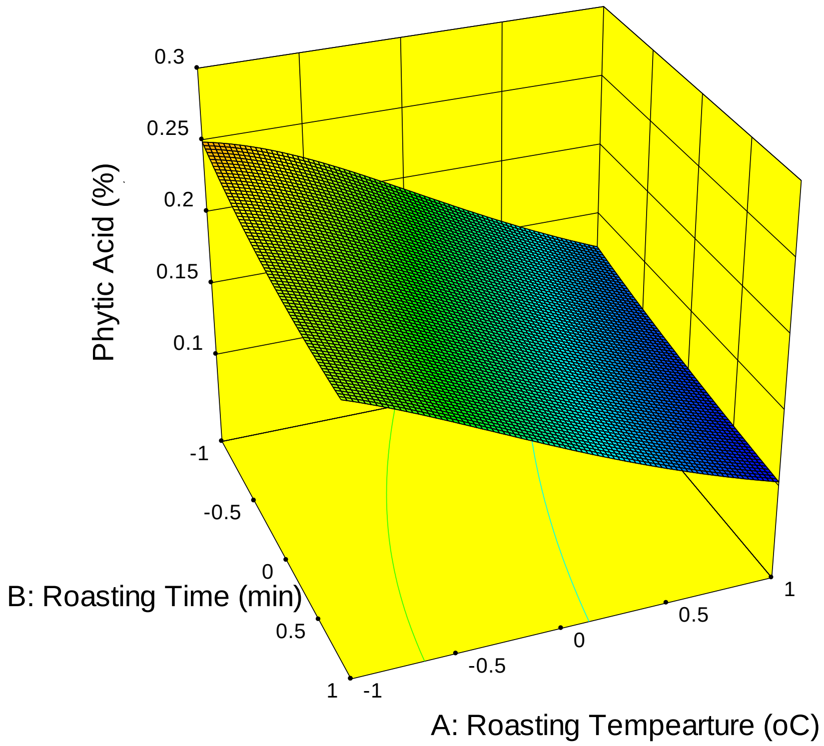

Fig.4.24: Effect of roasting temperature and roasting time on phytic acid for microwave oven

Influence of roasting temperature and roasting time on phytic acid is shown in Figures 4.24. Similar to the halogen and hot air oven, phytic acid values were found to be decreasing with roasting temperature and roasting time.

4.2.3.8 Optimization of variables

Table 4.33: Optimum levels of roasting conditions for pumpkin seed kernels for microwave oven

Independent variables	Coded levels	Predicted levels	Actual levels
Roasting Temperature (X_1)	-0.046	P-89.54	P-90
Roasting time (X_2)	0.118	3.8 min	4 min
Responses		**Values**	**Values**
Colour & appearance (1-9)		8.053	8.2
Flavour (1-9)		8.00	8.2
Odour (1-9)		8.243	8.1
Overall acceptability (1-9)		7.172	7.4
Hardness (g)		52.885	54.45
Fracturability (g)		4.929	4.87
Phytic acid (%)		0.17	0.192

For the optimization of different variables, a numerical optimization was carried out using Design Expert 10.0.1 statistical software, where all the responses were given similar importance. The desired results for each factor and response were chosen and assigned as per the ultimate aim. The best solution with a single formulation with different levels of variables was obtained which is presented in Table 4.33, along with the actual values of the optimized product.

4.2.4 Optimization of Roasting Conditions of Pumpkin Seed Kernel in Sand roasting

Effect of roasting temperature and roasting time on the responses i.e. sensory evaluation (colour and appearance, taste, odour, overall acceptability), texture profile analysis (hardness, fracturability), and phytic acid was determined and statistically analysed. Experimental data is shown in Table 4.34.

4.2.4.1 Effect of roasting temperature and roasting time on colour and appearance

Effect of process variables on colour and appearance is depicted in Table 4.34. The colour and appearance score ranged from 5.0 to 7.7. The maximum score (7.7) of colour and appearance was observed for experimental combination of 170ºC roasting temperature and 3 min roasting time. The minimum score (5.0) was observed for experimental combinations of 150ºC and 170ºC roasting temperature and 2 min and 4 min roasting time. It can be seen from the Table 4.36 that quadratic and interactive levels were highly significant at 1% level, as their F_{cal} values 21.196 and 24.579 was greater than their F_{tab}. (5.780 and 8.017), followed by linear level which is significant at 10%, as their F_{cal} 3.383 value was lesser than F_{tab} (2.575) value.

The regression analysis on colour and appearance is shown in Table 4.35. The model was found highly significant with F-value 14.81 which is greater than $F_{tab.}$ (4.042) at 1%. The values of R^2, adj.-R^2 were found to be 0.7791 and 0.7265 respectively. R^2 –adj value was observed to be relatively close to R^2 value, it ensures a relatively satisfactory adjustment of the quadratic model to the experimental data. The lack of fit was found non-significant for the model hence the model can be used to navigate the design. The result of regression coefficient shows the effect of roasting temperature has significant effect ($p<0.01$) at interactive level. At quadratic level, roasting temperature was significantly affected the colour and appearance ($p<0.01$).

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Table 4.34: Variables and responses of roasted pumpkin seed kernels in sand roasting (R_4)

*Maximum, ** Minimum

Expt No.	Roasting temperature (°C)	Roasting time (min)	Colour & Appearance (1-9)	Taste (1-9)	Odour (1-9)	Overall acceptability (OAA) (1-9)	Hardness (g)	Fracturability (g)	Phytic acid (%)
1.	160 (0)	2 (-1)	6.4	7.4	6.8	6.9	49.90	5.75	0.2049
2.	160 (0)	4 (1)	7.6	8.2*	8.4*	7.8	51.35	4.89	0.1632
3.	160 (0)	3 (0)	7.0	7.5	7.8	7.2	52.43	4.59	0.1563
4.	150 (-1)	2 (-1)	5.2	5.0**	5.4	5.0**	67.08*	7.14	0.2474*
5.	150 (-1)	3 (0)	5.8	6.5	5.8	5.8	66.16	6.16	0.1989
6.	160 (0)	3 (0)	7.2	8.0	7.5	7.6	50.52	4.9	0.1697
7.	150 (-1)	4 (1)	6.0	7.0	7.4	6.8	55.39	5.78	0.2158
8.	150 (-1)	2 (-1)	5.0**	5.8	5.5	5.0**	65.42	7.16	0.2099
9.	150 (-1)	2 (-1)	5.5	5.8	5.2	5.5	66.4	7.28*	0.2297
10.	160 (0)	3 (0)	6.8	7.8	7.1	7.8	51.31	4.59	0.174
11.	170 (1)	2 (-1)	6.8	7.6	6.8	7.5	45.65	3.88	0.1335
12.	170 (1)	2 (-1)	6.5	6.9	6.8	7.5	44.8	3.74	0.1176

13.	170 (1)	4 (1)	5.4	6.8	5.3	6.0	29.33	3.37	0.1091
14.	160 (0)	2 (-1)	5.9	7.0	7.0	6.9	50.27	4.80	0.1972
15.	170 (1)	4 (1)	5.0**	5.0**	5.1**	5.7	27.29**	3.09**	0.1233
16.	160 (0)	2 (-1)	6.2	7.2	7	6.8	53.13	5.36	0.1949
17.	170 (1)	2 (-1)	6.5	7.6	7.1	7.5	43.93	3.69	0.1276
18.	150 (-1)	3 (0)	5.8	6.8	5.9	6.5	64.32	6.23	0.2019
19.	170 (1)	3 (0)	5.8	6.9	6.4	7.0	41.67	3.62	0.1114
20.	150 (-1)	4 (1)	6.5	7	6.8	6.5	54.03	6.24	0.2158
21.	150 (-1)	3 (0)	6.2	6.2	6.2	6.6	64.12	5.35	0.2019
22.	170 (1)	4 (1)	5.7	5.0**	6.0	5.8	39.27	3.23	0.041**
23.	160 (0)	4 (1)	7.5	7.9	8.0	7.6	48.87	4.69	0.1598
24.	170 (1)	3 (0)	6.0	6.5	6.2	7.0	37.73	3.75	0.1044
25.	160 (0)	4 (1)	5.8	6.5	6.3	7.2	34.93	3.66	0.1094
26.	170 (1)	2 (-1)	6.5	7.0	7.0	6.5	45.65	3.93	0.2181
27.	170 (1)	3 (0)	7.7*	8	8.1	8.3*	49.91	3.92	0.1518

Table 4.35: Regression analysis of roasted pumpkin seed kernels in sand roasting (R_4)

Cons.	Colour & Appearance		Taste		Odour		Overall acceptability		Hardness		Fracturability		Phytic acid	
	Coeff.	P (%)	Coeff.	P (%)	Coeff.	P (%)	Coeff.	P (%)	Coeff.	P (%)	Coeff.	P (%)	Coeff.	P (%)
	0.14	0.01*	0.13	0.01*	0.13	0.01*	0.13	0.01*	0.019	0.01*	0.21	0.01*	0.17	0.01*
X_1	0.000013	99.57	0.000677	84.14	-0.0005	78.03	-0.011	0.01*	0.0051	0.01*	0.057	0.01*	-0.053	0.01*
X_2	-0.00634	1.65**	-0.00055	87.04	-0.0050	1.13**	-0.00472	1.77**	0.0024	0.06*	0.023	0.02*	-0.015	0.12*
X_1X_2	0.015	0.01*	0.020	0.01*	0.022	0.01*	0.019	0.01*	0.0013	8.53***	-0.0031	61.66	-0.0057	25.03
X_1^2	0.027	0.01*	0.025	0.03*	0.030	0.01*	0.022	0.01*	0.0021	5.53***	0.016	6.94***	-0.013	7.70***
X_2^2	0.00449	29.87	0.00424	47.21	-0.0009	77.68	0.00779	2.31**	0.0010	34.51	0.0023	79.17	0.011	10.80
R^2	77.91		67.72		90.24		88.89		82.19		88.37		90.84	
Adj.R^2	72.65		60.04		87.91		86.24		77.95		85.60		88.66	
F	14.81 (1% 4.042)		8.81 (1% 4.042)		38.82 (1% 4.042)		33.59 (1% 4.042)		19.39 (1% 4.042)		31.91 (1% 4.042)		41.67 (1% 4.042)	
LOF	NS		NS		NS		NS		NS		NS		NS	

*, ** and *** Significant at 1, 5 and 10% level of significance respectively, Coeff. = Coefficient, NS= Non significant, Cons.= Constant, LOF= Lack of Fit, X_1= Roasting temperature and X_2 = Roasting time

Roasting time was found to be significant ($p<0.05$) at linear level. Second order predictive quadratic equation for colour and appearance is given below

$$Y= 0.14+ 0.00001325X_1- 0.00634X_2+ 0.015X_1X_2+0.027X_1^2- 0.00449X_2^2$$

Where, Y is colour and appearance and X_1 and X_2 are roasting temperature and roasting time

Table 4.36: ANOVA for colour and appearance (sand roasting)

SOURCE	DF	SS	MS	F-Value
Model	5	0.007889	0.001600	14.81*
Linear	2	0.000724	0.000362	3.383***
Quadratic	2	0.004535	0.002268	21.196*
Interactive	1	0.002630	0.002630	24.579*
Error	21	0.002237	0.000107	
Total	26	0.010000		

***, **, * Significant at 10, 5 and 1% level

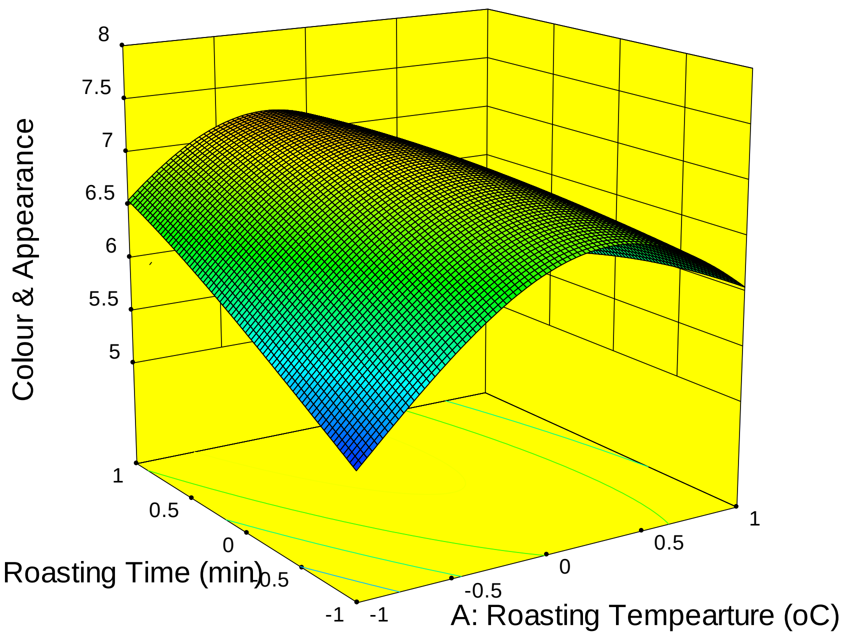

Fig.4.25: Effect of roasting temperature and roasting time on colour and appearance for sand roasting

Influence of roasting temperature and roasting time on colour and appearance is shown in Figure 4.25. It was observed that colour and appearance increases up to 170°C for 3 min roasting temperature and roasting time and decreased at lower and higher roasting temperature and roasting time.

4.2.4.2 Effect of roasting temperature and roasting time on taste

Effect of process variables on taste is depicted in Table 4.34. The score ranged from 5.0 to 8.2. The maximum score (8.2) of taste was observed for experimental combination of 160ºC roasting temperature and 4 min roasting time. The minimum score (5.0) was observed for experimental combinations of 150 and 170ºC roasting temperature and 2 and 4 min roasting time. It can be seen from the Table 4.37 that quadratic and interactive levels was highly significant at 1% level, as their F_{cal} values 9.62 and 24.92 were greater than F_{tab}.(5.780 and 8.017), while for linear level was found to be non-significant, as their F_{cal} (0.03) value was lesser than F_{tab} (2.575) value.

Table 4.37: ANOVA for taste (sand roasting)

SOURCE	DF	SS	MS	F-Value
Model	5	0.008845	0.001770	8.81*
Linear	2	0.000014	0.000007	0.03
Quadratic	2	0.003849	0.001924	9.62*
Interactive	1	0.004983	0.004983	24.92*
Error	21	0.004220	0.000200	
Total	26	0.013000		

***, **, * Significant at 10, 5 and 1% level

The regression analysis on taste is shown in Table 4.35. The model was found highly significant with F-value 8.81 which is greater than F_{tab} (4.042) at 1%. The values of R^2, adj-R^2 were found to be 0.6772 and 0.6004 respectively. R^2 -adj value was observed to be relatively close to R^2 value, it ensures a relatively satisfactory adjustment of the quadratic model to the experimental data. The lack of fit was found to be non-significant for the model hence the model can be used to navigate the design. The result of regression coefficient shows the effect of roasting temperature and roasting time has non-significant effect at linear level. Roasting temperature and roasting time has ($p<0.01$) significant level at interactive. At quadratic level, roasting temperature has ($p<0.01$) significance. Second order predictive quadratic equation for taste is given below

$$Y= 0.14+ 0.000013X_1- 0.00634X_2+0.015X_1X_2+0.027X_1^2+0.00449X_2^2$$

Where, Y is taste and X_1 and X_2 are roasting temperature and roasting time

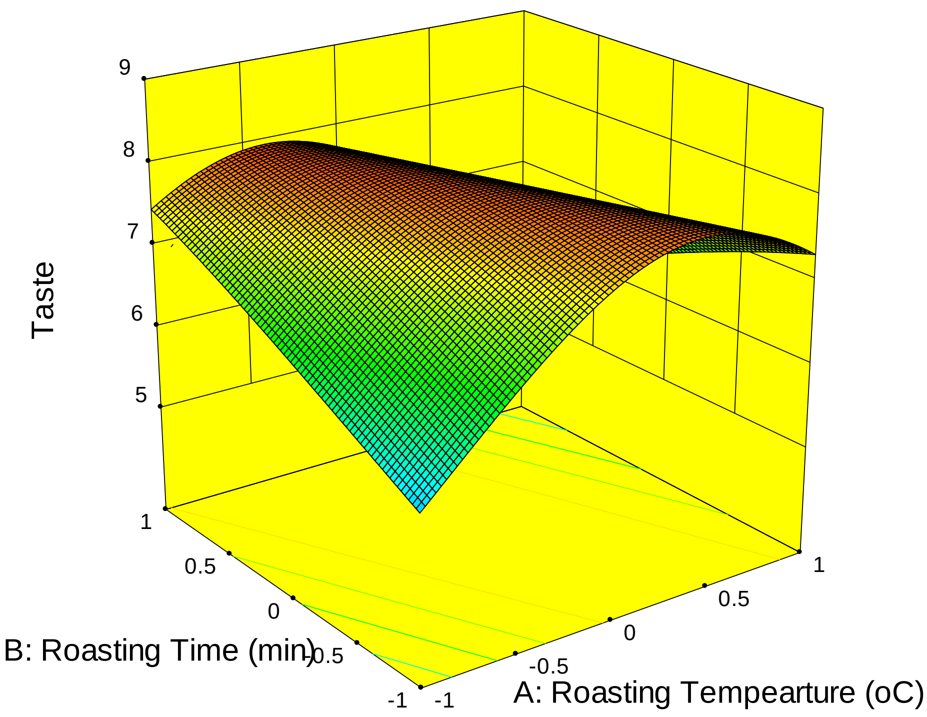

Fig.4.26: Effect of roasting temperature and roasting time on taste for sand roasting

Influence of roasting temperature and roasting time on taste is shown in Figure 4.26. It was observed that taste score increased up to 160°C roasting temperature and 4 min roasting time but reduced at lower and higher roasting temperature and roasting time.

4.2.4.3 Effect of roasting temperature and roasting time on odour

Effect of process variables on odour are depicted in Table 4.34. The score ranged from 5.1 to 8.4. The maximum score (8.4) of odour was observed for experimental combination of 160°C and 4 min. The minimum score (5.1) of odour was observed for experimental combination of 170°C and 4 min roasting time. It can be seen from the Table 4.38 that quadratic and interactive levels were highly significant at 1% level, as their F_{cal} values 46.61 and 94.34 were greater than F_{tab}. (5.780 and 8.017), followed by linear level which was found to be significant at 5% as their F_{cal} 3.93 value was greater than F_{tab} (3.467) value.

Table 4.38: ANOVA for odour (sand roasting)

SOURCE	DF	SS	MS	F-Value
Model	5	0.012000	0.002400	38.82*
Linear	2	0.000463	0.000232	3.93**
Quadratic	2	0.005510	0.002750	46.61*
Interactive	1	0.005566	0.005566	94.34*
Error	21	0.001248	0.000059	
Total	26	0.013000		

***, **, * Significant at 10, 5 and 1% level

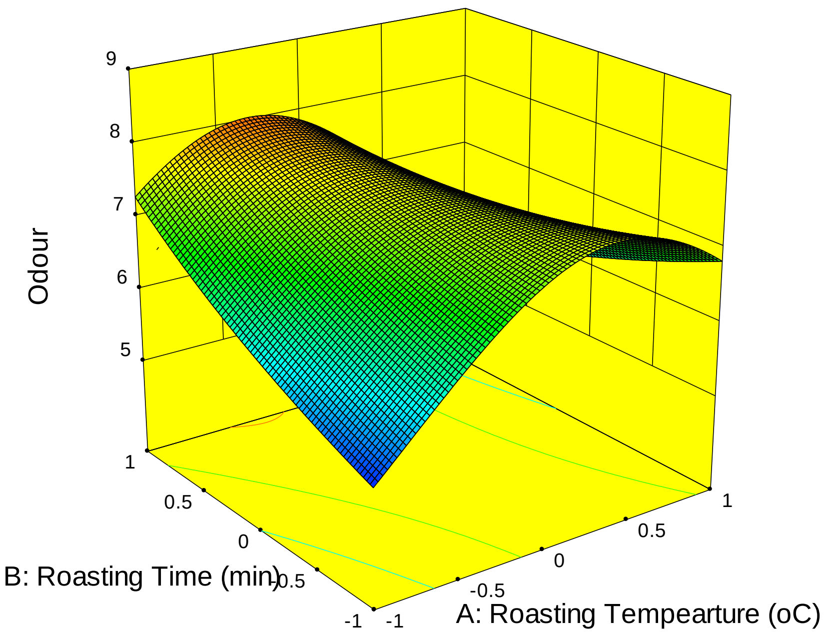

Fig. 4.27: Effect of roasting temperature and roasting time on odour for sand roasting

The regression analysis on odour is given in Table 4.35. The model was found highly significant with F-value 38.82 which is greater than F_{tab} (4.042) at 1%. The values of R^2, adj. R^2 were found to be 0.9024 and 0.8791 respectively. R^2 -adj value was observed to be relatively close to R^2 value, it ensures a relatively satisfactory adjustment of the quadratic model to the experimental data. The lack of fit was found non-significant for the model hence the model can be used to navigate the design. The result of regression coefficient shows the roasting time has significant effect ($p<0.05$) at linear level. At interactive level, roasting temperature and roasting time was highly significant at ($p<0.01$). Roasting temperature was significant ($p<0.01$) at quadratic level. Second order predictive quadratic equation for odour is given below

$$Y= 0.13-0.0005X_1- 0.0050X_2+0.022X_1X_2+0.030X_1^2- 0.0009X_2^2$$

Where, Y is odour and X_1 and X_2 are roasting temperature and roasting time

Influence of roasting temperature and roasting time on odour is shown in Figure 4.27. It was observed that odour scores were low at lower and higher level of roasting temperature and roasting time.

4.2.4.4 Effect of roasting temperature and roasting time on overall acceptability

Effect of process variables on overall acceptability is depicted in Table 4.34. The score ranged from 5.0 to 8.3. The maximum score (8.3) of overall acceptability was observed for experimental combination of 170ºC roasting temperature and 3 min roasting time. The minimum score (5.0) of overall acceptability was observed for experimental combination of 150ºC for 2 min roasting temperature roasting time. It can be seen from the Table 4.39 that linear, quadratic and interactive levels were significant at 1%, as their F_{cal} 21.31, 26.23 and 69.67 values was greater than F_{tab} (5.780 and 8.017) values.

Table 4.39: ANOVA for overall acceptability (sand roasting)

SOURCE	DF	SS	MS	F-Value
Model	5	0.01000	0.002000	33.59*
Linear	2	0.00265	0.001300	21.31*
Quadratic	2	0.00326	0.001600	26.23*
Interactive	1	0.00425	0.004250	69.67*
Error	21	0.00130	0.000061	
Total	26	0.01100		

***, **, * Significant at 10, 5 and 1% level

The regression analysis on overall acceptability is given in Table 4.35. The model was found highly significant with F-value 33.59 which is greater than F_{tab} (4.042) at 1%. The values of R^2, adj. R^2 were found to be 0.8889 and 0.8624 respectively. R^2 – adj. value was observed to be relatively close to R^2 value, it ensures a relatively satisfactory adjustment of the quadratic model to the experimental data. The lack of fit was found non-significant for the model hence the model can be used to navigate the design. The result of regression coefficient shows that the roasting temperature has significant effect ($p<0.01$) and roasting time ($p<0.05$) at linear level. At interactive level, roasting temperature and roasting time significantly affected the overall acceptability ($p<0.01$). The effect of roasting temperature and roasting time was significant ($p<0.01$) and ($p<0.05$) at quadratic level. Second order predictive quadratic equation for overall acceptability is given below

$$Y= 0.13- 0.011X_1- 0.00472X_2+0.019X_1X_2+0.022X_1^2+0.00779X_2^2$$

Where, Y is overall acceptability and X_1 and X_2 are roasting temperature and roasting time

Influence of roasting temperature and roasting time on overall acceptability is shown in Figure 4.28. It was observed that overall acceptability increased up to 170°C roasting temperature and 3 min roasting time but had minimum value at lower and higher roasting temperature and roasting time.

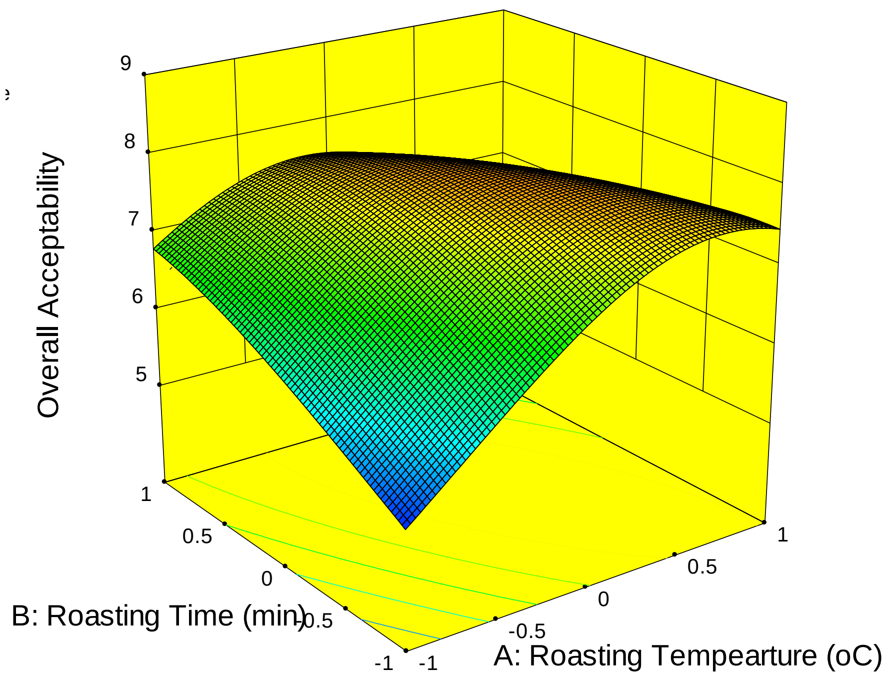

Fig. 4.28: Effect of roasting temperature and roasting time on overall acceptability for sand roasting

4.2.4.5 Effect of roasting temperature and roasting time on hardness

Effect of process variables on hardness is depicted in Table 4.34. It range from 27.29 g to 67.08 g. The maximum value (67.08 g) of hardness was observed for experimental combination of 150°C roasting temperature and 2 min roasting time. The minimum value (27.29 g) of hardness was observed for experimental combination of 170°C roasting temperature and 4 min roasting time. It can be seen from the Table 4.40

that linear and interactive levels has significant at 1% and 10%, as their F_{cal} values 44.31and 3.26 was greater than F_{tab}.(5.780 and 2.169) values, while quadratic level has non-significant effect, as their F_{cal} value 2.52 was lesser than F_{tab}.(2.575) value.

Table 4.40: ANOVA for hardness (sand roasting)

SOURCE	DF	SS	MS	F-Value
Model	5	0.000634	0.0001268	19.39*
Linear	2	0.000579	0.0002898	44.31*
Quadratic	2	0.000033	0.0000165	2.52
Interactive	1	0.000021	0.0000213	3.26***
Error	21	0.000137	0.0000065	
Total	26	0.000771		

***, **, * Significant at 10, 5 and 1% level

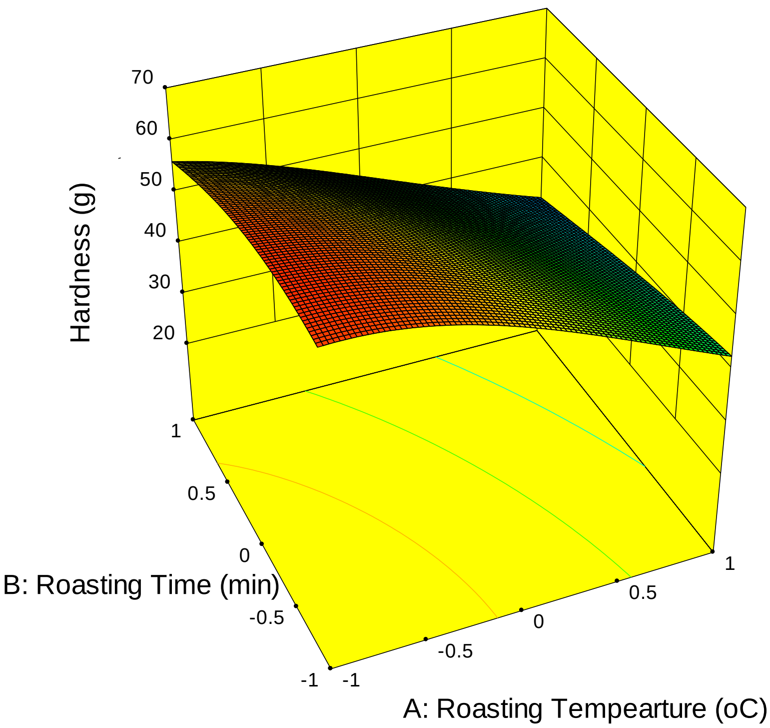

Fig. 4.29: Effect of roasting temperature and roasting time on hardness for sand roasting

The regression analysis on hardness is given in Table 4.35. The model was found highly significant with F-value 19.39 which is greater than F_{tab} (4.042) at 1%. The values of R^2, adj. R^2 were found to be 0.8219 and 0.7795 respectively. R^2–adj. value was observed to be relatively close to R^2 value, it ensures a relatively satisfactory adjustment of the quadratic model to the experimental data. The lack of fit was found non-significant for the model hence the model can be used to navigate the design. The result of regression coefficient shows the effect of roasting temperature and roasting time has significant effect ($p<0.01$) and ($p<0.1$) at linear and interactive levels. Roasting temperature has significant ($p<0.1$) at quadratic level. Second order predictive quadratic equation for hardness is given below

$$Y= 0.019+ 0.0051X_1+ 0.0024X_2+ 0.0013X_1X_2+ 0.0021X_1^2+ 0.0010X_2^2$$

Where, Y is hardness and X_1 and X_2 are roasting temperature and roasting time

Influence of roasting temperature and roasting time on hardness is shown in Figure 4.29. In both the cases, it was observed that hardness decreased with increases in roasting temperature and roasting time.

4.2.4.6 Effect of roasting temperature and roasting time on fracturability

Effect of process variables on fracturability is depicted in Table 4.34. The values ranged from 3.09 g to 7.28 g. The maximum value (7.28 g) of fracturability was observed for experimental combination of 150ºC roasting temperature at 2 min roasting time. The minimum value (3.09 g) of fracturability was observed for experimental combination of 170ºC roasting temperature and 4 min roasting time. It can be seen from the Table 4.41 that linear was significant at 1% level, as their F_{cal} values 78.11 was greater than their F_{tab}.(5.780) value while the interactive and quadratic levels was found to be non-significant as their F_{cal} values 1.865 and 0.258 were lesser than their F_{tab}.(2.169 and 2.575) values.

Table 4.41: ANOVA for fracturability (sand roasting)

SOURCE	DF	SS	MS	F-Value
Model	5	0.070	0.014	31.91*
Linear	2	0.06827	0.034135	78.11*
Quadratic	2	0.00163	0.000815	1.865
Interactive	1	0.0001128	0.0001128	0.258
Error	21	0.00917	0.000437	
Total	26	0.079		

***, **, * Significant at 10, 5 and 1% level

The regression analysis on fracturability is given in Table 4.35. The model was found highly significant with F-value 31.91 which is greater than F_{tab} (4.042) at 1%. The values of R^2 and adj. R^2 were found to be 0.8837 and 0.8560 respectively. R^2 -adj value was observed to be relatively close to R^2 value, it ensures a relatively satisfactory adjustment of the quadratic model to the experimental data. The lack of fit was found non-significant for the model hence the model can be used to navigate the design. The result of regression coefficient shows the effect of roasting temperature and roasting time has significant effect ($p<0.01$) at linear level. Roasting temperature was significant ($p<0.1$) at quadratic level. Second order predictive quadratic equation for fracturability is given below

$$Y= 21+ 0.057X_1+ 0.023X_2- 0.0031X_1X_2+ 0.016X_1^2+ 0.0023X_2^2$$

Where, Y is fracturability and X_1 and X_2 are roasting temperature and roasting time

Influence of roasting temperature and roasting time on fracturability is shown in Figures 4.30-4.31. In both the cases, it was observed that fracturability decreased with increases in roasting temperature and roasting time.

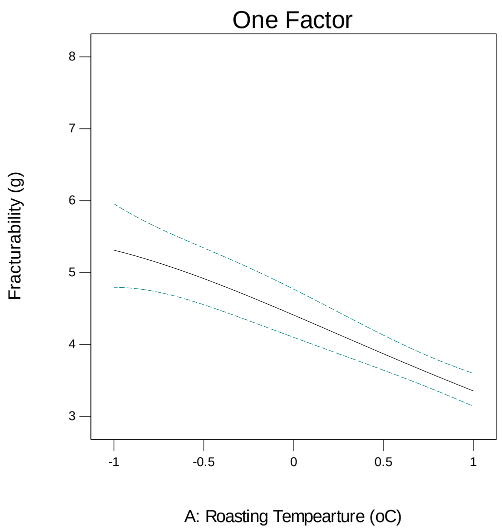

Fig. 4.30: Effect of roasting temperature on fracturability for sand roasting

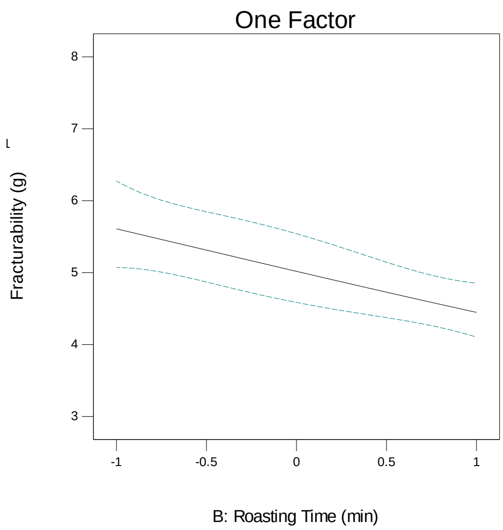

Fig. 4.31: Effect of roasting time on fracturability for sand roasting

4.2.4.7 Effect of roasting temperature and roasting time on phytic acid

Effect of process variables on phytic acid is depicted in Table 4.34. The values ranged from 0.041% to 0.2474%. The maximum value (0.2474%) of phytic acid was observed for experimental combination of 150ºC roasting temperature and 2 min roasting time. The minimum value (0.041%) of phytic acid was observed for experimental combination of 170ºC roasting temperature and 4 min roasting time.

Table 4.42 shows the effect of roasting temperature and roasting time at linear, quadratic and interaction levels. It can be seen from the table that linear and quadratic levels were significant at 1% and 10%, as their F_{cal} values 110.26 and 3.16 were greater than F_{tab}. (5.780 and 2.575), while the interactive level was found to be non-significant, as their F_{cal} 1.39 value was lesser than F_{tab} (2.169) value.

Table 4.42: ANOVA for phytic acid (sand roasting)

SOURCE	DF	SS	MS	F-Value
Model	5	0.057000	0.0114000	41.67*
Linear	2	0.060896	0.0304000	110.26*
Quadratic	2	0.001730	0.0008700	3.16***
Interactive	1	0.000385	0.0003853	1.39
Error	21	0.005789	0.0002757	
Total	26	0.063000		

***, **, * Significant at 10, 5 and 1% level

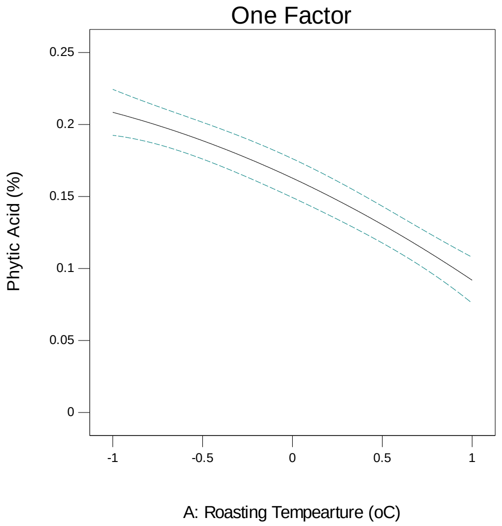

Fig. 4.32: Effect of roasting temperature on phytic acid for sand roasting

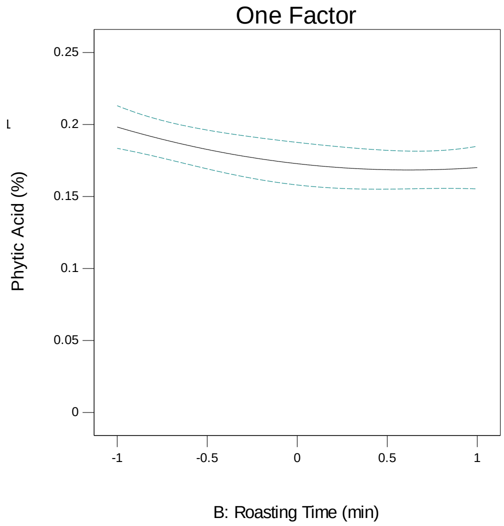

Fig. 4.33: Effect of roasting time on phytic acid for sand roasting

The regression analysis on phytic acid is given in Table 4.35. The model was found highly significant with F-value 41.67 which is greater than F_{tab} (4.042) at 1%. The values of R^2 and adj. R^2 were found to be 0.9084 and 0.8866 respectively. R^2 -adj value was observed to be relatively close to R^2 value, it ensures a relatively satisfactory adjustment of the quadratic model to the experimental data. The lack of fit was found non-significant for the model hence the model can be used to navigate the design. The result of regression coefficient shows the effect of roasting temperature and roasting time has highly significant effect ($p<0.01$) at linear level. Roasting temperature has significant effect ($p<0.1$) at quadratic level. Second order predictive quadratic equation for phytic acid is given below

$$Y= 0.17- 0.058X_1- 0.015X_2+ 0.0048X_1X_2- 0.017X_1^2+ 0.00037X_2^2$$

Where, Y is phytic acid and X_1 and X_2 are roasting temperature and roasting time

Influence of roasting temperature and roasting time on phytic acid is shown in Fig. 4.32-4.33. It was observed that phytic acid decreased with roasting temperature and roasting time. Similar results were also reported by Makinde and Akinoso (2014) for sesame seeds.

4.2.4.8 Optimization of variables

For the optimization of different variables, a numerical optimization was carried out using Design Expert 10.0.1 statistical software, where all the responses were given similar importance. The desired results for each factor and response were chosen and assigned as per the ultimate aim. The best solution with a single formulation with different levels of variables was obtained which is presented in Table 4.43, along with the actual values of the optimized product.

Table 4.43: Optimum levels of roasting conditions for pumpkin seed kernels for sand roasting

Independent variables	Coded levels	Predicted levels	Actual levels
Roasting Temperature (X_1)	-0.111	158.99 ºC	160 ºC
Roasting time (X_2)	0.855	2.145 min	2 min
Responses		**Values**	**Values**
Colour & appearance (1-9)		7.212	7.3
Flavour (1-9)		7.853	7.5
Odour (1-9)		7.863	7.5
Overall acceptability (1-9)		7.644	7.4
Hardness (g)		47.983	48.12
Fracturability (g)		4.529	4.12
Phytic acid (%)		0.169	0.172

4.2.5 Comparision of Optimized Roasted Pumpkin Seed Kernels using different Roasters

Table 4.44: Comparison of roasted pumpkin seed kernels by using different roasters

Independent variables	**Control**	**Halogen oven (R_1)**	**Hot air oven (R_2)**	**Microwave oven (R_3)**	**Sand roasting (R_4)**
	Actual levels				
Roasting temperature (X_1)	-	190^{o}C	160^{o}C	P-90	160^{o}C
Roasting time (X_2)	-	5 min	30 min	4 min	2 min
Responses	**Values**				
Colour and appearance	7.0	8.5	7.5	8.2	7.3
Taste	6.0	8.3	7.7	8.2	7.5
Odour	6.0	8.0	7.8	8.1	7.5
Overall acceptability	6.0	8.3	7.8	7.4	7.4
Hardness	59.73	44.62	44.35	54.45	48.12
Fracturability	2.251	4.531	3.91	4.87	4.12
Phytic acid	1.547	0.157	0.159	0.192	0.172

The optimal conditions of each roaster were compared (Table 4.44) in terms of the sensory evaluation scores, texture profile analysis and phytic acid content. Sand roasting is the most common conventional roasting method used for roasting peanuts, popcorns and other nuts products in India. Samples roasted in other roasting methods viz. halogen oven, hot air oven and microwave oven were compared with the conventional sand roasted sample as well as with the control unroasted sample.

All the optimal samples had good sensory scores, textural characteristics and low phytic acid content compared to the conventional sand roasting method and control sample. The sensory score for optimal halogen oven roasted sample had highest score of colour and appearance (8.5), taste (8.3), odour (8.0), and overall acceptability (8.3) compared to the other optimal roasting method. It was observed lower in hardness and higher in fracturability values in all the optimal roasted samples using different roasters as compared to the unroasted control sample. This might be due to the fact that during roasting, the moisture content of the pumpkin seed kernel was reduced and the texture become more crumbly and fragile (less hard). Samples roasted in halogen oven and hot air oven showed lower hardness values of 44.62g and 44.35g than the sample roasted in conventional sand roasting (48.12g) and microwave oven (54.45g) whereas, samples roasted in microwave and halogen oven showed higher fracturability values than other roasting methods. The phytic acid content was found to be lowest in sample roasted in halogen oven as compared to the other roasting methods. It was observed that hot air oven consumed more time of roasting as compared to the remaining roasters. All the present roasting methods were also more hygienic as compared to the conventional sand roasting method. In conclusion, by taking into the account the sensory score, texture profile analysis and phytic acid content value, the optimal halogen oven roasting method was considered best for roasting of pumpkin seed kernels and this method was considered for further development of different products.

4.3 STANDARDIZATION OF PROCESS PARAMETERS FOR THE PREPARATION OF ROASTED SALTED PUMPKIN SEED KERNELS

Experiments for standardizing process variables for the preparation of roasted salted pumpkin seed kernels were conducted as discussed in chapter III section 3.3. Most suitable combination of moisture conditioning and salt content were selected with respect to overall acceptability, texture profile analysis (hardness, fracturability). The data obtained for all twenty-seven experiments are tabulated in Table 4.45.

4.3.1 Effect of Moisture Conditioning and Salt Content on Overall Acceptability

Effect of process variables on overall acceptability is shown in Table 4.45. The score ranged from 6.5 to 8.8. The maximum score (8.8) of overall acceptability was observed for experimental combination of 10% moisture conditioning at 20% salt content. The minimum score (6.5) of overall acceptability was observed for experimental combination of 5% moisture conditioning and at 10% salt content. Table 4.47 shows the effect of moisture conditioning and salt content at linear, quadratic and interaction levels. It can be seen from the table that linear and quadratic levels were significant at 1% level, as their F_{cal} values (16.55 and 22.67) were greater than F_{tab} values (5.780), while for interactive effects it was not found to be significant, as their F_{cal} value 0.038 was lesser than F_{tab} (2.169) value.

Table 4.45: Variables and responses of roasted salted pumpkin seed kernels

Expt No.	Moisture conditioning (%)	Salt content (%)	Overall acceptability (1-9)	Hardness (g)	Fracturability (g)
1.	0 (10)	-1 (10)	8.0	50.11	5.470
2.	1 (15)	-1 (10)	7.4	42.25	4.729
3.	-1 (5)	-1 (10)	6.7	61.32	6.942
4.	0 (10)	-1 (10)	7.9	51.74	5.567
5.	-1 (-5)	-1 (10)	6.5**	60.21	6.214
6.	0 (10)	0 (15)	8.2	49.27	5.527
7.	-1 (-5)	-1 (10)	7.0	61.72	6.112
8.	1 (15)	-1 (10)	7.0	30.26	4.811
9.	1 (15)	1 (20)	7.8	29.72	3.911
10.	1 (15)	-1 (10)	7.0	29.42	5.014
11.	0 (10)	0 (15)	8.0	50.72	5.642
12.	0 (10)	0 (15)	7.4	53.02	5.524
13.	1 (15)	1 (20)	7.5	42.01	3.812
14.	-1 (5)	0 (15)	7.2	59.92	6.971*
15.	1 (15)	0 (15)	7.6	35.11	3.898
16.	-1 (5)	0 (15)	7.1	61.78*	6.014
17.	1 (15)	1 (20)	7.8	32.17	3.914
18.	-1 (5)	1 (20)	7.4	61.02	6.712
19.	0 (10)	-1 (10)	7.0	48.12	5.472
20.	0 (10)	1 (20)	8.5	50.12	5.611
21.	-1 (5)	1 (20)	7.2	59.27	6.512
22.	-1 (5)	0 (15)	6.9	58.21	5.921
23.	0 (10)	1 (20)	8.5	45.12	5.412
24.	0 (10)	1 (20)	8.8*	51.72	5.558
25.	1 (15)	0 (15)	7.0	29.27	3.146**
26.	-1 (5)	1 (20)	7.5	57.98	7.592
27.	1 (15)	0 (15)	7.5	28.72**	3.272

* Maximum, ** Minimum

Table 4.46: Regression analysis of roasted salted pumpkin seed kernels

Cons.	Overall acceptability		Hardness		Fracturability	
	Coeff.	P (%)	Coeff.	P (%)	Coeff.	P (%)
	7.97	0.01*	0.021000	0.01*	5.25	0.01*
X_1	0.17	2.15**	0.007057	0.01*	-1.25	0.01*
X_2	0.36	0.01*	0.000034	95.95	-0.07	44.07
X_1X_2	-0.02	84.63	-0.000296	71.44	-0.37	0.33*
X_1^2	-0.81	0.01*	0.003645	0.41*	-0.23	16.92
X_2^2	0.09	44.05	-0.000689	54.87	0.42	1.54**
R^2	78.98		85.89		90.76	
Adj.R^2	73.98		82.53		88.56	
F	15.78 (1% 4.042)		25.56 (1% 4.042)		23.24 (1% 4.042)	
LOF	NS		NS		NS	

*, ** and *** Significant at 1, 5 and 10% level of significance respectively, Coeff. = Coefficient, NS= Non significant, Cons.= Constant, LOF= Lack of Fit, X_1= moisture conditioning and X_2 = salt concentration

Table 4.47: ANOVA for overall acceptability for roasted salted pumpkin seed kernels

SOURCE	DF	SS	MS	F-Value
Model	5	6.830	1.370	15.78*
Linear	2	2.880	1.440	16.55*
Quadratic	2	3.944	1.972	22.67*
Interactive	1	0.003	0.003	0.038
Error	21	1.820	0.087	
Total	26	8.650		

***, **, * Significant at 10, 5 and 1% level

The regression analysis on overall acceptability is given in Table 4.46. The model was found highly significant with F-value 15.78 which is greater than F_{tab} (4.042) at 1%. The values R^2 and adj. R^2 were found to be 0.7898 and 0.7398 respectively. R^2 -adj value was observed to be relatively close to R^2 value, it ensures a relatively satisfactory adjustment of the quadratic model to the experimental data. The lack of fit was found non-significant for the model hence the model can be used to navigate the design. The effect of moisture conditioning ($p<0.05$) and salt content ($p<0.01$) was significant at linear level. At interactive level, moisture conditioning and salt content showed non-significantly effect on the overall acceptability. The effect of moisture conditioning showed significant effect ($p<0.01$) while salt content showed non-significant effect at quadratic level. Second order predictive quadratic equation for overall acceptability is given below

$$Y= 7.97+ 0.17X_1+ 0.36X_2- 0.017X_1X_2- 0.81X_1^2+ 0.094X_2^2$$

Where, Y is overall acceptability and X_1 and X_2 are moisture conditioning and salt content

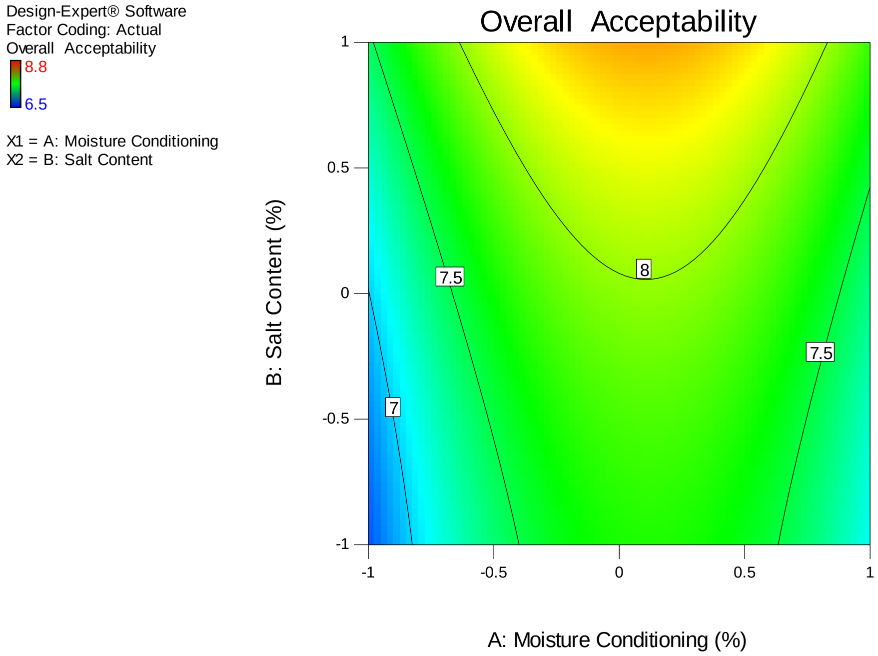

Fig.4.34: Effect of moisture conditioning and salt content on overall acceptability for roasted salted pumpkin seed kernels

Influence of moisture conditioning and salt content on overall acceptability is shown in Figure 4.34. The results showed that overall acceptability increased with increase in salt content from 10% to 20%. It was also observed that overall acceptability increased with increase in moisture conditioning from 5% to 10% but decreased with further increase in moisture conditioning.

4.3.2 Effect of Moisture Conditioning and Salt content on Hardness

Hardness is defined **as** peak force in the first compression. Effect of process variables on hardness is depicted in Table 4.45. The values ranged from 28.72g to 61.78g. The maximum hardness (61.78g) was observed for experimental combination of 5% moisture conditioning at 15% salt content. The minimum hardness (28.72g) was observed for experimental combination of 15% moisture conditioning at 15% salt content.

Table 4.48 shows the effect of moisture conditioning and salt content at linear, quadratic and interaction levels. It can be seen from the table that linear level is highly significant at 1% level, followed by quadratic which is significant at 5% level of significance as their F_{cal} values 58.46 and 5.385 were greater than F_{tab} (5.780 and 3.467), while for interactive it was found to be non-significant, as their F_{cal} value 0.138 was lesser than F_{tab} 2.169 value.

Table 4.48: ANOVA for hardness for roasted salted pumpkin seed kernels

SOURCE	DF	SS	MS	F-Value
Model	5	0.0009801	0.000196	25.56*
Linear	2	0.0008964	0.000448	58.46*
Quadratic	2	0.0000826	0.000041	5.39**
Interactive	1	0.0000011	0.000001	0.14
Error	21	0.0001610	0.000008	
Total	26	0.0011410		

***, **, * Significant at 10, 5 and 1% level

The regression analysis on hardness is given in Table 4.46. The model was found highly significant with F-value 25.56 which is greater than F_{tab} (4.042) at 1%. The values of R^2 and adj. R^2 were found to be 0.8589 and 0.8253. R^2 -adj value was observed to be relatively close to R^2 value, it ensures a relatively satisfactory adjustment of the quadratic model to the experimental data. The lack of fit was found non-significant for the model hence the model can be used to navigate the design. The effect of moisture conditioning has significant effect ($p<0.01$) and salt content has non-significant effect at linear level. At interactive level, there was non-significant effect of moisture conditioning and salt content. Moisture conditioning was significant ($p<0.01$) and salt content was non-significant at quadratic level. Second order predictive quadratic equation for hardness is given below

$$Y= 0.021+ 0.007057X_1+ 0.00003355X_2- 0.0002966X_1X_2+ 0.003645X_1^2- 0.0006891X_2^2$$

Where, Y is hardness and X_1 and X_2 are moisture conditioning and salt content

Influence of moisture conditioning and salt content on hardness is shown by contour graph in Figure 4.35. It was observed that hardness decreased with increased in moisture conditioning and there was no significant effect in hardness on salt content. This might be because of increase in softness of seed at higher moisture content at higher moisture conditioning. Sharma *et al.*, (2009) also reported similar results for sunflower seeds. They found that hardness decreased for different varieties of sunflower seeds with increasing in moisture content from 6.24% to 14.31%. Others authors also reported a decreasing trend in hardness with increase in moisture content for different seeds, viz. fenugreek seeds (Meghwal and Goswami, 2012), soybean seeds (Deshpande and Bal, 2001) and pomegranate seeds (Kingsly *et al.*, 2006).

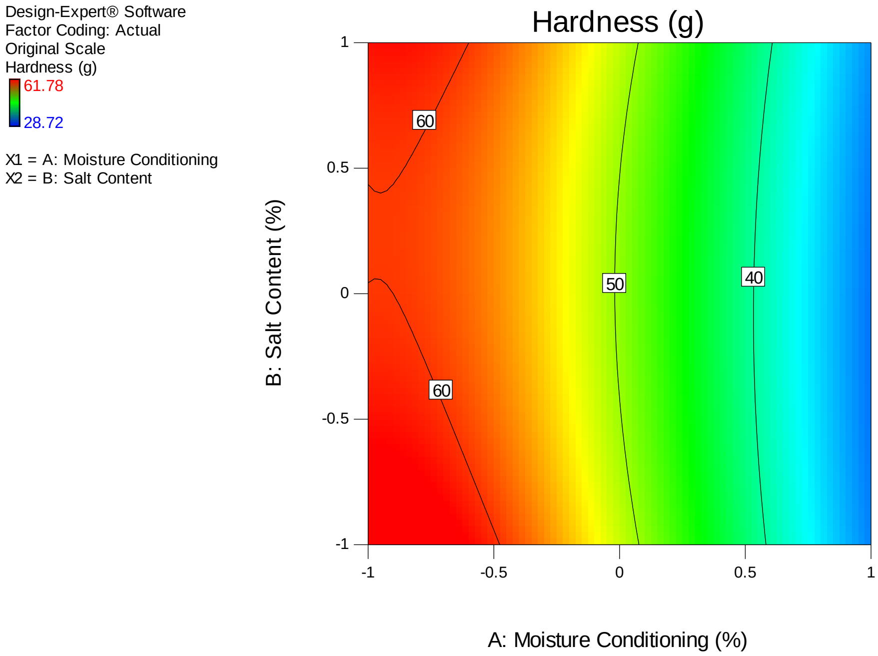

Fig.4.35: Effect of moisture conditioning and salt content on hardness for roasted salted pumpkin seed kernels

4.3.3 Effect of Moisture Conditioning and Salt Content on Fracturability

Fracturability is the ability of any material to be fractured or broken. When force is applied to test the hardness of the material, a point is obtained at which the material starts to fracture. This first fracture force is termed as fracturability (Kahyaoglu and Kaya, 2006). Effect of process variables on fracturability is depicted in Table 4.45. The values ranged from 3.146g to 6.971g. The maximum value (6.971g) of fracturability was observed for experimental combination of 5% moisture conditioning at 15% salt content. The minimum value (3.146g) of fracturability was observed for experimental combination of 15% moisture conditioning at 15% salt content. Table 4.49 shows the effect of moisture conditioning and salt content at linear, quadratic and interaction levels. It can be seen from the table that linear and interactive level is highly significant at 1% level, followed by quadratic at 5% level significance, as their F_{cal} values 93.91, 11.07 and 4.53 were greater than F_{tab} (5.780, 8.017 and 3.467) values.

Table 4.49: ANOVA for fracturability for roasted salted pumpkin seed kernels

SOURCE	DF	SS	MS	F-Value
Model	5	31.20	6.24	41.24*
Linear	2	28.17	14.09	93.91*
Quadratic	2	1.36	0.68	4.53**
Interactive	1	1.66	1.66	11.07*
Error	21	3.18	0.15	
Total	26	34.37		

***, **, * Significant at 10, 5 and 1% level

The regression analysis on fracturability is given in Table 4.56. The model was found highly significant with F-value 23.24 which is greater than F_{tab} (4.042) at 1%. The values of R^2 and adj. R^2 were found to be0.9076 and 0.8856. R^2 -adj value was observed to be relatively close to R^2 value, it ensures a relatively satisfactory adjustment of the quadratic model to the experimental data. The lack of fit was found non-significant for the model hence the model can be used to navigate the design. The effect of moisture conditioning ($p<0.01$) and salt content has non-significant effect at linear level. At interactive level, moisture conditioning and salt content significantly effect the fracturability at ($p<0.01$). Moisture conditioning has non-significant effect while salt content has significant effect at quadratic level ($p<0.05$). Second order predictive quadratic equation for fracturability is given below

$$Y= 5.25- 1.25X_1- 0.072X_2- 0.37X_1X_2- 0.23X_1^2+ 0.42X_2^2$$

Where, Y is fracturability and X_1 and X_2 are moisture conditioning and salt content

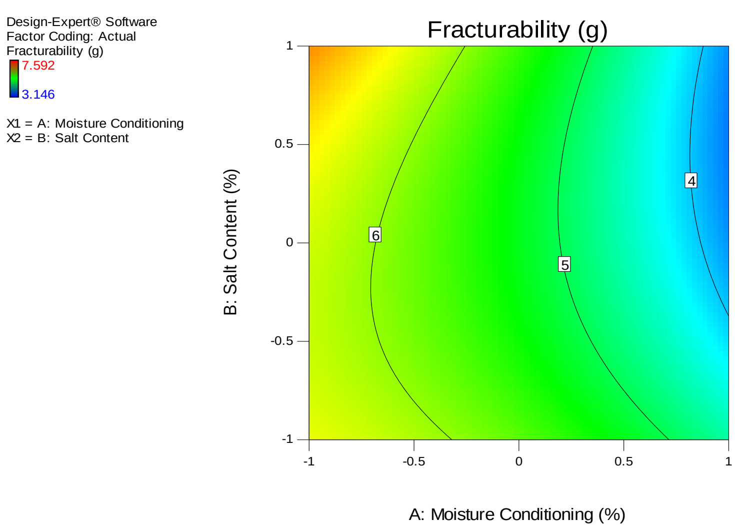

Fig. 4.36: Effect of moisture conditioning and salt content on fracturability for roasted salted pumpkin seed kernels

Influence of moisture conditioning and salt content on fracturability is shown by contour graph in Figure 4.36. The graph shows that fracturability of roasted salted pumpkin seed kernels decreased with increase in moisture conditioning and there was no change in fracturability with change in salt content. This might be due to the more fragile and crumble nature of roasted seeds due to lesser moisture content. The findings were in accordance with the results reported by (Meghwal and Goswami, 2012) who reported decreasing trend in fracturability (5500 to 1000g) with increasing moisture content for fenugreek seeds and Gupta and Das (2000), who revealed that the force required for sunflower seed hull or kernel rupture decreased as moisture content increased from 4% to 20% d.b. The force required for initiating cumin seed rupture were also found decreasing from 15.7 to 11.96 N and 58.2 to 28.8 N, with increase in moisture content from 5.7% to 15% d.b., for vertical and horizontal orientations, respectively (Saiedirad *et al*., 2008).

4.3.4 Optimization of Different Variables

For optimization of different variables, a numerical optimization technique was carried out using Design Expert 10.0.1 statistical software, where all the responses were given similar importance. The desired results for each factor and response were chosen and assigned as per the ultimate aim. The ultimate aims were as follows, in range moisture conditioning, in range salt content, maximum overall acceptability, minimum hardness and maximum fracturability. The best concentration with a single formulation with different levels of variables was obtained which is presented in Table 4.50, along with the actual values of the optimized product.

Table 4.50: Optimum levels of moisture conditioning and salt content for the preparation of roasted salted pumpkin seed kernels

Independent variables	Coded levels	Predicted levels	Actual levels	Control
Moisture conditioning (X_1)	0.332	11.66%	12%	-
Salt content (X_2)	0.999	20%	20%	-
Responses		**Values**		
Overall acceptability (1-9)		8.383	8.4	6.0
Hardness (g)		45.123	45.22	59.73
Fracturability (g)		5.035	5.10	2.251

The Optimized conditions gives moisture conditioning of 0.332 (11.66%), salt content of 0.999 (20%), overall acceptability of 8.383, hardness of 45.123g and fracturability of 5.035 g with desirability factor of 0.860, which is presented in below ramps (Fig. 4.37). The experimental and predicted values of the responses for the optimized roasted salted pumpkin seed kernels were almost similar. It can be observed that both the statistical design and experimental were in good accordance to optimize the product. The optimal combinations has good overall acceptability and textural characteristics of hardness and fracturability as compare to the control sample.

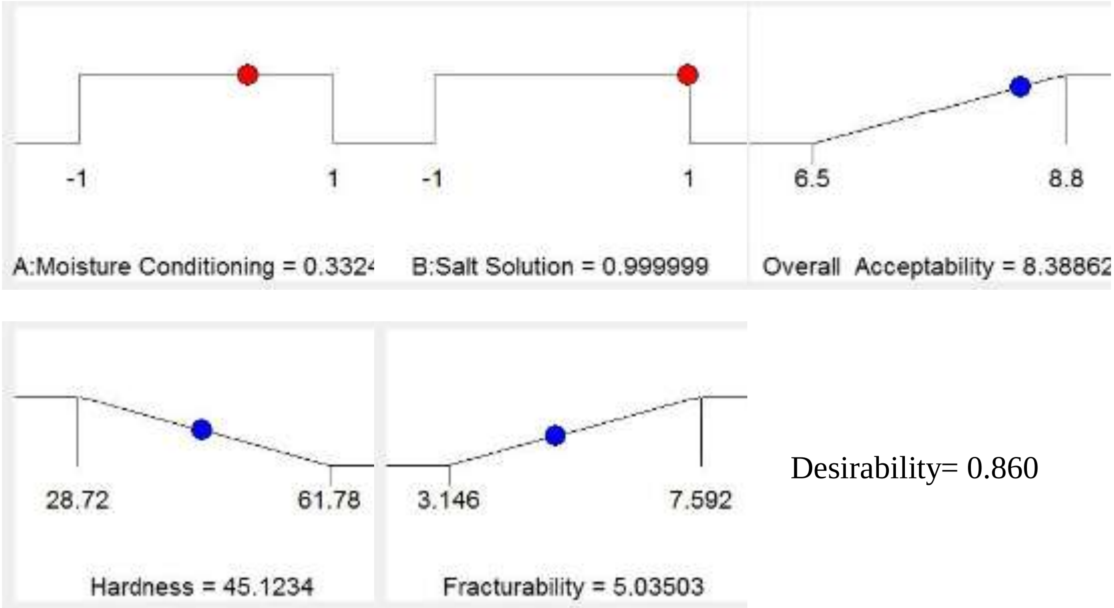

Figure 4.37: Optimized conditions for roasted salted pumpkin seed kernels

4.3.5 Evaluation of Roasted salted pumpkin seed kernels

The proximate composition, fatty acid profile, sensory evaluation and microbiological analysis of optimized roasted salted pumpkin seed kernels were carried out as per the methods explained in the previous chapter and the results are presented in Tables 4.51 and 4.52.

Plate 4.1: Optimized roasted salted pumpkin seed kernels

The average proximate composition of roasted salted pumpkin seed kernels are found to be 2.41% moisture, 31.97% crude protein, 38.54% crude fat, 4.34% ash content, 2.34% crude fibre and 22.38% total carbohydrate. The moisture content of roasted salted pumpkin seed kernels has lower moisture content as compared to the unroasted pumpkin seed sample. Soleimanieh *et al*., (2015) also reported decreasing in moisture content of sunflower seed kernels with roasting. The results of moisture content was found to be slightly higher than the roasted pistachios nuts as reported by Nikzadeh and Sedaghat (2008).

Table 4.51: Proximate composition of roasted salted pumpkin seed kernels

Parameters	**Mean value±S.D.**
Moisture, (%)	2.41 ± 0.12
Crude protein, (%)	31.97± 1.12
Crude fat, (%)	38.54± 0.93
Ash, (%)	4.34± 0.43
Crude fibre, (%)	2.34± 0.08
Total carbohydrate, (%)	22.38± 1.05
Sensory Score	
Colour & appearance	8.2
Taste	7.4
Odour	8.2
Overall acceptability	8.2

The sensory scores was evaluated for optimized roasted salted pumpkin seed kernels using 9-point hedonic scale for different variables colour & appearance, flavour, body and texture and overall acceptability. The scores were found to be 8.2, 7.4, 8.2 and 8.2 for colour & appearance, flavour, body and texture and overall acceptability respectively. The results of the sensory scores showed that the optimized roasted salted pumpkin seed kernels has good overall acceptability because the sensory scores of all the sensory attributes are above 6.5.

4.3.5.1. Fatty Acid Profile of Optimized Roasted salted pumpkin seed kernels

Table 4.52: Fatty acid profile of optimized roasted salted pumpkin seed kernels

Sl.no.	**Variables**	**Content, %**
1	Palmitic acid	18.65
2	Palmitolic acid	0.28
3	Stearic acid	12.87
4	Oleic acid	30.23
5	Linoleic acid	36.25
6	Linolenic acid	0.19
7	Arachidic acid	0.33
8	Behenic acid	0.25
9	Eursic acid	0.51

Table 4.52 shows the fatty acid profile of optimized roasted salted pumpkin seed kernels. The major fatty acids were linoleic acid (36.25%) and oleic acid (30.23%) while the other fatty acids identified were palmitic acid (18.65%), palmitolic acid (0.28%), stearic acid (12.87%), linolenic acid (0.33%), arachidic acid (0.33%), behenic acid (0.25%) and eursic acid (0.51%). The gas chromatograph graph of fatty acid profile of pumpkin seed oil is shown in appendix III (b). Rodriguez-Miranda *et al.,* (2013) and Gohari *et al*., (2011) also reported linoleic acid, oleic acid, palmitic acid and stearic acid as the most abundant fatty acids of pumpkin seed oil. The concentration of major fatty acids as studied in the present work could be comparable with other cucurbits seed oils. *Cucumeropsis manni* seed oil had a range of 15-24% and 10-12.3% palmitic and linoleic acid as reported by Badifu (1991) and Fokou *et al.,* (2009). Palmitic acid (10.7-11.36%), stearic acid (7.04-9.00%), oleic acid (13.25-44.11%) and linoleic acid (34.77-68.3%) were also detected as the most abundant fatty acids in *Citrullus lanatus* seed oils and *Cucurbita maxima* seed oils such as watermelon, pumpkin, and safflower seeds by El- Adawy and Taha (2001); Milovanovic and Picuric-Jovanovic (2005); Mariod *et al*., (2009); Nyam *et al*., (2009); Baboli and Kordi, (2010) and Rezig *et al.,* (2012).

4.3.5.2 Microbiological analysis of roasted salted pumpkin seed kernels

Microbiological analysis of optimized roasted salted pumpkin seed kernels was carried out for standard plate count, coliform count and yeast and mold count to evaluate the quality and safety of the product. It was observed that coliforms and yeast and mold count were not found and standard plate count was found to be 2 x 10^3 cfu/g.

4.4 STANDARDIZATION OF PROCESS PARAMETERS FOR THE PREPARATION OF PUMPKIN SEED SPREAD

Experiments for standardizing process parameter for the preparation of pumpkin seed spread were conducted as discussed in chapter III section 3.3. Most suitable combination of hydrogenated vegetable oil and lecithin were selected with respect to overall acceptability, (OAA), textural profile analysis (hardness, adhesiveness, cohesiveness), and L*, a*, b* values. The data obtained for all twenty-seven experiments are tabulated in Table 4.53.

4.4.1 Effect of Hydrogenated Vegetable Oil and Lecithin on Overall Acceptability

Effect of process variables on overall acceptability is shown in Table 4.53. The score ranged from 6.3 to 8.9. The maximum score (8.9) of overall acceptability was observed for experimental combination of 20% hydrogenated vegetable oil and 1% lecithin. The minimum score (6.3) of overall acceptability was observed for experimental combination of 10% hydrogenated vegetable oil and 0.5% lecithin.

Table 4.53: Variables and responses of pumpkin seed spread

* Maximum, ** Minimum

Expt No.	Hydrogenated vegetable oil (%)	Lecithin (%)	Overall acceptability (1-9)	Hardness (g)	Adhesiveness (g/sec)	Cohesiveness	Colour value L*	Colour value a*	Colour value b*
1.	15 (0)	1.0 (0)	7.5	192.63	-169.81	0.581	57.98	3.32	24.27
2.	15 (0)	1.0 (0)	6.9	180.21	-164.82	0.577	56.61	3.63	24.10
3.	15 (0)	0.5 (-1)	6.8	243.36	-199.81	0.451	55.21	3.29	25.42
4.	10 (-1)	0.5 (-1)	6.7	280.39	-213.04**	0.448	51.27	1.61**	31.99*
5.	10 (-1)	1.5 (1)	6.4	148.22	-139.33	0.692*	54.32	2.54	27.42
6.	15 (0)	1.5 (1)	7.1	149.77	-126.91	0.681	56.31	4.85	24.00
7.	10 (-1)	1.5 (1)	6.9	145.63	-142.74	0.684	53.78	2.73	27.99
8.	10 (-1)	1.5 (1)	6.8	152.19	-139.28	0.689	54.17	2.76	28.72
9.	15 (0)	0.5 (1)	6.6	270.12	-210.70	0.461	56.72	3.39	24.99
10.	20 (1)	1.0 (0)	8.7	170.2	-152.58	0.598	57.68	7.42	24.51
11.	20 (1)	1.0 (0)	8.9*	169.21	-150.92	0.584	56.71	7.21	21.41
12.	10 (-1)	1.0 (0)	6.9	190.77	-174.00	0.512	52.78	1.89	28.77
13.	10 (-1)	0.5 (-1)	6.3**	260.12	-207.44	0.402**	45.92**	1.95	30.72
14.	20 (1)	1.0 (0)	8.0	150.76	-116.40	0.667	59.21	7.65	23.51

15.	15 (0)	1.0 (0)	7.1	143.23**	-121.72	0.678	57.23	5.93	23.41
16.	20 (1)	0.5 (-1)	7.4	261.24	-183.79	0.479	57.71	7.52	23.12
17.	15 (0)	0.5 (-1)	6.7	251.33	-187.51	0.442	57.71	3.83	22.82
18.	15 (0)	1.5 (1)	7.3	150.22	-120.23	0.669	56.21	5.47	24.57
19.	15 (0)	1.0 (0)	6.9	185.27	-160.71	0.568	58.63	3.13	24.72
20.	20 (1)	1.5 (1)	7.8	148.63	-104.15*	0.659	58.12	7.85*	24.17
21.	10 (-1)	1.0 (0)	6.6	180.78	-180.72	0.509	53.92	2.13	28.12
22.	10 (-1)	0.5 (-1)	6.5	207.44	-207.53	0.424	49.28	1.94	29.72
23.	20 (1)	1.0 (0)	8.3	162.22	-156.21	0.579	56.98	6.29	22.61
24.	20 (1)	0.5 (-1)	7.6	291.42*	-199.21	0.474	57.71	6.29	24.21
25.	10 (-1)	1.0 (0)	6.6	170.12	-176.37	0.535	52.71	2.14	29.11
26.	20 (1)	0.5 (-1)	7.6	271.48	-183.72	0.468	52.13	6.23	22.71
27.	20 (1)	1.5 (1)	7.1	149.98	-127.10	0.663	59.78*	6.23	20.21**

Table 4.54: Regression analysis of pumpkin seed spread

Cons.	Overall acceptability		Hardness		Adhesiveness		Cohesiveness		Colour value L*		Colour value a*		Colour value b*	
	Coeff.	P (%)	Coeff.	P (%)	Coeff.	P (%)	Coeff.	P (%)	Coeff.	P (%)	Coeff.	P (%)	Coeff.	P (%)
	0.14	0.01*	0.0056	0.01*	-164.01	0.01*	1.77	0.01*	57.53	0.01*	0.28	0.01*	24.09	0.01*
X_1	-0.014	0.01*	-0.0000081	91.63	-11.47	0.01*	-0.070	0.01*	2.66	0.01*	-0.16	0.01*	-3.12	0.01*
X_2	-0.0034	4.29**	0.00142	0.01*	-36.38	0.01*	-0.37	0.01*	1.41	0.29*	-0.048	0.01*	-0.65	2.27**
X_1X_2	0.0018	35.88	0.0000944	32.34	1.03	58.28	0.076	0.02*	-0.52	32.18	0.041	0.01*	0.51	12.85
X_1^2	-0.0033	24.15	0.0000834	53.45	-1.67	53.01	0.033	17.67	-2.29	0.47*	0.051	0.05*	1.80	0.08*
X_2^2	0.0061	3.69**	-0.0003326	2.0**	2.32	38.67	0.064	1.25**	-0.84	25.98	-0.029	2.62**	0.25	59.42
R^2	80.22		94.41		96.81		97.49		75.33		96.72		88.60	
Adj.R^2	75.51		93.08		96.05		96.89		69.45		95.94		85.88	
F	17.04 (1% 4.042)		70.92 (1% 4.042)		127.61 (1% 4.042)		162.81 (1% 4.042)		12.82 (1% 4.042)		124.03(1% 4.042)		32.64(1% 4.042)	
LOF	NS		NS		NS		NS		NS		NS		NS	

*, ** and *** Significant at 1, 5 and 10% level of significance respectively, Coeff. = Coefficient, NS= Non significant, Cons.= Constant, LOF= Lack of Fit, X_1= Hydrogenated vegetable oil and X_2 = Lecithin

Table 4.55 shows the effect of hydrogenated vegetable oil and lecithin at linear, quadratic and interaction levels. It can be seen from the table that linear and quadratic levels were significant at 1% and 10%, as their F_{cal} values 38.94 and 3.210 were greater than F_{tab} (4.4042 and 2.575) values, while for interactive levels, it was not found to be significant, as their F_{cal} value 0.880 was lesser than F_{tab} (2.169) value.

Table 4.55: ANOVA for overall acceptability for pumpkin seed spread

SOURCE	**DF**	**SS**	**MS**	**F-Value**
Model	5	0.003824	0.0007648	17.04*
Linear	2	0.003496	0.0017478	38.94*
Quadratic	2	0.000288	0.0001441	3.21***
Interactive	1	0.000039	0.0000395	0.88
Error	21	0.000943	0.0000449	
Total	26	0.004766		

***, **, * Significant at 10, 5 and 1% level

The regression analysis on overall acceptability is given in Table 4.54. The model was found highly significant with F-value 17.04 which is greater than F_{tab} (4.042) at 1%. The values of R^2 and adj. R^2 values were found to be 0.8022 and 0.7551 respectively. R^2 -adj (0.7551) value was observed to be relatively close to R^2 (0.8022) value, it ensures a relatively satisfactory adjustment of the quadratic model to the experimental data. The lack of fit was found non-significant for the model hence the model can be used to navigate the design.

The effect of hydrogenated vegetable oil ($p<0.01$) and lecithin ($p<0.05$) has significant effect at linear level. At interactive level, hydrogenated vegetable oil and lecithin were not significantly affected the overall acceptability. The effect of lecithin has significant effect ($p<0.05$) while hydrogenated vegetable oil has shown no significant effect at quadratic level. Second order predictive quadratic equation for overall acceptability is given below

$$Y= 0.14-0.014X_1- 0.0034X_2+ 0.00182X_1X_2- 0.00330X_1^2+ 0.00610X_2^2$$

Where, Y is overall acceptability and X_1 and X_2 are hydrogenated vegetable oil and lecithin

Influence of hydrogenated vegetable oil and lecithin on overall acceptability is shown in Figures 4.38-4.39. It can be seen that overall acceptability increased with increase in hydrogenated vegetable oil but slightly changed with increased in lecithin. This might be due to the smooth body and texture and good spreadability of pumpkin seed spread by the addition of lecithin and hydrogenated vegetable oil.

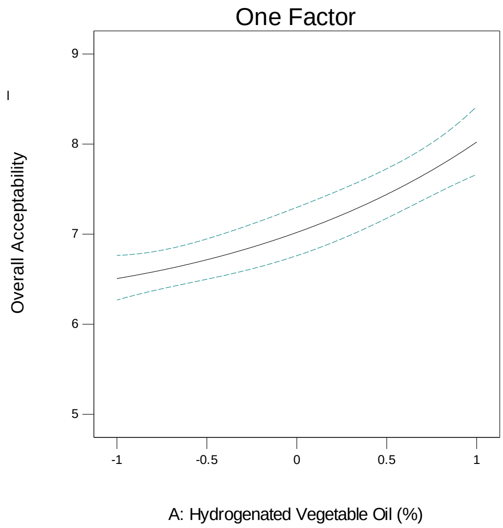

Fig.4.38: Effect of hydrogenated vegetable oil on overall acceptability for pumpkin seed spread

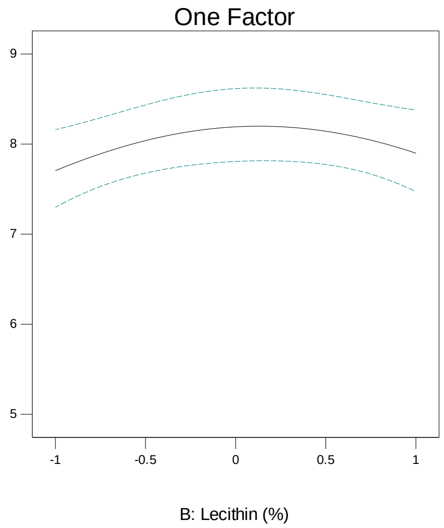

Fig.4.39: Effect of lecithin on overall acceptability for pumpkin seed spread

4.4.2 Effect of Hydrogenated Vegetable Oil and Lecithin on Hardness

The effect of process variables on hardness is shown in Table 4.53. The values ranged from 143.23g to 291.42g. The maximum value (291.42g) of hardness was observed for experimental combination of 20% hydrogenated vegetable oil and 0.5% lecithin. The minimum value (143.23g) of hardness was observed for experimental combination of 15% hydrogenated vegetable oil and 1.0% lecithin. Table 4.56 shows the effect of hydrogenated vegetable oil and lecithin at linear, quadratic and interaction levels. It can be seen from the table that linear level is highly significant at 1% level, followed by quadratic which is significant at 10%, as their F_{cal} values 172.91 and 3.362 were greater than F_{tab} (4.042 and 2.575) values, while for interactive levels, it was not found to be significant, as their F_{cal} value 1.019 was lesser than F_{tab} (2.169) value.

Table 4.56: ANOVA for hardness for pumpkin seed spread

SOURCE	DF	SS	MS	F-Value
Model	5	0.00003712	0.000007424	70.12*
Linear	2	0.00003631	0.000018156	172.91*
Quadratic	2	0.00000071	0.000000353	3.36***
Interactive	1	0.00000011	0.000000107	1.02
Error	21	0.00000219	0.000000105	
Total	26	0.00006932		

***, **, * Significant at 10, 5 and 1% level

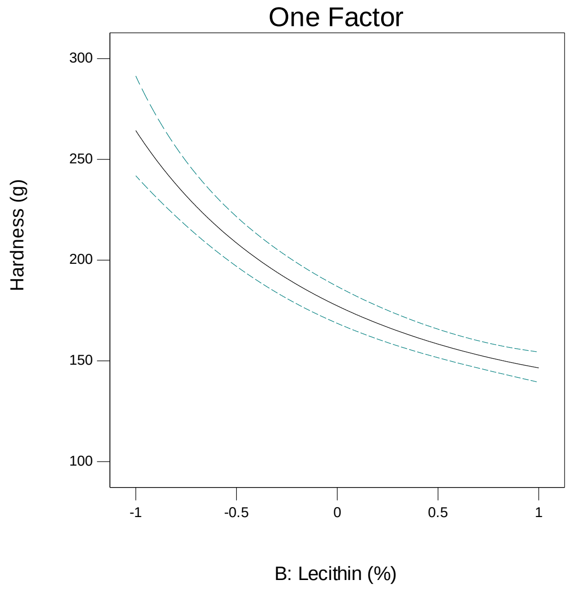

Fig.4.40: Effect of lecithin on hardness for pumpkin seed spread

The regression analysis on hardness is given in Table 4.54. The model was found highly significant with F-value 70.12 which is greater than F_{tab} (4.042) at 1%. The values of R^2 and adj. R^2 were found to be 0.9441 and 0.9308 respectively. R^2 -adj value was observed to be relatively close to R^2 value, it ensures a relatively satisfactory adjustment of the quadratic model to the experimental data. The lack of fit was found non-significant for the model hence the model can be used to navigate the design. Hydrogenated vegetable oil has non-significant effect while lecithin has significant effect ($p<0.01$) at linear level. Lecithin was significant ($p<0.05$) at quadratic level. At interactive level, there was no significant effect of hydrogenated vegetable oil and lecithin. Second order predictive quadratic equation for hardness is given below

$$Y= 0.0056- 0.0000081X_1+ 0.00142X_2 + 0.0000944X_1X_2+ 0.00008341X_1^2- 0.0003326X_2^2$$

Where, Y is hardness and X_1 and X_2 are hydrogenated vegetable oil and lecithin

Effect of lecithin on hardness is shown in Figure 4.40. It was observed that hardness decreased with increase in lecithin. This might be due to the fact that the samples prepared with higher amount of emulsifier contained less oil. The emulsifier composed of mono-acylglycerols of fatty acids, had a high melting point and also addition of more lecithin, promotes more lubrication between the components used for making the pumpkin seed spread and leads to reduced in hardness. The results are corelated with the results obtained by Elleuch *et al.*, (2014). They observed that there was a significant reduction, up to 43.7% in the hardness values of fibre-fortified halva supplied with emulsifier compared with halva containing only 1% of fibre. Decreasing in hardness by increasing emulsifier concentration in bread were reported by Karimi *et al*., (2012).

4.4.3 Effect of Hydrogenated Vegetable Oil and Lecithin on Adhesiveness

Effect of process variables on adhesiveness is shown in Table 4.53. The values ranged from -213.037g/sec to -104.153g/sec. The maximum value (-104.153g/sec) of adhesiveness was observed for experimental combination of 20% hydrogenated vegetable oil at 1.5% lecithin. The minimum value (-213.037g/sec) of adhesiveness was observed for experimental combination of 10% hydrogenated vegetable oil at 0.5% lecithin. Table 4.57 shows the effect of hydrogenated vegetable oil and lecithin at linear, quadratic and interaction levels. It can be seen from the table that linear level is highly significant at 1%, as their F_{cal} values 318.28 was greater than F_{tab} (4.042) value, while for quadratic and interactive levels, it was not found to be significant, as their F_{cal} values 0.5946 and 0.3113 were lesser than F_{tab} (2.575 and 2.169) values.

Table 4.57: ANOVA for adhesiveness for pumpkin seed spread

SOURCE	DF	SS	MS	F-Value
Model	5	26253.92	5250.784	127.61*
Linear	2	26192.19	13096.09	318.28*
Quadratic	2	48.93	24.46	0.59
Interactive	1	12.81	12.81	0.31
Error	21	864.09	41.15	
Total	26	27118.01		

***, **, * Significant at 10, 5 and 1% level

The regression analysis on adhesiveness is given in Table 4.54. The model was found highly significant with F-value 127.61 which is greater than F_{tab} (4.042) at 1%. The values of R^2 and adj. R^2 were found to be 0.9681 and 0.9605 respectively. R^2 -adj (0.9605) value was observed to be relatively close to R^2 (0.9681) value, it ensures a relatively satisfactory adjustment of the quadratic model to the experimental data. The lack of fit was found non-significant for the model hence the model can be used to navigate the design. The effect of hydrogenated vegetable oil and lecithin showed significant effect ($p<0.01$) at linear level. Hydrogenated vegetable oil and lecithin showed non-significant effect at interactive and quadratic level. Second order predictive quadratic equation for adhesiveness is given below

$Y = -164.01 - 11.47X_1 - 36.38X_2 - 1.03X_1X_2 - 1.67X_1^2 + 2.32X_2^2$

Where, Y is adhesiveness and X_1 and X_2 are hydrogenated vegetable oil and lecithin

Influence of hydrogenated vegetable oil and lecithin on adhesiveness is shown in Figures 4.41- 4.42. In both the cases, it was observed that adhesiveness decreased with increase in hydrogenated vegetable oil and lecithin, which is a desired property. This may be due to the reason that lecithin enhance consistency of the product. Elleuch *et al*., (2014) reported similar effect of emulsifier in their product.

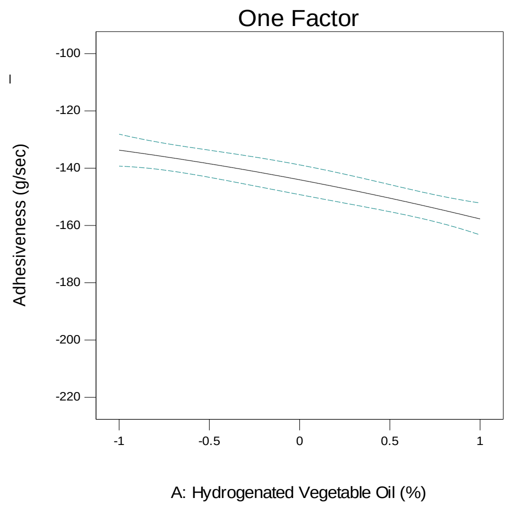

Fig. 4.41: Effect of hydrogenated vegetable oil on adhesiveness for pumpkin seed spread

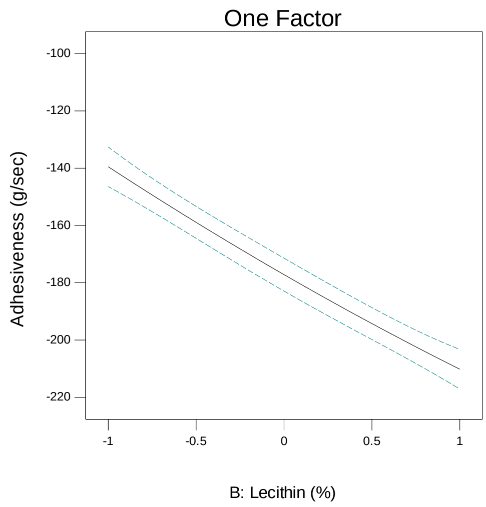

Fig. 4.42: Effect of lecithin on adhesiveness for pumpkin seed spread

4.4.4 Effect of Hydrogenated Vegetable Oil and Lecithin on Cohesiveness

Effect of process variables on cohesiveness is depicted in Table 4.53. The values ranged from 0.402 to 0.692. The maximum value (0.692) of hardness was observed for experimental combination of 10% hydrogenated vegetable oil and 1.5% lecithin. The minimum value (0.402) of hardness was observed for experimental combination of 10% hydrogenated vegetable oil and 0.5% lecithin. Table 4.58 shows the effect of hydrogenated vegetable oil and lecithin at linear, quadratic and interaction levels. It can be seen from the table that linear and interactive levels are highly significant at 1% level, as their F_{cal} values 395.0 and 20.91 were greater than F_{tab} (4.4042 and 8.017) values, followed by quadratic level, which is significant at 5%, as their F_{cal} value 4.788 was greater than F_{tab} (3.467) value.

Table 4.58: ANOVA for cohesiveness for pumpkin seed spread

SOURCE	DF	SS	MS	F-Value
Model	5	2.710	0.5420	162.81*
Linear	2	2.607	1.3035	395.00*
Quadratic	2	0.032	0.0158	4.79**
Interactive	1	0.069	0.0690	20.91*
Error	21	0.070	0.0033	
Total	26	2.780		

***, **, * Significant at 10, 5 and 1% level

The regression analysis on cohesiveness is given in Table 4.54. The model was found highly significant with F-value 162.81 which is greater than F_{tab} (4.042) at 1%. The values of R^2 and adj. R^2 were found to be 0.9749 and 0.9689 respectively. R^2 -adj value was observed to be relatively close to R^2 value, it ensures a relatively satisfactory adjustment of the quadratic model to the experimental data. The lack of fit was found non-significant for the model hence the model can be used to navigate the design. Hydrogenated vegetable oil and lecithin have significant effect ($p<0.01$) at linear and interactive levels. Hydrogenated vegetable oil was significant ($p<0.05$) at quadratic level. Second order predictive quadratic equation for cohesiveness is given below

$$Y= 1.77- 0.070X_1- 0.37X_2+0.076X_1X_2+0.033X_1^2+0.064X_2^2$$

Where, Y is cohesiveness and X_1 and X_2 are hydrogenated vegetable oil and lecithin

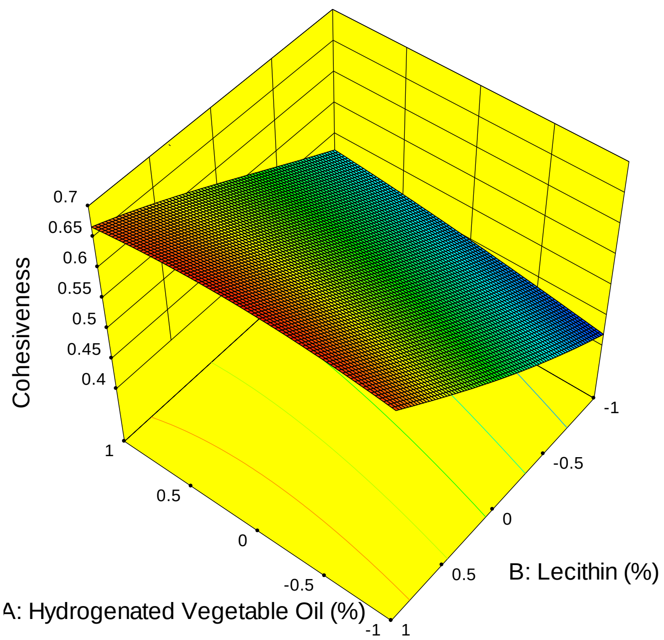

Fig. 4.43: Effect of hydrogenated vegetable oil and lecithin on cohesiveness for pumpkin seed spread

Effect of hydrogenated vegetable oil and lecithin on cohesiveness is shown in Figure 4.43. It was observed that cohesiveness increased with increase in lecithin but it slightly increased with hydrogenated vegetable oil. This phenomena may be due to the ability of lecithin to emulsify the product effectively. Elleuch *et al.*, (2014) reported that improved in cohesiveness of halva with the addition of emulsifier.

4.4.5 Effect of Hydrogenated Vegetable Oil and Lecithin on Colour Value L*

Effect of process variables on colour value L* is depicted in Table 4.53. The value ranged from 45.92 to 52.78. The maximum value (52.78) of colour value L* was observed for experimental combination of 20% hydrogenated vegetable oil and 1.5% lecithin. The minimum value (45.92) of colour value L* was observed for experimental combination of 10% hydrogenated vegetable oil and 0.5% lecithin. Table 4.59 shows the effect of hydrogenated vegetable oil and lecithin at linear, quadratic and interaction levels. It can be seen from the table that linear level is highly significant at 1% level, followed by quadratic which is significant at 5% level, as their F_{cal} values 25.89 and 5.671 were greater than F_{tab} (4.042 and 3.467) values, while for interactive levels, it was not found to be significant, as their F_{cal} value 1.029 was lesser than F_{tab} (2.169) value.

Table 4.59: ANOVA for colour value L* for pumpkin seed spread

SOURCE	DF	SS	MS	F-Value
Model	5	202.09	40.418	12.82*
Linear	2	163.12	81.560	25.89*
Quadratic	2	35.73	17.865	5.67**
Interactive	1	3.24	3.240	1.03
Error	21	66.19	3.150	
Total	26	268.28		

***, **, * Significant at 10, 5 and 1% level

The regression analysis on colour value L* is given in Table 4.54. The model was found highly significant with F-value 12.82 which is greater than F_{tab} (4.042) at 1%. The values of R^2 ans adj. R^2 were found to be 0.7533 and 0.6945 respectively. R^2 -adj (0.6945) value was observed to be relatively close to R^2 (0.7533) value, it ensures a relatively satisfactory adjustment of the quadratic model to the experimental data. The lack of fit was found non-significant for the model hence the model can be used to navigate the design. Hydrogenated vegetable oil and lecithin have significant effect ($p<0.01$) at linear level. At interactive level, there was non-significant effect of hydrogenated vegetable oil and lecithin. Hydrogenated vegetable oil was significant ($p<0.01$) at quadratic level. Second order predictive quadratic equation for colour value L* is given below

$$Y= 57.53+ 2.66X_1+ 1.41X_2- 0.52X_1X_2- 2.29X_1^2- 0.84X_2^2$$

Where, Y is colour value L* and X_1 and X_2 are hydrogenated vegetable oil and lecithin

Effect of hydrogenated vegetable oil and lecithin on colour value L* is shown in Figures 4.44-4.45. It was observed that colour value L* slightly increased with hydrogenated vegetable oil and lecithin. This might be attributed due to the positive effect of emulsifiers which enhance lightness of the products.

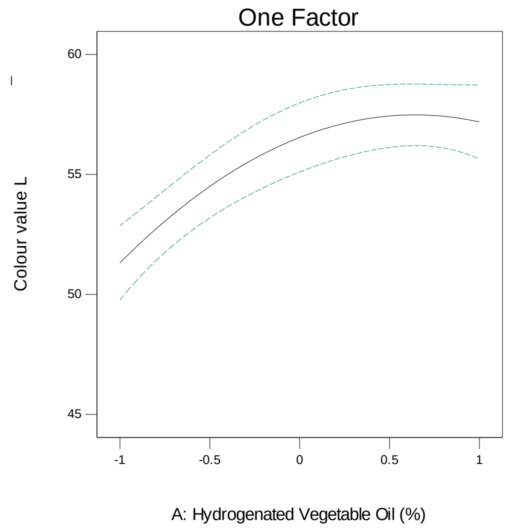

Fig.4.44: Effect of hydrogenated vegetable oil on colour value L* for pumpkin seed spread

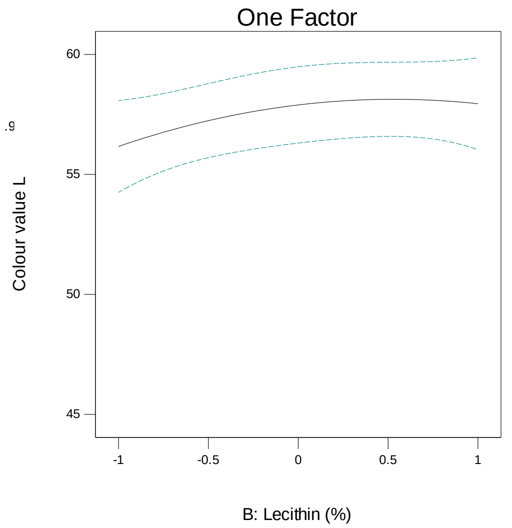

Fig.4.45: Effect of lecithin on colour value L* for pumpkin seed spread

4.4.6 Effect of Hydrogenated Vegetable Oil and Lecithin on Colour Value a*

Effect of process variables on colour value a* is shown in Table 4.53. The values ranged from 1.61 to 7.85. The maximum value (7.85) of colour value a* was observed for experimental combination of 20% hydrogenated vegetable oil and 1.5% lecithin. The minimum value (1.61) of colour value a* was observed for experimental combination of 10% hydrogenated vegetable oil and 0.5% lecithin. Table 4.60 shows the effect of hydrogenated vegetable oil and lecithin at linear, quadratic and interaction levels. It can be seen from the table that linear, quadratic and interactive levels were highly significant at 1%, as their F_{cal} values 287.92, 11.148 and 22.105 were greater than F_{tab} (4.042 and 8.017) values.

The regression analysis on colour value a* is given in Table 4.54. The model was found highly significant with F-value 124.03 which is greater than F_{tab} (4.042) at 1%. The values of R^2 and adj. R^2 were found to be 0.9672 and 0.9594 respectively. R^2

-adj value was observed to be relatively close to R^2 value, it ensures a relatively satisfactory adjustment of the quadratic model to the experimental data. The lack of fit was found non-significant for the model hence the model can be used to navigate the design. Hydrogenated vegetable oil and lecithin have significant effect ($p<0.01$) at linear and interactive levels. Hydrogenated vegetable oil ($p<0.01$) and lecithin ($p<0.05$) were significant at quadratic level. Second order predictive quadratic equation for colour value a* is given below

$$Y= 0.28- 0.16X_1- 0.048X_2+ 0.041X_1X_2+ 0.051X_1^2- 0.029X_2^2$$

Where, Y is colour value a* and X_1 and X_2 are hydrogenated vegetable oil and lecithin

Table 4.60: ANOVA for colour value a* for pumpkin seed spread

SOURCE	DF	SS	MS	F-Value
Model	5	0.560000	0.11200	124.03*
Linear	2	0.521000	0.26050	287.92*
Quadratic	2	0.020173	0.01009	11.148*
Interactive	1	0.020000	0.02000	22.105*
Error	21	0.019000	0.00090	
Total	26	0.580000		

***, **, * Significant at 10, 5 and 1% level

Effect of hydrogenated vegetable oil and lecithin on colour value a* is shown in Figure 4.46. It was observed that colour value a* increased with hydrogenated vegetable oil and lecithin.

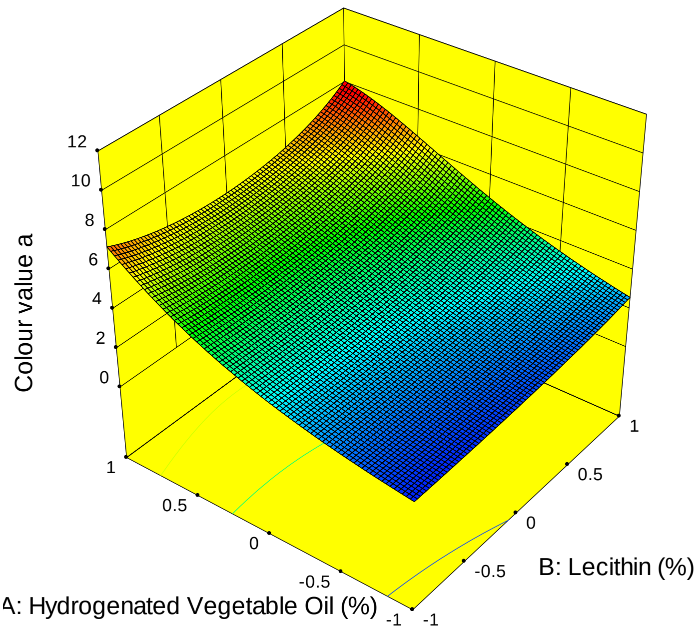

Fig.4.46: Effect of hydrogenated vegetable oil and lecithin on colour value a* for pumpkin seed spread

4.4.7 Effect of Hydrogenated Vegetable Oil and Lecithin on Colour Value b*

Effect of process variables on colour value b* is depicted in Table 4.53. The value ranged from 20.21 to 31.99. The maximum value (31.99) of colour value b* was observed for experimental combination of 10% hydrogenated vegetable oil and 0.5% lecithin. The minimum value (20.21) of colour value b* was observed for experimental combination of 20% hydrogenated vegetable oil and 1.5% lecithin. Table 4.61 shows the effect of hydrogenated vegetable oil and lecithin at linear, quadratic and interaction levels. It can be seen from the table that linear and quadratic levels were highly significant at 1%, followed by interactive which is significant at 10%, as their F_{cal} values 72.48, 7.88 and 2.50 were greater than F_{tab} (4.042 and 2.169) values.

Table 4.61: ANOVA for colour value b* for pumpkin seed spread

SOURCE	DF	SS	MS	F-Value
Model	5	205.43	41.086	32.64*
Linear	2	182.46	91.230	72.48*
Quadratic	2	19.83	9.9150	7.88*
Interactive	1	3.15	3.1500	2.50***
Error	21	26.43	1.2586	
Total	26	231.87		

***, **, * Significant at 10, 5 and 1% level

The regression analysis on colour value b* is given in Table 4.54. The model was found highly significant with F-value 32.64 which is greater than F_{tab} (4.042) at 1%. The values of R^2 and adj. R^2 were found to be 0.8860 and 0.8588 respectively. R^2 –adj value was observed to be relatively close to R^2 value, it ensures a relatively satisfactory adjustment of the quadratic model to the experimental data. The lack of fit was found non-significant for the model hence the model can be used to navigate the design. Hydrogenated vegetable oil and lecithin have significant effect ($p<0.01$) at linear level. At interactive level, there was non-significant effect of hydrogenated vegetable oil and lecithin. Hydrogenated vegetable oil was significant ($p<0.05$) at quadratic level. Second order predictive quadratic equation for colour value b* is given below

$$Y= 24.09- 3.12 X_1- 0.65X_2+ 0.51X_1X_2+ 1.80X_1^2+ 0.25X_2^2$$

Where, Y is colour value b* and X_1 and X_2 are hydrogenated vegetable oil and lecithin Effect of hydrogenated vegetable oil and lecithin on colour value b* is shown in Figures 4.47-4.48. It was observed that colour value b* decreased with increase in hydrogenated vegetable oil and slightly decreased with increase in lecithin.

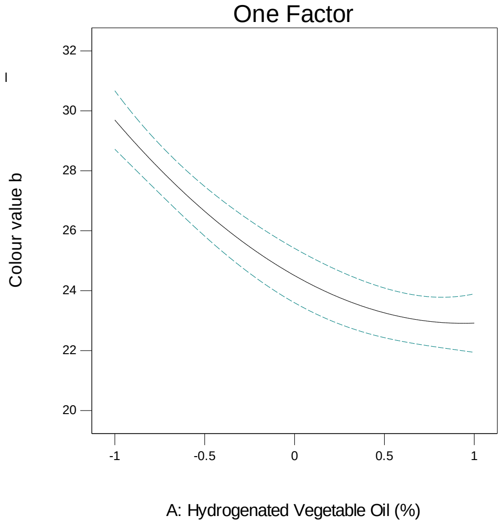

Fig. 4.47: Effect of hydrogenated vegetable oil on colour value b* for pumpkin seed spread

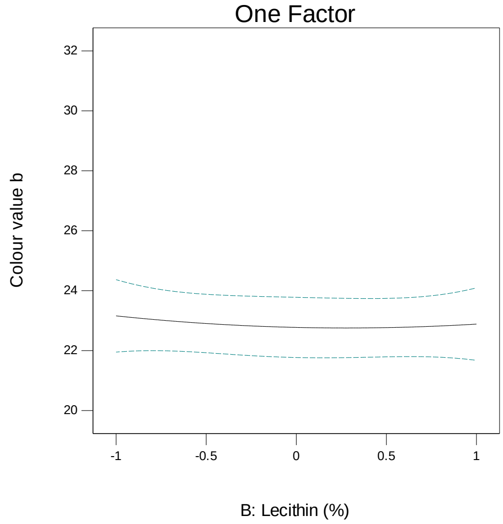

Fig.4.48: Effect of lecithin on colour value b* for pumpkin seed spread

4.4.8 Optimization of Pumpkin Seed Spread

Based on the results of sensory evaluation, texture profile analysis (hardness, cohesiveness, adhesiveness) and colour values (L*, a*, b*) using different levels of hydrogenated vegetable oil and lecithin, a product of good desirability was obtained. The main aim of the optimization technique was to determine the best possible combination of the factors that would result a highly acceptable product. Numerical optimization was carried out using Design Expert 10.0.1 statistical software, where all the responses were given similar importance. The criteria that uses to obtain this solution is depicted in Table 4.62. A single formulation with different levels of ingredients was obtained which is presented in Table 4.62.

Table 4.62: Conditions for optimization of variables for pumpkin seed spread

Name	Goal	Lower Limit	Upper Limit
A:Hydrogenated vegetable oil	is in range	-1	1
B:Lecithin	is in range	-1	1
Overall acceptability (OAA)	maximize	5.89	8.92
Hardness	minimize	143.231	291.42
Adhesiveness	maximize	-213.037	-104.153
Cohesiveness	minimize	0.402	0.692
Colour value L*	is in range	52	58
Colour value a*	is in range	4	8
Colour value b*	is in range	20	28

The experimental and predicted values of responses for the optimized pumpkin seed spread were almost similar. It can be observed that both the statistical design and experimental were in good accordance to optimize the product. The optimal combinations has good overall acceptability, textural characteristics and colour values of L*, a*, b* as compare to the control sample.

Table 4.63: Optimum levels of roasting conditions for pumpkin seed spread

Independent variables	Coded levels	Predicted levels	Actual levels	Control
Hydrogenated vegetable oil (X_1)	1	20	20	-
Lecithin (X_2)	-0.531	0.7345	0.7	-
Responses		**Values**		
Overall acceptability (1-9)		8.023	8.2	6.5
Hardness (g)		211.122	211.855	221.05
Adhesiveness (g/sec)		-157.709	-158.44	-104.14
Cohesiveness		0.524	0.520	0.691
Colour value L*		57.186	57.119	57.34
Colour value a*		6.481	6.508	6.452
Colour value b*		22.918	23.005	25.34

Desirability = 0.920

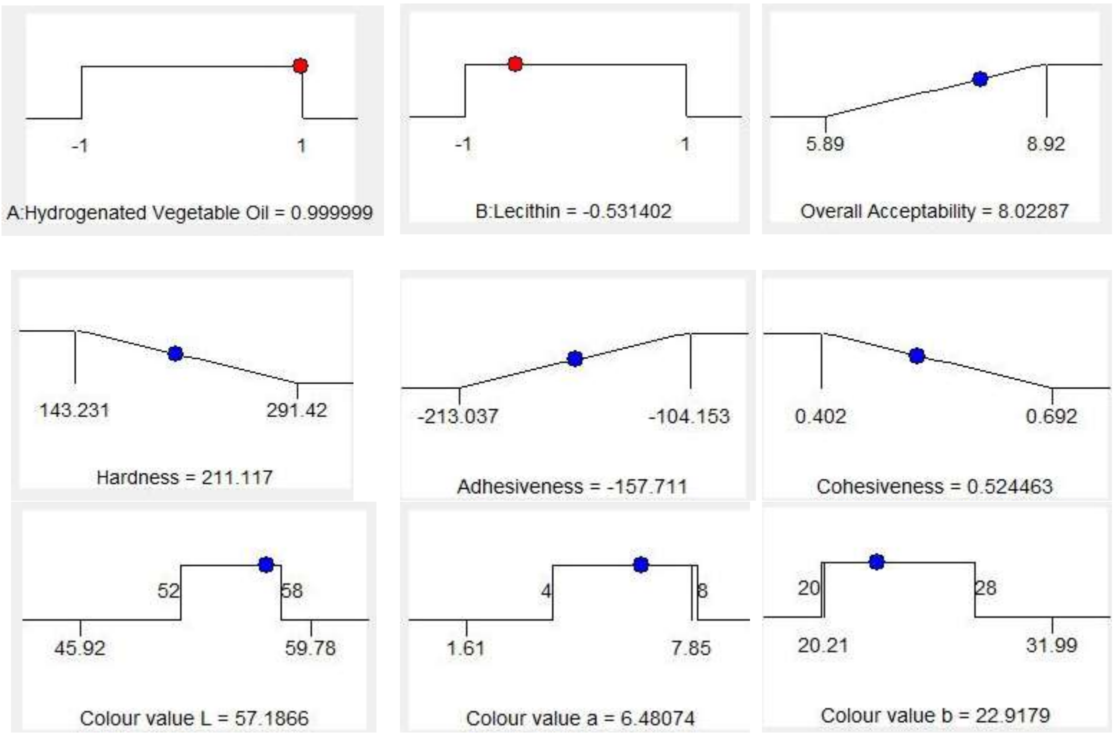

Fig. 4.49 Optimized conditions for pumpkin seed spread

The Optimized combination gives hydrogenated vegetable oil of 20 (20%), lecithin of 0.7345 (0.7%), overall acceptability of 8.2, hardness of 211.855g, adhesiveness of -158.44g, cohesiveness of 0.520g/sec and L*, a*, b* colour values of 57.119, 6.508, 23.005 with desirability factor of 0.920, which is presented in ramps (Fig. 4.49).

4.4.9 Evaluation of Optimized Pumpkin Seed Spread

4.4.9.1 Physicochemical analysis

The chemical analysis of optimized pumpkin seed spread was carried out as per the methods explained in the previous chapter and the results are presented in Tables 4.64.

Plate. 4.2: Optimized pumpkin seed spread

The proximate composition of pumpkin seed spread was found to be 0.38 ± 0.04% moisture, 31.96 ± 1.14% crude protein, 42.45 ± 1.24 crude fat, 4.18 ± 0.02% ash, 2.37 ± 0.05% crude fibre and 19.04% total carbohydrate content. The results obtained were lower in moisture content and higher in crude protein content than the peanut spread fortified with soy flour by Mazaheri-Tehrani *et al.,* (2009).

The values of fat content was found to be slightly lower than the value reported by Dimic *et al*., 2013 for commercial fat oilseeds spread (sunflower, pumpkin, sesame, peanut and walnut).

Ash content was found within the range of values reported by Mazaheri-Tehrani *et al.,* (2009) for oilseed spreads fortified with soy flour. Total carbohydrates values was found to be in the range of 10.50 ± 0.8 to 28.50 ± 0.3 g/100g reported by Abd-Elsattar *et al*., (2016) of commercial peanut butter and soy butters.

Table 4.64: Chemical analysis of optimized pumpkin seed spread

Parameters	Mean value±S.D.
Moisture, (%)	0.38 ± 0.04
Crude protein, (%)	31.96± 1.14
Crude fat, (%)	42.45± 1.24
Ash, (%)	4.18± 0.02
Crude fibre, (%)	2.37± 0.05
Total carbohydrate, (%)	19.04
Peroxide value, (meq/kg oil)	0.4 ± 0.05
Viscosity, (Pa.s)	3.558
Particle size	40.122
Reducing sugar	14.55
Non-reducing sugar	11.55
Total sugar	25.9
pH	6.4
Free fatty acid (% oleic acid)	0.284

The peroxide value, viscosity, pH and free fatty acids of optimized pumpkin seed spread are found to be 0.4±0.05 meq/kg oil, 3.558 Pa-s at 24.3ºC, 6.4 and 0.284 (% oleic acid) respectively. pH value was found to be similar to the values reported by Lima *et al*., (2012). Free fatty acid value was similar with the values given by Habib *et al*., (2015). The product showed low FFA and low peroxide value which again indicated that product can be stored for longer duration without deterioration. The results are in good accordance reported by Borchani *et al*., (2010).

The reducing sugar, non-reducing sugar and total sugar are found to be 14.55%, 11.55% and 25.90% respectively for the optimized pumpkin seed spread. The sugar content was found to be in accordance with the values reported by Mazaheri-Tehrani *et al*., (2009) for peanut spreads fortified with soy flour. Particle size of pumpkin seed spread was found as 40.122 microns.

4.4.9.2 Sensory evaluation

Sensory attributes of pumpkin seed spread in terms of colour and appearance, flavor, body and texture and overall acceptability was carried out as per the methods explained in previous chapter. It was found to be 8.0, 8.2, 8.5 and 8.2 scores for colour and appearance, flavor, body and texture and overall acceptability respectively. The results of sensory scores shows that optimized pumpkin seed spread has good acceptability because the sensory scores for all the sensory attribute were above 6.0.

4.4.9.3 Colour

The colour values of the pumpkin seed spread was determined using Tintometre (Lovibond, Model RT850i) as explained in previous chapter. The attributes of colour, the L* value is a measure of lightness, ranging from 0 (black) to 100 (white), the a* value ranges from -100 (greenness) to +100 (redness) and the b* value ranges from -100 (being blue) to +100 (yellowness). The colour values of L*, a* and b* were found to be 57.119, 6.508 and 23.005. The colour values were found to be in range with the values reported by Mijeni, (2017) for sesame fat spread.

4.4.9.4 Texture profile analysis

The textural properties viz. hardness, adhesiveness and cohesiveness for the optimized pumpkin seed spread was found to be 211.855 g, -175.44 g/sec and 0.520 respectively. The textural properties obtained were found to be in range with the values reported by Mijeni, (2017) for sesame fat spread.

4.4.9.5 Microbiological analysis

Pumpkin seed spread was evaluated for standard plate count, coliforms count and yeast and mold count by using the methods described in previous. It was observed that coliforms, yeast and mold counts were absent and the standard plate count was found to be 2 x 10^3 cfu/g indicating that the product was safe and has good quality.

4.5 STANDARDIZATION OF PROCESS VARIABLES FOR PREPARATION OF DEFATTED PUMPKIN SEED FLOUR

Pumpkin seed kernels were grouped into three parts, unroasted, roasted and sprouted for the preparation of defatted pumpkin seed flour. Roasting of pumpkin seed kernels was done using the optimized halogen oven as discussed in section 4.2. Sprouting and defatting of pumpkin seed was done using seed germinator and soxhlet apparatus as per the methods explained in previous chapter. The effect of pumpkin seeds viz. unroasted, roasted and sprouted pumpkin seed on the responses i,e. protein content, fat content and water absorption capacity (WAC) were determined and statistically analysed. Experimental data is shown in Table 4.65.

4.5.1 Effect of Types of Pumpkin Seeds on Protein Content

Effect of process variables on protein content is depicted in Table 4.65. The values ranged from 65.89% to 66.91%. The maximum value (66.91%) of protein content was observed

Table 4.65: Variables and responses of defatted pumpkin seed flour

Expt. No	Type of pumpkin seed	Protein content (%)	Fat content (%)	WAC (%)
1	3 (SPSF)	66.91	3.32	19.97
2	1 (UPSF)	65.89**	4.32	18.11
3	3 (SPSF)	66.92*	2.92	19.81
4	2 (RPSF)	66.21	5.62*	18.99
5	3 (SPSF)	66.81	2.19	20.05
6	1 (UPSF)	66.08	4.11	18.06**
7	2 (RPSF)	66.27	5.39	18.69
8	2 (RPSF)	66.47	5.22	18.86
9	1 (UPSF)	66.10	4.62	18.23
10	2 (RPSF)	66.13	5.34	18.97
11	3 (SPSF)	66.91	2.14**	20.12*
12	1 (UPSF)	65.89**	4.65	18.34

* Maximum, ** Minimum, UPSF= Unroasted defatted pumpkin seed flour, RPSF= Roasted defatted pumpkin seed flour, SPSF= Sprouted defatted pumpkin seed flour

Table 4.66: Regression analysis of defatted pumpkin seed flour

Cons.	Protein content (%)		Fat content (%)		WAC (%)	
	Coeff.	P (%)	Coeff.	P (%)	Coeff.	P (%)
	66.38	0.01*	4.15	3.60**	19.02	0.01*
X	0.45	0.01*	-0.88	3.60**	0.90	0.01*
R^2	89.58		56.98		95.97	
Adj.R^2	88.54		55.66		95.56	
F	85.96 (1% 10.044)		15.86 (1% 10.044)		237.89 (1% 10.044)	
LOF	NS		NS		NS	
*, ** and *** Significant at 1, 5 and 10% level of significance respectively, Coeff. = Coefficient, NS= Non-significant, Cons.= Constant, LOF= Lack of Fit, C.V.= Coefficient of Variance, Std. dev= Standard deviation, X= Types of pumpkin seed (unroasted, roasted and sprouted)						

for experiment number 3 (sprouted defatted pumpkin seed flour) and the minimum value (65.89%) was observed for experiment number 2 and 12 (unroasted defatted pumpkin seed flour). Table 4.67 shows the effect of type of pumpkin seed at linear level. It can be seen from the table that linear level is highly significant at 1%, as their F_{cal} value 84.74 was greater than F_{tab} (10.044).

Table 4.67: ANOVA for protein content for defatted pumpkin seed flour

SOURCE	DF	SS	MS	F-Value
Model	1	1.61	1.61	85.96*
Linear	1	1.61	1.61	84.74*
Error	10	0.19	0.019	
Total	11	1.80		

***, **, * Significant at 10, 5 and 1% level of significance respectively
$F_{tab\ (1,\ 10)}$ = 10.044 (1%); $F_{tab\ (1,\ 10)}$ = 4.965 (5%); $F_{tab\ (1,\ 10)}$ = 3.285(10%) [Model & Linear]

The regression analysis on protein content is given in Table 4.66. The model was found highly significant with F-value 85.54 which is greater than F_{tab} (10.044) at 1%. The values of R^2 and adj. R^2 were found to be 0.8958 and 0.8854 respectively. R^2 -adj value was observed to be relatively close to R^2 value, it ensures a relatively satisfactory adjustment of the quadratic model to the experimental data. The lack of fit was found non-significant for the model hence the model can be used to navigate the design. The effect of type of pumpkin seed showed significant effect ($p<0.01$) on protein content. Second order predictive linear equation for protein content is given below

$Y= 66.38+ 0.45X$

Where, Y is protein content and X is type of pumpkin seed

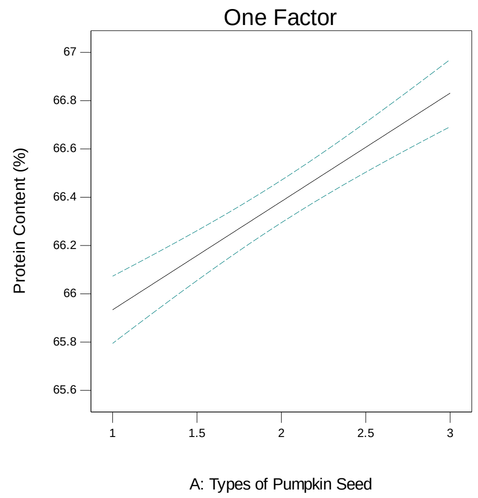

Fig. 4.50: Effect of types of pumpkin seed on protein content

Influence of type of pumpkin seed on protein content is shown in Figure 4.50. It was observed that protein content increased from unroasted, roasted and sprouted defatted pumpkin seed flour. The values of protein content observed for the defatted pumpkin seed flour (65.89-66.92%) are within the ranges reported for the defatted meals from Mexican (*Cucurbita pepo*) pumpkin seeds by Rodriguez-Miranda *et al.* (2013) and Oshodi and Fagbemi (1992).

Fagbemi (2007) reported that processing showed significant effects on the levels of nutrients in fluted defatted pumpkin seed flours. The author also found the highest protein content in germinated defatted pumpkin seed flour as compared to roasted and raw defatted pumpkin seed flour. Similar results was also reported by Giami (2003) that germinated defatted pumpkin seed flour had higher protein content as compared to ungerminated defatted pumpkin seed flour. Sprouting enhanced protein quality of the defatted pumpkin seed flour. Pumpkin seed can be used as a potential source of nutrient in human diet if adequately processed.

4.5.2 Effect of Types of Pumpkin Seeds on Fat Content

Effect of process variables on fat content is shown in Table 4.65. The values ranged from 2.14% to 5.62%. The maximum value (5.62%) of fat content was observed for the experimental number 4 (roasted defatted pumpkin seed flour) and the minimum value (2.14%) was observed for the experiment number 11 (sprouted defatted pumpkin seed flour). Table 4.68 shows the effect of type of pumpkin seed at linear level. It can be seen from the table that linear level is highly significant at 10%, as their F_{cal} value 3.699 was greater than F_{tab} (3.285) value.

Table 4.68: ANOVA for fat content for defatted pumpkin seed flour

SOURCE	DF	SS	MS	F-Value
Model	1	6.20	6.20	15.86**
Linear	1	6.20	6.20	3.699**
Error	10	10.57	1.676	
Total	11	16.76		

***, **, * Significant at 10, 5 and 1% level of significance respectively
$F_{tab\ (1,\ 10)}$ = 10.044 (1%); $F_{tab\ (1,\ 10)}$ = 4.965 (5%); $F_{tab\ (1,\ 10)}$ = 3.285(10%) [Model & Linear]

The regression analysis on fat content is given in Table 4.66. The model was found highly significant with F-value 15.86 which is greater than F_{tab} (10.044) at 1%. The value of R^2 and adj. R^2 were found to be 0.5698 and 0.5066 respectively. R^2 -adj (0.5066) value was observed to be relatively close to R^2 (0.5698) value, it ensures a relatively satisfactory adjustment of the quadratic model to the experimental data. The lack of fit was found non-significant for the model hence the model can be used to navigate the design. The effect of type of pumpkin seed has significant effect ($p<0.05$) at linear level. Second order predictive linear equation for fat content is given below

$$Y= 4.15- 0.88X$$

Where, Y is fat content and X is type of pumpkin seed

Influence of type of pumpkin seed on fat content is shown in Figure 4.51. It was observed that roasted defatted pumpkin seed flour has higher fat content, as compared to unroasted and sprouted defatted pumpkin seed flour. The results obtained were in accordance with the findings of Fagbemi, (2007), who reported that the fat content, which increased from roasted, unroasted and germinated defatted pumpkin seed flour. A lesser fat content of bread fortified with germinated pumpkin seed meal as compared to the bread prepared with fortified raw and roasted pumpkin seed meal was reported by El-Soukkary (2001).

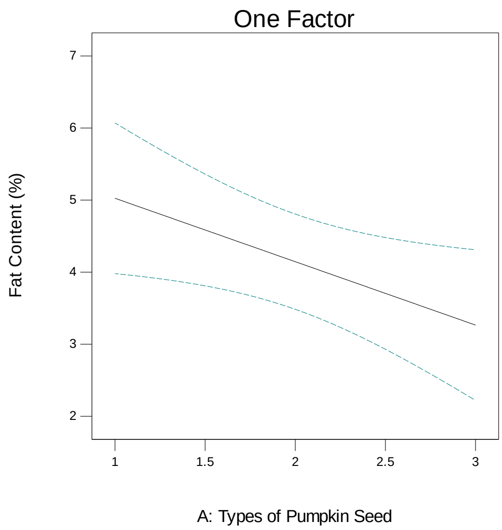

Fig. 4.51: Effect of types of pumpkin seed on fat content

4.5.3 Effect of Types of Pumpkin Seeds on Water Absorption Capacity

Effect of process variables on water absorption capacity is shown in Table 4.66. The values ranged from 18.06% to 20.12%. The maximum value (20.12%) of water absorption capacity was observed for experiment number 11 (sprouted defatted pumpkin seed flour) and the minimum value (18.06%) was observed for experiment number 6 (unroasted defatted pumpkin seed flour). Table 4.69 shows the effect of type of pumpkin seed at linear level. It can be seen from the table that linear level is significant at 1% level, as their F_{cal} value 241.11 was greater than F_{tab} (10.044) value.

The regression analysis on water absorption capacity is given in Table 4.66. The model was found highly significant with F-value 237.89 which is greater than F_{tab} (10.044) at 1%. The values of R^2 and adj. R^2 were found to be 0.9597 and 0.9556 respectively. R^2 -adj (0.9556) value was observed to be relatively close to R^2 (0.9597) value, it ensures a relatively satisfactory adjustment of the quadratic model to the experimental data. The lack of fit was found non-significant for the model hence the model can be used to navigate the design. The effect of type of pumpkin seed has significant effect ($p<0.01$) at linear level. Second order predictive linear equation for water absorption capacity is given below

Y= 19.02+ 0.90X

Where, Y is water absorption capacity and X is type of pumpkin seed

Table 4.69: ANOVA for water absorption capacity for defatted pumpkin seed flour

SOURCE	DF	SS	MS	F-Value
Model	1	6.51	6.51	237.89*
Linear	1	6.51	6.51	241.11*
Error	10	0.27	0.027	
Total	11	6.78		

***, **, * Significant at 10, 5 and 1% level of significance respectively
$F_{tab\ (1,\ 10)}$ = 10.044 (1%); $F_{tab\ (1,\ 10)}$ = 4.965 (5%); $F_{tab\ (1,\ 10)}$ = 3.285(10%) [Model & Linear]

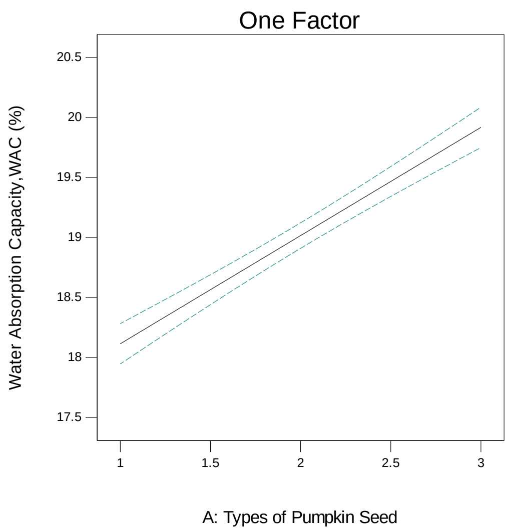

Fig. 4.52: Effect of types of pumpkin seed on water absorption capacity

Influence of type of pumpkin seed on water absorption capacity is shown in Figure 4.52. It was observed that defatted roasted defatted pumpkin seed flour has higher water absorption capacity as compared to unroasted and sprouted defatted pumpkin seed flour. Similar results were also reported by Hamed *et al.,* (2008). The increase in water absorption capacity could be caused by the dissociation of proteins that might occur as a result of heating and denaturation (Abbey and Ibeh, 1987).

4.5.4 Optimization of Defatted pumpkin seed flour

Numerical optimization was carried out using the Design Expert 10.0.1 statistical software, where all the responses were given similar importance. Based on the results of responses of protein content, fat content and water absorption capacity (WAC) of the defatted pumpkin seed flour prepared from unroasted, roasted and sprouted pumpkin seeds, a product of good desirability was obtained for evaluation. The main aim of the optimization technique was to determine the best possible combination of the factor that would result a highly acceptable product. The criteria that uses to obtain this solution is depicted in Table 4.70. A single formulation obtained is presented in Table 4.71.

Table 4.70: Conditions for optimization of variables for defatted pumpkin seed flour

Name	Goal	Lower limit	Upper limit
X: Types of pumpkin seeds	is in range	1	3
Protein content (%)	maximize	65.89	66.92
Fat content (%)	minimize	2.14	5.62
Water absorption capacity, WAC (%)	maximize	18.06	20.12

The experimental and predicted values of the responses for the optimized defatted pumpkin seed flour were almost similar. It can be observed that both the statistical design and experiments were in good accordance to optimize the product.

Table 4.71: Optimum levels of defatted pumpkin seed flour

Independent variables	Coded levels	Predicted levels	Actual levels
X: Types of pumpkin seeds	3	SPSF	SPSF
Responses		**Values**	**Values**
Protein content (%)		66.8312	66.91
Fat content (%)		3.26583	3.25
Water absorption capacity, WAC (%)		19.918	20.50

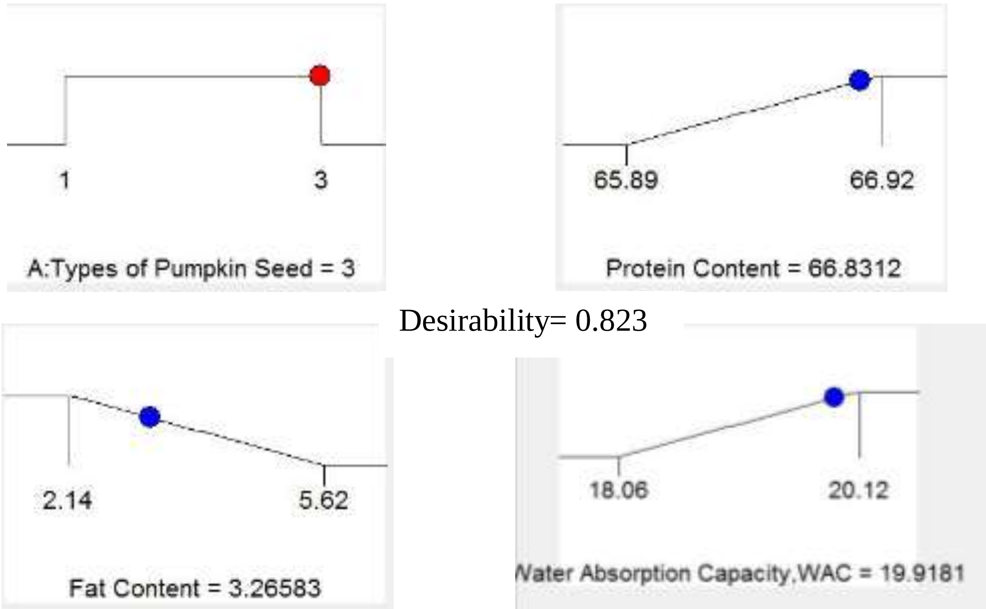

Fig 4.53: Optimized conditions for defatted pumpkin seed flour

The optimized condition gives the type of pumpkin seed of 3 (sprouted pumpkin seed), protein content of 66.8312, fat content of 3.26583 and water absorption capacity of 19.9181% with desirability factor of 0.823, which is presented in ramps (Figure 4.53).

4.5.5 Evaluation of Defatted pumpkin seed flour

Plate 4.3: Optimized defatted pumpkin seed flour

4.5.5.1 Physiochemical analysis

The chemical analysis, mineral content, thermal properties, microbial analysis of optimized defatted pumpkin seed flour was carried out as per the methods explained in previous chapter and the results are presented in Tables 4.72 and 4.73.

The moisture content, crude protein, crude fat, ash content, crude fibre, total carbohydrate of the optimized defatted pumpkin seed flour were found to be 1.84 ± 1.05%, 66.91 ± 0.81%, 3.32 ± 1.23%, 8.83 ± 0.23%, 6.92 ± 0.05% and 14.42± 1.12% respectively. The moisture, crude protein, ash and crude fibre content of the optimized sample was found to be in accordance with the results reported by Fagbemi, (2007). Crude protein was found to be slightly lower than the value reported by Giami, (2003). The values of total carbohydrate content was lower and crude fibre was higher as compared to the findings of Rodriguez-Miranda *et al.,* (2013).

Table 4.72. Chemical analysis of optimized defatted pumpkin seed flour

Parameters	**Mean values ±S.D**
Moisture, (%)	1.84 ± 1.05
Crude protein, %	66.91 ± 0.81
Crude fat, %	3.25 ± 1.23
Ash, %	8.83 ± 0.23
Crude fibre, %	6.92 ± 0.05
Total carbohydrate, %	14.42± 1.12
Phytic acid, %	0.589±0.50
In-vitro protein digestibility, %	59.32± 0.15
Particle size (microns)	43.758
Water absorption capacity, %	20.5 ± 0.12
Bulk density, g/ml	1.74 ± 1.02
Peroxide value, meq/kg oil	0.23
Free fatty acid, % oleic acid	0.15
Colour value L*	95.8 ± 0.18
Colour value a*	-2.5 ± 0.52
Colour value b*	12 ± 0.18

Phytic acid content in optimized defatted pumpkin seed flour was less and this might be due to the sprouting process of pumpkin seed prior to defatting. Decrease in phytic acid content due to germination process was reported by Enujiugha *et al.*, (2003) in African oil bean seed flour, Megat Rusydi and Azrina (2012) in soy bean and peanut flour and Afam Anene and Anyaegbu (2016) in mungbean flour. Phytic acid values were found to be marginally higher than the value reported by Atuonwu and Akobundu (2010).

The In-vitro protein digestibility of optimized defatted pumpkin seed flour was found to be (59.32± 0.15) %. The value obtained was lower than reported by El-Adawy and Taha (2001) for pumpkin and watermelon kernel flour and the difference may be due to nature of the protein and anti-nutritional factors in the seed. The result were in agreement with those reported by Giami and Wackuku (1997) who found that the processing (include roasting) of pulses significantly improved the IVPD.

Particle size of optimized defatted pumpkin seed flour was analysed by laserscattering particle size distribution analyzer (Sympatec, Helos BF, Germany) and size was found to be 43.758 microns.

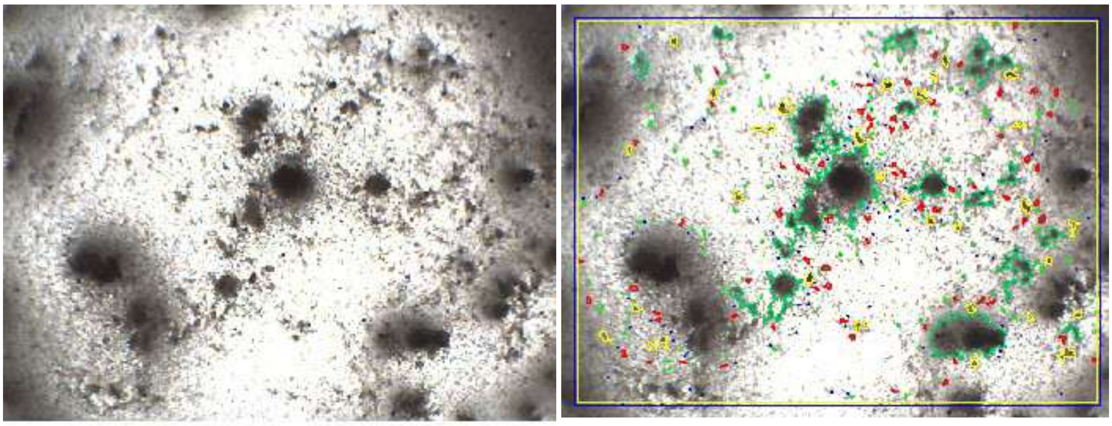

Plate 4.4: Particle size analysis of optimized defatted pumpkin seed flour

The value observed for bulk density (1.74 ± 1.02) g/ml was lower than the range of bulk density values (5.25 to 7.47 g/ml) reported by Adeleke and Odedeji (2010) for wheat and sweet potato flour blends.

Water absorption capacity of optimized defatted pumpkin seed flour was found to be 20.5±0.12 %, which was found to be lower than that (25%) stated by El-Adawy and Taha (2001).

Peroxide value and free fatty acid content was found to be 0.23 meq/kg oil and 0.15 % oleic acid respectively. The colour values of L*(95.8 ± 0.18), a* (-2.5 ± 0.52) and b* (12 ± 0.18) were found to be in the similar range which were reported by Rodriguez-Miranda *et al.*, (2013) for defatted pumpkin seed meal as 96± 0.81, -2.6 ± 0.00 and 12 ± 0.05 as L*, a* and b* of colour values.

4.5.5.1. Mineral content

Mineral content of optimized defatted pumpkin seed flour is shown in Table 4.73. The most abundant mineral were found to be phosphorus (1983 mg/g), magnesium (769.1 mg/g) and potassium (758.3 mg/g) while the other minerals cobalt (1.0 mg/g) and copper (3.6 mg/g) were present in trace levels. The minerals phosphorus, magnesium, potassium, iron and zinc were higher than the sesame seed flour (Makinde and Akinoso, 2014). Lazos, (1992) also reported that phosphorus, potassium, magnesium were the most abundant source of mineral in defatted pumpkin seed flour.

Table 4.73. Mineral content of optimized defatted pumpkin seed flour

Sl.no.	Minerals	Mean value (mg/100g)
1	Iron (Fe)	21.8
2	Manganese (Mn)	11.4
3	Zinc (Zn)	20.7
4	Copper (Cu)	3.6
5	Phosphorus (P)	1983.7
6	Potassium (K)	758.3
7	Calcium (Ca)	55.8
8	Magnesium (Mg)	769.1
9	Sodium (Na)	15.7
10	Cobalt (Co)	1.0

4.5.5.2 Thermal properties

The thermal properties of optimized defatted pumpkin seed flour was determined by using the differential scanning calorimetry (DSC) as explained in previous chapter. Thermal properties graph is shown in appendix IV (b). The thermal properties viz. onset temperature (T_o), peak temperature (T_p) and enthalpy, (ΔH) of optimized defatted pumpkin seed flour were found to be 104.04^{o}C, 66.31^{o}C and 116.5383 J/g respectively. The present findings are in accordance with the results reported by Rodriguez-Miranda *et al*., (2013).

4.5.5.3 Microbiological analysis

Microbiological analysis of defatted pumpkin seed flour was carried out for standard plate count, coliform count and yeast and mold count to evaluate the quality and safety of the product. It was observed that coliforms and yeast and mold count were not found and standard plate count was found to be 10 x 10^2 cfu/g.

4.6 SHELF LIFE EVALUATION OF VALUE ADDED PRODUCTS FROM PUMPKIN SEEDS

Quality changes are likely to take place during storage of food products and it is necessary to evaluate the physicochemical characteristics of value added pumpkin seed products during storage. The storage conditions and the results obtained for value added products from pumpkin seeds were evaluated at regular intervals.

4.6.1 Shelf Life Evaluation of Roasted salted pumpkin seed kernels

Roasted salted pumpkin seed kernels was prepared as per the optimized conditions of moisture conditioning and salt concentration, packed in aluminium laminated pouches, stored and evaluated for storage studies at ambient conditions (30±2°C). Samples were taken at every 15 days and analysed for moisture, peroxide value, sensory evaluation and microbial characteristics for a period of three months.

4.6.1.1 Physiochemical characteristics during storage

Physicochemical analysis of roasted salted pumpkin seed kernels in terms of moisture (%) and peroxide value (meq/kg oil) was carried out as per the methods explained in previous chapter and the results are presented in Table 4.74.

The moisture content in the product was found to increase during storage (Figure 4.97). The mean values showed that there was a marginal increase in moisture content (2.45±0.06% to 2.99±0.01%) during storage (Figure 4.54).

The results showed that during three months of the storage period, the peroxide value was significantly ($p<0.05$) increased from 0.40±0.05 meq/kg oil to 0.61±0.04 meq/kg oil (Figure 4.55). Lesser peroxide value implies lesser chances of rancidity of the product. The peroxide value was however within the range of acceptability of product.

4.6.1.2 Sensory attributes of roasted salted pumpkin seed kernels during storage

Sensory characteristics of the product in terms of colour and appearance, taste, odour and overall acceptability was carried out as per the methods explained in previous chapter and the results are presented in Table 4.74. Effect of storage on sensory attributes

Table 4.74: Changes in physicochemical characteristics and sensory attributes of roasted salted pumpkin seed kernels during storage

Parameters	Storage period (days)							SEm	CD (0.05)	CV (%)
	0	15	30	45	60	75	90			
Moisture,%	2.45±0.06	2.54±0.16	2.57±0.04	2.73±0.21	2.76±0.01	2.89±0.10	2.99±0.01	0.05	0.14	3.11
Peroxide value, meq/kg oil	0.40±0.05	0.50±0.07	0.53±0.05	0.55±0.06	0.59±0.04	0.59±0.03	0.61±0.04	0.03	0.08	8.38
Colour and appearance	8.77±0.25	8.67±0.21	8.57±0.21	8.33±0.21	8.13±0.15	8.13±0.25	7.93±0.06	0.11	0.35	2.37
Taste	8.51±0.14	8.47±0.06	8.15±0.30	7.74±0.14	7.52±0.04	7.22±0.52	6.96±0.28	0.16	0.49	3.68
Odour	8.45±0.13	8.16±0.51	7.80±0.23	7.57±0.02	7.52±0.04	7.22±0.52	6.92±0.24	0.16	0.49	3.68
Overall acceptability	8.76±0.16	8.53±0.48	8.33±0.42	8.28±0.32	7.92±0.04	7.75±0.12	7.42±0.53	0.18	0.56	3.93

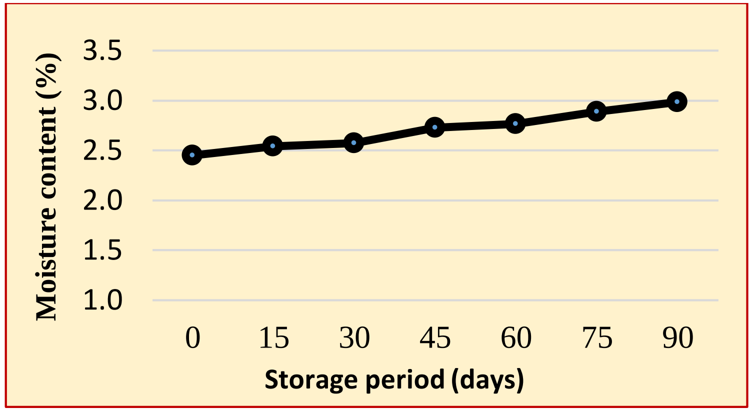

Fig. 4.54: Changes in moisture content of roasted salted pumpkin seed kernels during storage

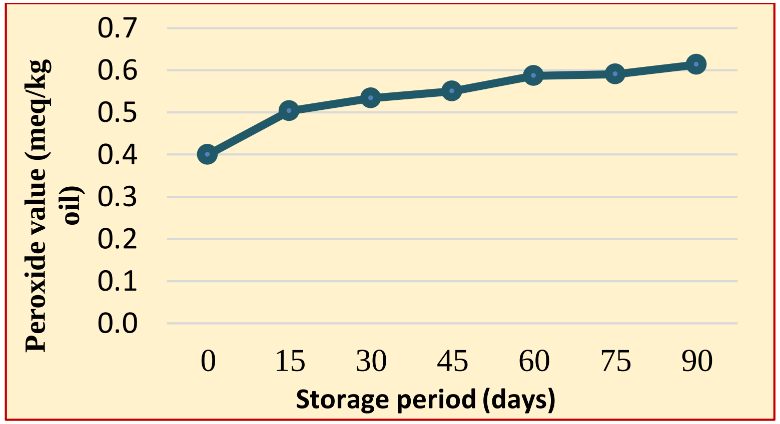

Fig. 4.55: Changes in peroxide value of roasted salted pumpkin seed kernels during storage

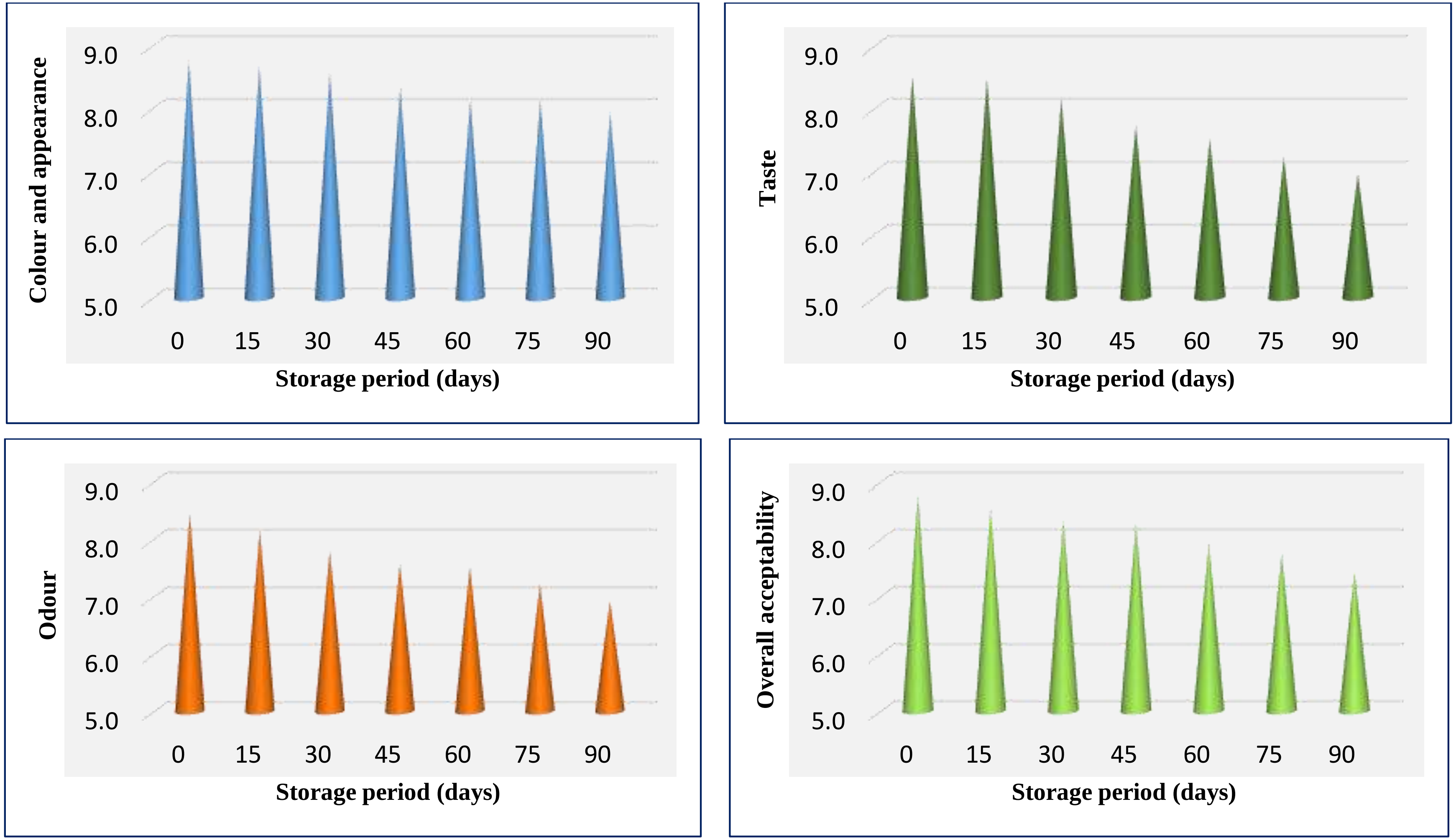

Fig. 4.56: Changes in sensory attributes of roasted salted pumpkin seed kernels during storage

for roasted salted pumpkin seed kernels stored in aluminium laminated pouches are shown in Figure 4.56. It was observed that the scores for sensory parameters dropped marginally throughout the storage. The results indicated that there was a gradual decrease in colour and appearance (8.77±0.25 to 7.93±0.06), taste (8.51±0.14 to 6.96±0.28), odour (8.45±0.13 to 6.92±0.24) and overall acceptability (8.76±0.16 to 7.42±0.53) respectively. However, they remained close to the acceptable level even at the end of storage period of 3 months.

4.6.1.3 Microbiological Evaluation of roasted salted pumpkin seed kernels during storage

Microbial counts of stored roasted salted pumpkin seed kernels were carried out as per the methods explained in previous chapter. A marginal increase in standard plate count was noticed. The fresh sample had count of 2 x 10^3 log cfu/g and at 90 days, the count was 45 x 10^3 log cfu/g respectively. Coliforms and yeast and molds count were absent throughout the storage period. The counts indicates the product was safe throughout the storage period.

4.6.2 Shelf Life Evaluation of Pumpkin Seed Spread

Pumpkin seed spread was prepared as per the optimized method and packed in glass jar, stored and evaluated for storage studies at ambient conditions (30±2°C) as well as refrigerated conditions (5±2°C). Samples were taken at every 15 days and analysed for free fatty acid, pH, texture profile analysis, sensory evaluation and microbial characteristics for a period of three months.

4.6.2.1 Physiochemical characteristics during storage

Physicochemical analysis of pumpkin seed spread in terms of free fatty acid (% oleic acid), pH, texture profile analysis (hardness, adhesiveness, and cohesiveness) were carried out as per the methods explained in previous chapter and the results are presented in Tables 4.75 and 4.76.

Changes in FFA (% oleic acid) levels of pumpkin seed spread during storage are presented in Figures 4.54 and 4.59 for ambient (30±2ºC) and refrigerated (5±2ºC) conditions. Marginal increase in FFA was observed for both the storage conditions (Table 4.88). The initial (0 day) FFA was 0.28±0.003 % and 0.28±0.003% oleic acid and after three months (90 day) of storage period was 0.34±0.003% and 0.33±0.002%

oleic acid for ambient (30±2ºC) and refrigerated (5±2ºC) conditions respectively. However, the product was well within the range of acceptable FFA even after 90 days storage.

The pH value in the product was found to decrease during storage at both the storage temperatures (Figures 4.57 and 4.62). The results showed that during three months of the storage period, the pH value was marginally decreased from 6.42±0.03 to 6.20±0.10 and from 6.42±0.03 to 6.12±0.11 for ambient and refrigerated conditions during storage (Tables 4.58 and 4.63). We can predict that pumpkin seed spread can be stored safely up to three months.

The results observed for changes in textural characteristics viz. hardness, adhesiveness and cohesiveness were depicted in Tables 4.75 and 4.76.

From the analytical data it was noted that there were minor variations during both storage temperatures. We can predict that pumpkin seed spread can be stored without physicochemical characteristics, textural variation up to three months of storage.

Sensory attribute of the product in terms of colour and appearance, taste, odour and overall acceptability was carried out as per the methods explained in previous chapter. Slight variation in sensory attributes were found during storage at both the temperatures (Table 4.67 and 4.68). It was observed that almost all the scores for sensory parameters dropped marginally throughout the duration of storage at both temperatures. The results indicated that there was a gradual decrease in colour and appearance (8.37 to 7.93), flavor (8.53 to 7.01), odour (8.53 to 6.98) and overall acceptability (8.80 to 7.42) respectively for the product stored at ambient condition, while the corresponding values for the product stored in refrigerated condition were 8.77 to 8.00, 8.51 to 7.17, 8.45 to 6.98 and 8.76 to 7.46 respectively. It was observed that the product remained close to the acceptable level even at the end of storage period of 3 months for both temperatures.

Microbial counts of stored pumpkin seed spread were carried out as per the methods explained in previous chapter. Pumpkin seed spread stored at 5±2˚C and 30±2˚C was analysed for microbial evaluation at 15 days interval upto three months and the results obtained are tabulated in Table 4.76.

Table 4.75: Changes in physicochemical characteristics of pumpkin seed spread during storage (30±2°C)

Parameters	Storage period (days)							SEm	CD (0.05)	CV (%)
	0	15	30	45	60	75	90			
Free fatty acid,%	0.28±0.003	0.29±0.001	0.30±0.001	0.31±0.01	0.33±0.002	0.33±0.01	0.34±0.003	0.002	0.007	1.26
pH	6.42±0.03	6.40±0.001	6.33±0.03	6.28±0.10	6.24±0.06	6.21±0.09	6.20±0.01	0.04	0.12	1.08
Hardness, g	211.93±0.10	210.23±0.32	208.48±0.72	200.30±0.17	195.63±0.12	192.28±0.16	190.25±0.10	0.14	0.42	0.12
Adhesiveness, g/sec	-175.37±0.55	-174.33±0.42	-174.27±0.25	-174.17±0.21	-174±0.26	-173.93±0.64	-173.5±0.70	0.25	0.76	0.25
Cohesiveness	0.53±0.01	0.54±0.01	0.54±0.01	0.57±0.03	0.57±0.05	0.58±0.05	0.58±0.07	0.02	0.05	5.25

Table 4.76: Changes in physicochemical characteristics of pumpkin seed spread during storage (5±2°C)

Parameters	Storage period (days)							SEm	CD (0.05)	CV (%)
	0	15	30	45	60	75	90			
Free fatty acid,%	0.28±0.003	0.29±0.006	0.29±0.012	0.31±0.006	0.32±0.004	0.32±0.010	0.33±0.002	0.003	0.008	1.50
pH	6.42±0.03	6.38±0.03	6.28±0.08	6.24±0.05	6.18±0.06	6.14±0.12	6.12±0.11	0.04	0.11	1.01
Hardness, g	211.93±0.10	210.57±0.90	209.48±0.72	200.63±0.62	195.36±0.36	192.38±0.26	190.38±0.32	0.27	0.82	0.23
Adhesiveness, g/sec	-175.37±0.55	-174.47±0.45	-174.37±0.21	-174.17±0.21	-174.00±0.26	-174.00±0.53	-173.90±0.66	0.21	0.63	0.21
Cohesiveness	0.53±0.01	0.54±0.001	0.54±0.001	0.57±0.03	0.56±0.03	0.57±0.04	0.57±0.07	0.02	0.05	4.70

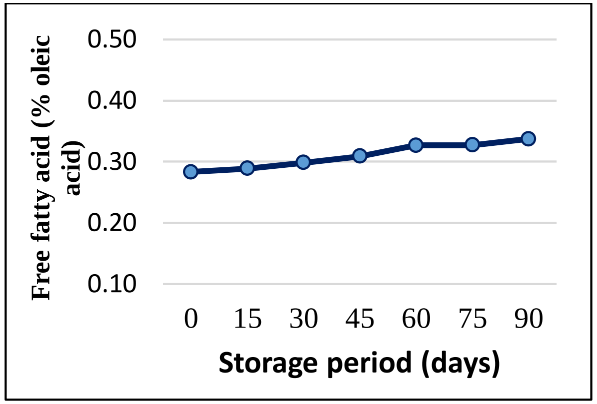

Fig. 4.57: Changes in free fatty acid of pumpkin seed spread during storage (30±2˚C)

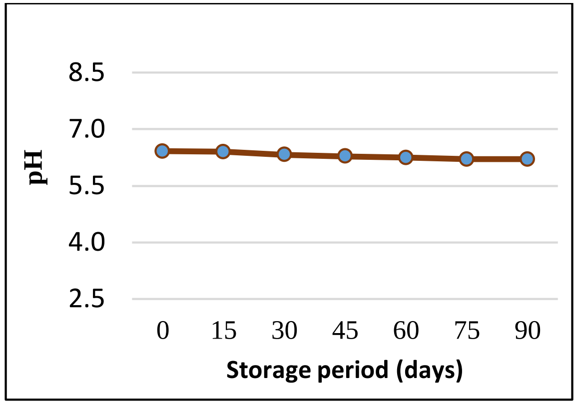

Fig. 4.58: Changes in pH of pumpkin seed spread during storage (30±2˚C)

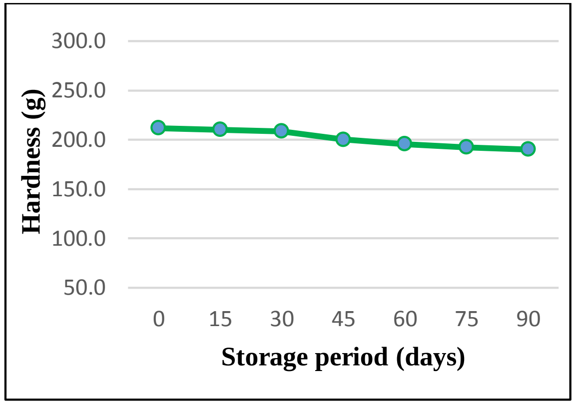

Fig. 4.59: Changes in hardness of pumpkin seed spread during storage (30±2˚C)

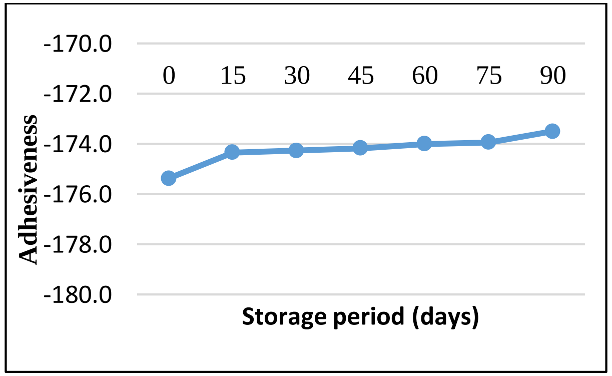

Fig. 4.60: Changes in adhesiveness of pumpkin seed spread during storage (30±2˚C)

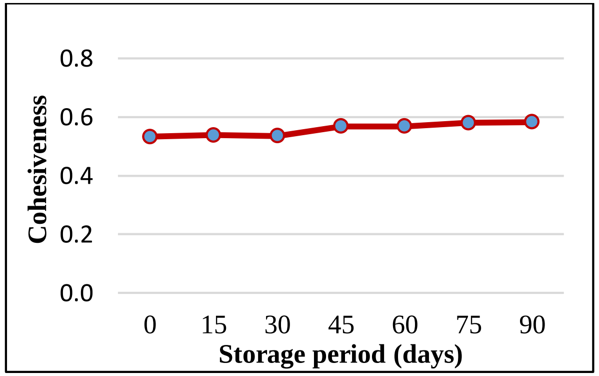

Fig. 4.61: Changes in cohesiveness of pumpkin seed spread during storage (30±2˚C)

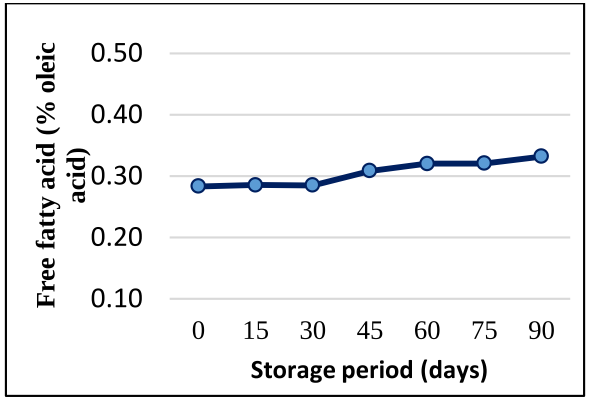

Fig. 4.62: Changes in free fatty acid of pumpkin seed spread during storage (5±2˚C)

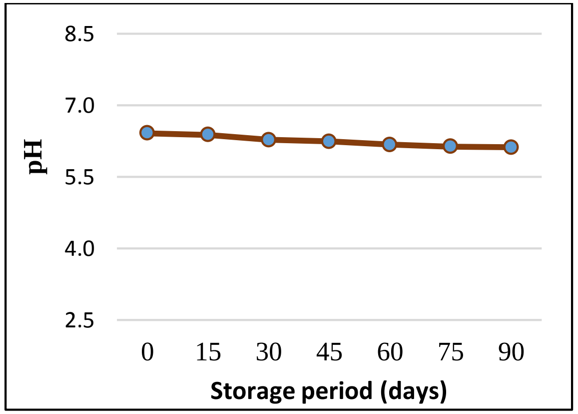

Fig. 4.63: Changes in pH of pumpkin seed spread during storage (5±2˚C)

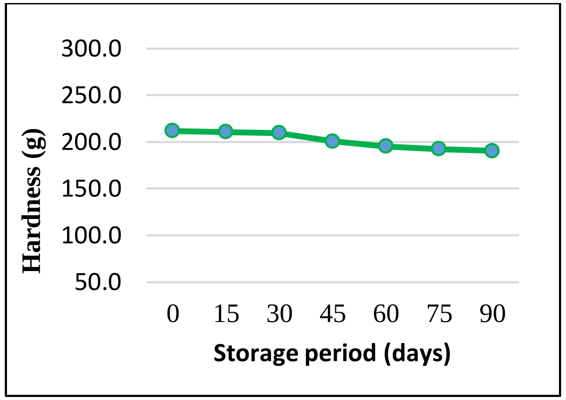

Fig. 4.64: Changes in hardness of pumpkin seed spread during storage (5±2˚C)

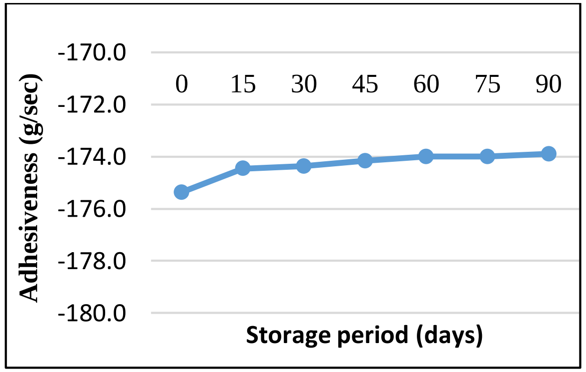

Fig. 4.65: Changes in adhesiveness of pumpkin seed spread during storage (5±2˚C)

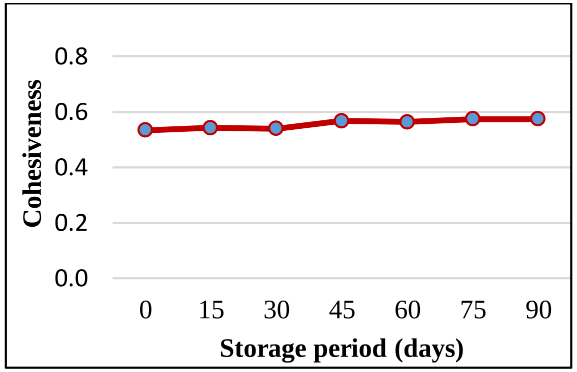

Fig. 4.66: Changes in cohesiveness of pumpkin seed spread during storage (5±2˚C)

Table 4.77: Changes in sensory attributes of pumpkin seed spread during storage (30±2ºC)

Parameters	Storage period (days)							SEm	CD (0.05)	CV (%)
	0	15	30	45	60	75	90			
Colour and appearance	8.37±0.15	8.33±0.12	8.27±0.12	8.21±0.17	8.13±0.15	8.13±0.25	7.93±0.06	0.09	0.27	1.88
Flavour	8.53±0.11	8.47±0.06	8.15±0.30	7.74±0.14	7.53±0.03	7.23±0.53	7.01±0.24	0.14	0.42	3.05
Body and texture	8.53±0.11	8.20±0.54	7.80±0.23	7.59±0.01	7.52±0.04	7.26±0.56	6.98±0.17	0.17	0.51	3.78
Overall acceptability	8.80±0.10	8.54±0.46	8.33±0.42	8.24±0.27	7.92±0.04	7.72±0.11	7.42±0.53	0.18	0.55	3.84

Table 4.78: Changes in sensory attributes of pumpkin seed spread during storage (5±2ºC)

Parameters	Storage period (days)							SEm	CD (0.05)	CV (%)
	0	15	30	45	60	75	90			
Colour and appearance	8.77±0.25	8.60±0.10	8.55±0.18	8.37±0.15	8.17±0.15	8.15±0.25	8.00±0.17	0.11	0.33	2.22
Flavour	8.51±0.14	8.50±0.01	8.25±0.28	7.84±0.06	7.62±0.13	7.28±0.59	7.17±0.53	0.17	0.50	3.65
Body and texture	8.45±0.13	8.20±0.46	7.87±0.33	7.62±0.07	7.53±0.06	7.28±0.40	6.98±0.17	0.14	0.42	3.09
Overall acceptability	8.76±0.16	8.57±0.52	8.38±0.46	8.29±0.30	7.93±0.06	7.82±0.19	7.46±0.54	0.19	0.57	4.00

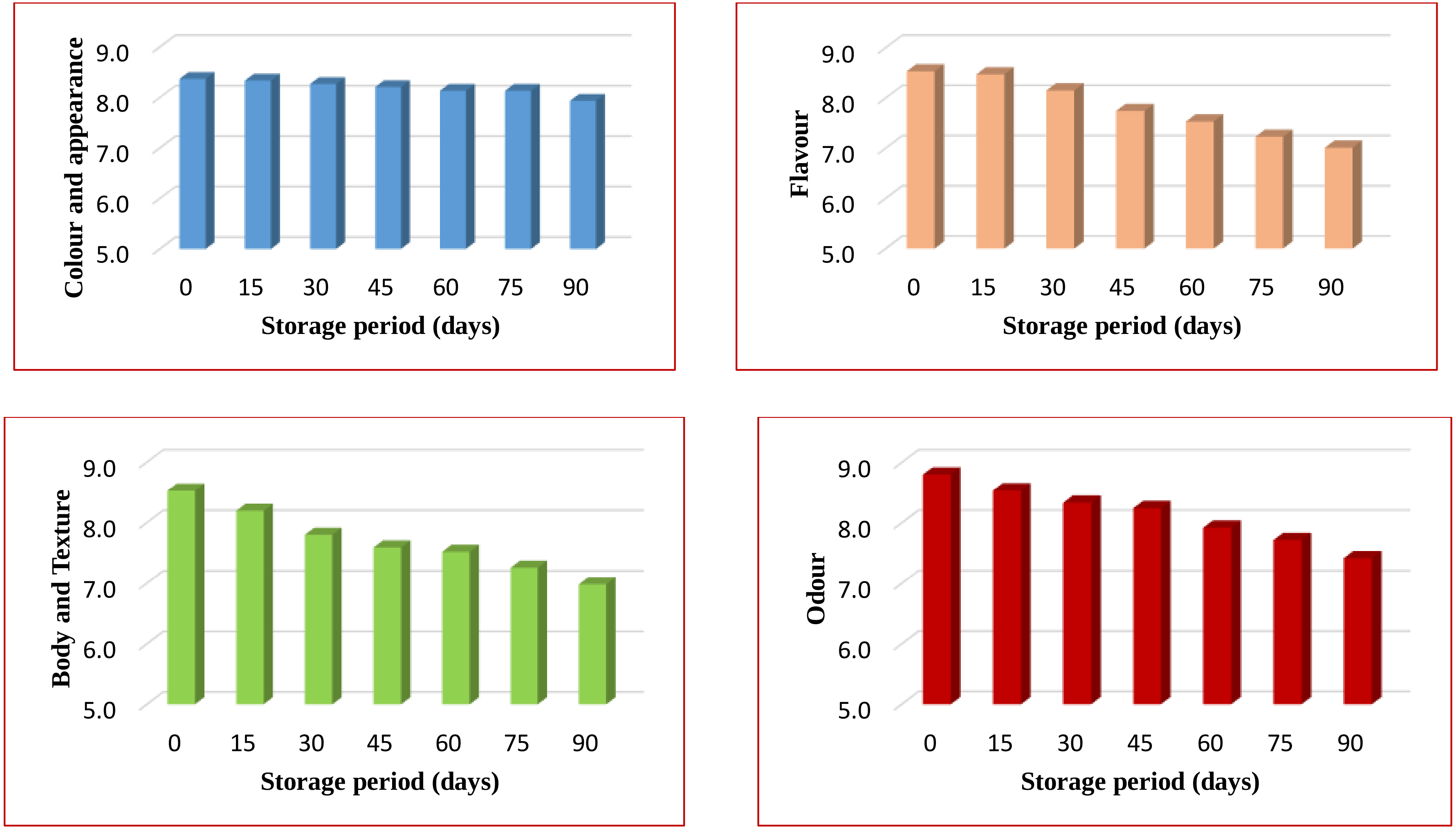

Fig. 4.67: Changes in sensory attributes of pumpkin seed spread during storage (30±2˚C)

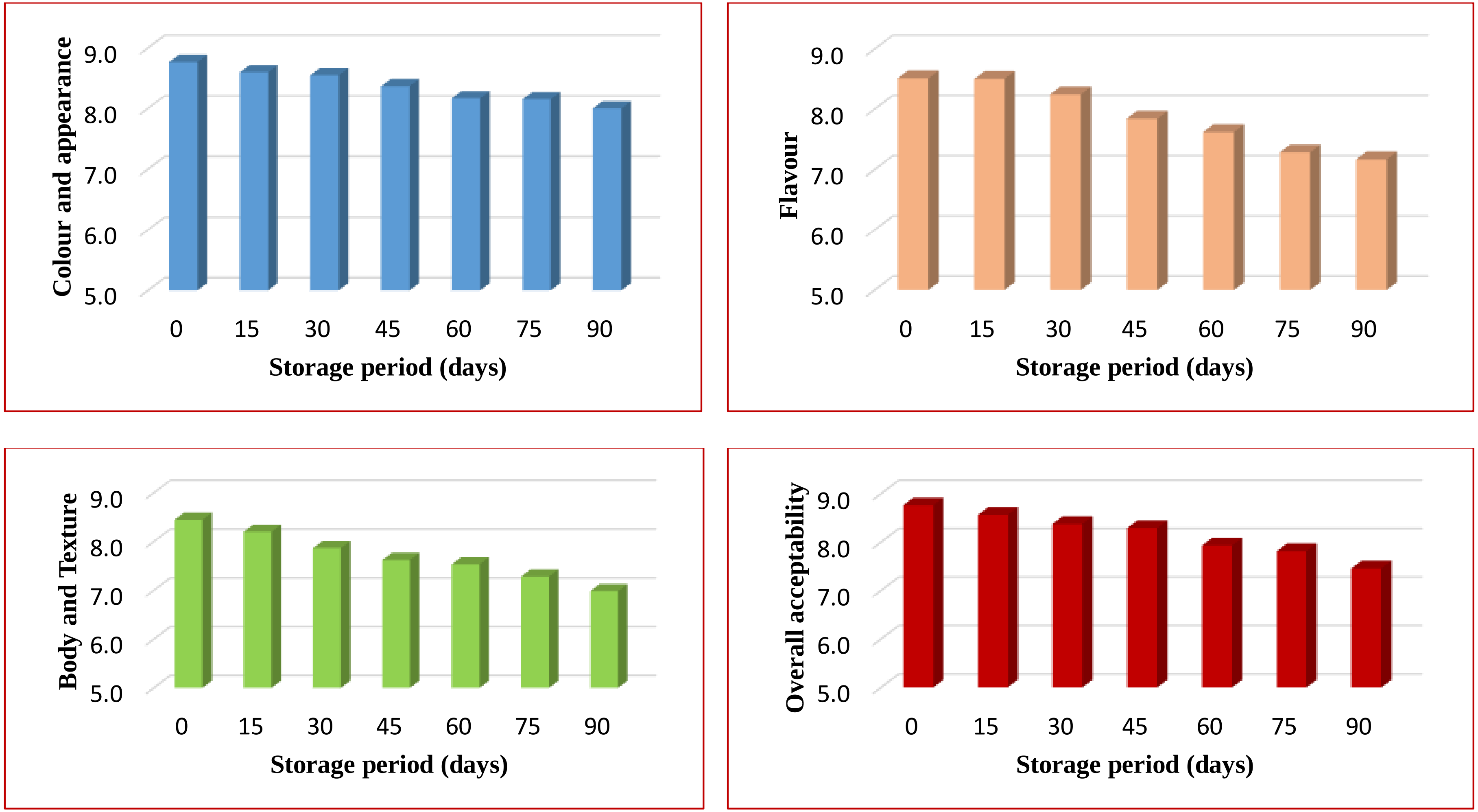

Fig. 4.68: Changes in sensory attributes of pumpkin seed spread during storage (5±2˚C)

Table 4.79: Microbiological analysis of pumpkin seed spread stored at 5±2˚C and 30±2˚C

Storage temperature	Parameter	0 day	15 day	30 day	45 day	60 day	75 day	90 day
5±2˚C	Standard plate count (cfu/g) x 10^3	2	5	12	20	22	35	46
30±2˚C	Standard plate count (cfu/g) x 10^3	2	8	29	30	44	46	55

From the analytical data it can be observed that coliform bacteria and yeast and mold were absent in the product. There was marginal increase in standard plate count for product stored at both temperatures. The results are in accordance with Gandhi (2009) who reported similar results for sesame butter with shelf life for six months.

4.6.3 Shelf Life Evaluation of Defatted pumpkin seed flour

Defatted pumpkin seed flour was prepared as per the optimized method, packed in aluminium laminated pouches, stored and evaluated for storage studies at ambient conditions (30±2°C). Samples were taken at every 15 days and analysed for moisture, free fatty acid, water absorption capacity and microbial characteristics for a period of three months and the results are presented in Table 4.80.

The moisture content in the product was found to increase during storage (Figure 4.69). The results showed that during three months of the storage period, the moisture content was marginally decreased from 1.84±0.02% to 1.65±0.05%.

The results indicated that there was a marginal increase in free fatty acid (0.15±0.01% oleic acid to 0.19±0.002% oleic acid) of defatted pumpkin seed flour during storage (Figure 4.70).

The mean values showed that there was a marginal decrease in water absorption capacity (20.51±0.001 to 20.15±0.05) of defatted pumpkin seed flour during storage (Figure 4.71).

Table 4.80: Changes in physicochemical characteristics of defatted pumpkin seed flour during storage

Parameters	Storage period (days)							SEm	CD (0.05)	CV (%)
	0	15	30	45	60	75	90			
Moisture,%	1.84±0.02	1.84±0.01	1.79±0.01	1.76±0.01	1.75±0.01	1.72±0.02	1.65±0.05	0.01	0.03	1.09
Free fatty acid, % oleic acid	0.15±0.01	0.16±0.003	0.17±0.01	0.18±0.005	0.18±0.01	0.18±0.01	0.19±0.002	0.005	0.01	4.74
Water absorption capacity, %	20.51±0.001	20.45±0.005	20.35±0.004	20.25±0.04	20.15±0.01	20.13±0.01	20.15±0.05	0.01	0.36	0.10

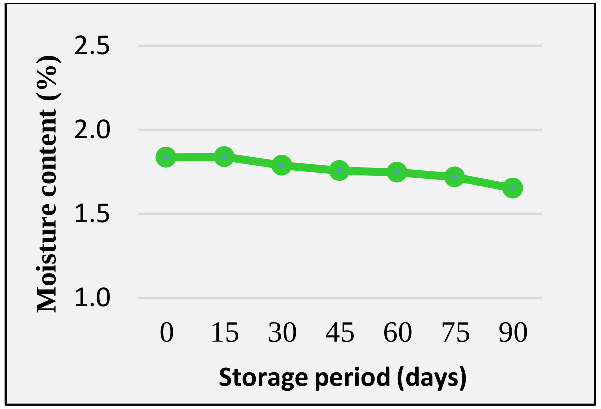

Fig. 4.69: Changes in moisture content of defatted pumpkin seed flour during storage

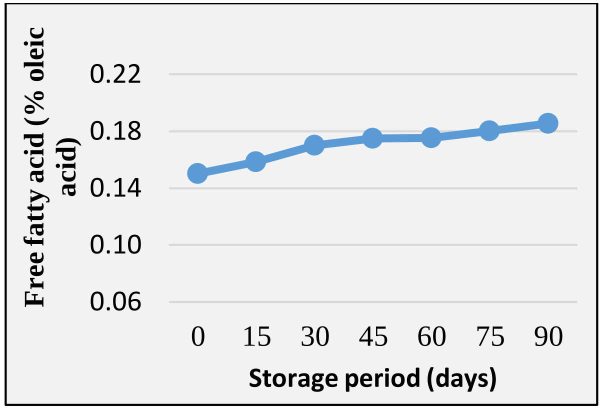

Fig. 4.70: Changes in free fatty acid of defatted pumpkin seed flour during storage

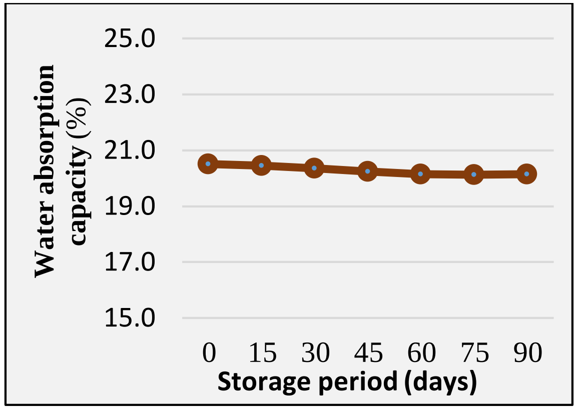

Fig. 4.71: Changes in water absorption capacity of defatted pumpkin seed flour during storage

4.6.3.2 Microbiological Evaluation of defatted pumpkin seed flour during storage

Microbial count of defatted pumpkin seed flour stored in aluminium laminate pouches at room temperature (30±2˚C) were carried out as per the methods explained in previous chapter. The results showed that the standard plate count on 0 day was 10 x 10^2 log cfu/g and at the end of 90 days, it was 280 x 10^2 log cfu/g. Coliforms and yeast and molds count were not observed throughout the storage period of three months. The product can be considered safe with respect to microbiological parameter even after 90 days.

Similar findings were reported by Manpreet Kaur (2017) for raw and roasted defatted pumpkin seed flour stored in air tight glass container for 60 days. The microbial count was observed that the bacterial count increased with the increased storage time and yeast and mould was not detected in first month of storage in both raw and roasted defatted pumpkin seed flour. The results obtained for microbial count during storage was found to be lesser than the microbial count of defatted peanut flour (1.4 x 10^4 CFU/g) as reported by Bansal (2013) after three months of storage in polythene bag at ambient temperature (25-35°C).

Based on the storage studies, it can be concluded that the value added products from pumpkin seed viz. roasted salted pumpkin seed kernels, pumpkin seed spread and defatted pumpkin seed flour can be stored in aluminium laminate pouches and glass jar with adequate shelf-life with respect to physicochemical, microbiological criteria as well as sensory characteristics.

CHAPTER V
SUMMARY AND CONCLUSIONS

India is the world's second largest producer of fruits and vegetables. Annually, food industry generate large amount of wastes or by-products from a variety of sources. High-value natural compounds can be found in most of these fruits and vegetables residues and many of them having health-promoting characteristics. The food materials generally discarded by industries actually can add nutrients to various preparations and value addition to products. The combined efforts of waste minimization during the production, environmentally friendly preservation of the products, and utilization of by product would substantially reduce the amount of waste, as well as boost the environmental profile of fruits and vegetables processing industry.

Pumpkin is a versatile fruit and is used for various food processing applications. It has been used for pies, curry, soups, stews, jam, sweet, marmalade, beverage, baby foods, ice-cream, instant pumpkin kofta and breads. Though the flesh have found their way into the Indian diet for time immemorial, the seeds have almost always been discarded as waste in spite of having a great nutritive value.

Pumpkin seeds have a high nutritional value, provides good quality oil and excellent source of protein and also has pharmacological activities. Pumpkin seeds are rich natural source of protein ranging from 25 to 37% and oil ranging from 37 to 45% and are renowned as valuable high protein oil seeds for human consumption. Edible oil extracted from pumpkin seeds has been highly acceptable and considered very healthy for health. Pumpkin seeds and pumpkin seed oil is rich in unsaturated fatty acids especially omega 3 fatty acids. These seeds are also rich in phytosterols, polyunsaturated fatty acids, antioxidant vitamins such as carotenoids and tocopherol, trace elements such as zinc, iron and magnesium. Moreover, pumpkin seeds are rich in amino acids like lysine, tyrosine, tryptophan, methionine and also rich in iron, thus being recommendable to children and adolescents prone to anemia caused due to iron deficiency.

In spite of being highly nutritious and having known medicinal values, pumpkin seeds have still not come into the limelight and are relatively less acceptable amongst the people as compared to other oil seeds like groundnuts and cashew nuts, though nutritionally the seeds of pumpkin can easily be compared to the above mentioned seeds. So, it gives new opportunity to explore the possibilities for the production technologies for value added products from pumpkins seeds, which are rich in nutrients and as a novel products to combat wastages of pumpkin seeds. Considering the significant importance of pumpkin seed, the present investigation was carried with following objectives.

1. To study physicochemical characteristics of pumpkin seeds.
2. To optimize the roasting parameters of pumpkin seeds.
3. To standardize process parameters for preparation of pumpkin seed snacks.
4. To optimize the process parameters for pumpkin seed spread.
5. To standardize process parameters for preparation of pumpkin seed flour.
6. To evaluate shelf life of value added pumpkin seed products.

Pumpkin seeds were procured from single source from local market, Anand, Gujarat. Experiments were performed at College of Food Processing Technology & Bio-Energy. The seeds were cleaned manually to remove any unwanted particles like damaged seeds, undersized and immature seeds and other extraneous materials. Cleaning was done by winnowing and hand sorting and then dehulled manually. Samples were then packed in airtight plastic bags and stored in refrigerator till further analysis.

The physicochemical characteristics viz. length, width, thickness, geometric mean diameter, true density, bulk density, porosity, 1000 seed weight and husk content, moisture, protein, crude fat, crude fibre, ash, carbohydrate and phytic acid content were determined for both whole pumpkin seed and kernel. The mineral content, fatty acid profile and thermal properties of pumpkin seed kernels were also determined.

During the preliminary trials of the study, it was found that roasted whole pumpkin seeds were unacceptable due to too much fibrous material on hull and not organoleptically acceptable in sensory evaluation, Hence, further studies of development of value added products were carried out from pumpkin seed kernels.

Completely Randomized Design (CRD) was adopted for experimental design. For the optimization of roaster for roasting pumpkin seed kernels and value added products from pumpkin seed kernels viz. pumpkin seed snacks, pumpkin seed spread and pumpkin seed flour, full second order model was fitted in various responses and independent variables using least square regression analysis. Data analysis was done by using Design expert 10.0.1 software. Effect of independent variables on the responses for different value added products were interpreted using the models.

Four different roasters viz. halogen oven, hot air oven, microwave oven and sand roasting were used for the standardization of roaster for roasting pumpkin seed kernels. The roasting temperature and roasting time for halogen oven, hot air oven, microwave oven and sand roasting were 180, 190 and 200°C for 4, 6 and 8 min, 150, 160 and 170°C for 10, 20 and 30 min; P-80, P-90 and P-100 for 3, 4, and 5 min and 150, 160, 170°C for 2, 3 and 4 min respectively. Optimized sample of each of the four roasters were then compared and the best roaster was selected for roasting pumpkin seed kernels for further preparation of value added products based on dependable parameters i, e, sensory evaluation (colour and appearance, taste, odour, overall acceptability), texture profile analysis (hardness, fracturability) and phytic acid content.

Pumpkin seed kernels were processed into three different products for the study viz. pumpkin seed snacks, pumpkin seed spread and pumpkin seed flour. Optimized roaster was used for the development of different products.

Roasted salted pumpkin seed kernels were prepared using pumpkin seed kernels. The independent variables for the experiments were moisture conditioning (5, 10 and 15%) and salt concentration (10, 15 and 20%) and the process parameters were optimized on the basis of maximum sensory evaluation (overall acceptability), minimum hardness and maximum fracturability of texture profile analysis.

The independent variables for the preparation of pumpkin seed spread were hydrogenated vegetable oil (10, 15 and 20%) and soya lecithin (0.5, 1.0, and 1.5%) respectively. The sugar, salt and spices (1:1:1 ratio of cinnamon, nutmeq and ginger powder) were added at the rate of 7, 1.5 and 2 percent in all the experiments. The process parameters were optimized on the basis of maximum sensory evaluation (overall acceptability), minimum hardness, maximum adhesiveness and maximum cohesiveness of texture profile analysis and in range L*, a* and b* colour values.

Pumpkin seed kernels were grouped into three parts, unroasted, roasted and sprouted for the preparation of pumpkin seed flour. Roasting of pumpkin seed kernels was done using the optimized oven. Sprouting and defatting of pumpkin seeds was done using seed germinator and soxhlet apparatus. The process parameters were optimized on the basis of maximum protein content, minimum fat content and maximum water absorption capacity.

The different optimized value added products from pumpkin seed kernels viz. roasted salted pumpkin seed kernels, pumpkin seed spread and defatted pumpkin seed flour were evaluated for physicochemical properties, sensory evaluation and microbiological analysis.

The roasted salted pumpkin seed kernels, pumpkin seed spread and defatted pumpkin seed flour were prepared through standardized process parameters for storage study. The pumpkin seed snacks and pumpkin seed flour were packed in aluminium laminate pouches and stored at ambient (30±2^{o}C) storage conditions while the pumpkin seed spread was stored at ambient (30±2^{o}C) and refrigerated (5±2^{o}C) storage conditions for three months to carry out shelf-life evaluation. The samples were analysed for physicochemical characteristics, sensory attributes and microbiological parameters at an interval of 15 days during storage. The microbiological parameters were analysed in terms of standard plate counts, yeasts and molds count and coliform counts.

The following conclusions could be drawn from the present investigation.

1. The average length, width and thickness of whole pumpkin seed was 16.81±0.91 mm, 8.87±0.61 mm and 2.75±0.18 mm respectively, while the corresponding values for kernel were 11.65±0.69 mm, 5.80±0.26 mm and 2.52±0.29 mm and the geometric mean diameter of the seed and kernel was 7.42±0.35 and 5.54±0.29 mm respectively.
2. The seeds had a lower bulk density and a higher true density than the kernels. For the seed, the bulk density and true density was 398±0.80 kg/m3 and 1157±1.02 kg/m3, while the corresponding densities for the kernel were 475±0.95 kg/m3 and 1068.81±0.94 kg/m3 respectively.

3. The porosity of whole seed and kernel were 65.60±0.47% and 55.52±0.55% and the 1000 seed weight for the corresponding were 202.2±0.75g and 148.1±0.87g respectively. The husk content of the pumpkin seed was 26.75±0.98%.
4. The whole pumpkin seeds and kernels had good nutritional value. The proximate composition of whole pumpkin seed were moisture (5.53±0.26%), protein (28.90±1.36%), fat (31.75±0.45%), fibre (4.59±1.01%), ash (6.90±0.14%) and carbohydrate (27.86±1.50%), and corresponding composition of kernel were 4.43±0.44%, 31.98±1.18%, 38.29±1.51%, 4.26±0.43%, 2.36±0.10% and 33.11±2.94% respectively.
5. The average fatty acid composition of pumpkin seed kernel was linoleic acid (37.89%), oleic acid (27.75%), palmitic acid (17.63%), stearic acid (14.96%), palmitolic acid (0.33%), arachidic acid (0.30%), erusic acid (0.21%), behenic acid (0.21%) and linolenic acid (0.18%).
6. The average mineral composition of pumpkin seed kernel was Zinc (907 mg), Phosphorus (848.6 mg), manganese (487 mg), potassium (404.9 mg), magnesium (335.6 mg), copper (124 mg), calcium (25.7 mg), iron (16.1 mg), sodium (2.2 mg) and cobalt (0.6 mg).
7. The optimized roasting temperature and roasting time of pumpkin seed kernels roasted in halogen oven were observed at 190^{o}C for 5 min with the sensory scores of colour and appearance (8.5), taste (8.3), odour (8.0), overall acceptability (8.3), textural characteristics values of hardness (44.62g), fracturability (4.531g) and phytic acid (0.157%).
8. The optimized roasting temperature and roasting time of pumpkin seed kernels roasted in hot air oven were observed at 160^{o}C for 30 min with the sensory scores of colour and appearance (7.5), taste (7.7), odour (7.8), overall acceptability (7.8), textural characteristics values of hardness (44.35g), fracturability (3.912g) and phytic acid (0.159%).
9. For microwave oven, the optimized roasting temperature and roasting time conditions of pumpkin seed kernels were observed at P-90 for 4 min with the sensory scores of colour and appearance (8.2), taste (8.2), odour (8.1),overall acceptability (7.4), textural characteristics values of hardness (54.45g), fracturability (4.87g) and phytic acid (0.192%).
10. The optimized roasting temperature and roasting time of pumpkin seed kernels roasted in sand roasting were observed at 160^{o}C for 2 min with the sensory

scores of colour and appearance (7.3), taste (7.5), odour (7.5), overall acceptability (7.4), textural characteristics values of hardness (48.12g), fracturability (4.12g) and phytic acid (0.172%).

11. The optimal conditions of each roaster were compared in terms of the sensory evaluation scores, texture profile analysis and phytic acid content. All the optimal samples had good sensory scores, textural characteristics and low phytic acid content compared to the conventional sand roasting method and control sample.

    The sensory score for optimal halogen oven roasted sample had highest sensory scores compared to the other optimal roasting method.

    It was observed low hardness and high fracturability values in all the roasted samples using different roasters as compared to the unroasted control sample. This might be due to the fact that during roasting, the moisture content of the pumpkin seed kernel was reduced and the texture become more crumbly and fragile. Samples roasted in halogen oven and hot air oven showed lower hardness values of 44.62g and 44.35g than the sample roasted in conventional sand roasting (48.12g) and microwave oven (54.45g) whereas, samples roasted in microwave and halogen oven showed higher fracturability values than other roasting methods.

    The phytic acid content was found to be lowest in sample roasted in halogen oven compared to the other roasting methods. It was observed that hot air oven consumed more time of roasting as compared to the remaining roasters. All the roasting methods were also more hygienic as compared to the conventional sand roasting method.

    In conclusion, by taking into the account the sensory score, texture profile analysis and phytic acid content, halogen oven roasting method was considered best for roasting of pumpkin seed kernels and this method was considered for further experiments to develop different products.

12. Roasted salted pumpkin seed kernels were found to be the best for the experimental combinations 12% moisture conditioning and 20% salt concentration with an overall acceptability score of 8.38, hardness of 45.123g and fracturability of 5.035 g respectively.

The proximate composition of roasted salted pumpkin seed kernels are found to be 2.41% moisture, 31.97% crude protein, 38.54% crude fat, 4.34% ash, 2.34% crude fibre and 22.38% total carbohydrates.

The sensory attribute scores were found to be 8.2, 7.4, 8.2 and 8.2 for colour & appearance, flavour, body and texture and overall acceptability respectively. The results of the sensory scores showed that the optimized roasted salted pumpkin seed kernels had good overall acceptability because the sensory scores of all the sensory attributes were above 7.0.

The major fatty acids identified were linoleic acid (36.25%) and oleic acid (30.23%) while the other fatty acids were palmitic acid (18.65%), palmitolic acid (0.28%), stearic acid (12.87%), linolenic acid (0.33%), arachidic acid (0.33%), behenic acid (0.25%) and eursic acid (0.51%) respectively.

It was observed that coliforms and yeast and mold count were not found and standard plate count was found to be 2 x 10^3 cfu/g, indicating the safety of the product.

13. The roasted salted pumpkin seed kernels was analyzed for changes in various physicochemical, sensory attributes and microbiological analysis during storage. A marginal decrease in moisture content (2.45% to 2.99%) during storage was observed. The initial mean value of peroxide value was 0.40 meq/kg oil and it was significantly increased to 0.61 meq/kg oil at the end of 3 months storage.

    There was a gradual decrease in colour and appearance (8.77 to 7.93), taste (8.51 to 6.96), odour (8.45 to 6.92) and overall acceptability (8.76 to 7.42) scores respectively. However, they remained at acceptable level even at the end of storage period of 3 months.

    Standard plate count was marginally increased in storage period. The initial count was found to be 2 x 10^3 log cfu/g and it was increased to 45 x 10^3 log cfu/g at the end of storage period of 3 months. No coliforms and yeast and molds count were observed throughout the storage period, which indicates the safety of the product throughout storage.

14. Developed pumpkin seed spread was optimized with experimental combinations of 20% hydrogenated vegetable oil and 0.7% lecithin with the overall acceptability score (8.2), hardness (211.855g), adhesiveness (-

158.49g/sec), cohesiveness (0.520), colour values of L* (57.119), a*(6.508) and b*(23.005) respectively.

The proximate composition of pumpkin seed spread was found to be 0.38% moisture, 31.96% crude protein, 42.45% crude fat, 4.18% ash, 2.37% crude fibre and 19.04% total carbohydrate content.

The peroxide value, viscosity, pH and free fatty acids of pumpkin seed spread were found to be 0.4±0.05 meq/kg oil, 3.558 Pa-s at 24.3°C, 6.4 and 0.284 (% oleic acid) respectively.

The reducing sugar, non-reducing sugar and total sugar were found to be 14.55%, 11.55% and 25.90% respectively for the optimized pumpkin seed spread.

The sensory attributes were found to be 8.0, 8.2, 8.5 and 8.2 scores for colour and appearance, flavor, body and texture and overall acceptability respectively. The results of sensory scores shows that optimized pumpkin seed spread had good acceptability because the sensory scores for all the sensory attribute were above 8.0. The colour values of L*, a* and b* were found to be 57.119, 6.508 and 23.005.

The textural properties viz. hardness, adhesiveness and cohesiveness for the optimized pumpkin seed spread was found to be 211.855 g, -175.44 g/sec and 0.520 respectively.

It was observed that coliforms, yeast and mold counts were absent and the standard plate count was found to be 2 x 10^3 cfu/g indicating that the product was safe with good quality characteristics.

15. The pumpkin seed spread was analyzed for changes in various physicochemical, sensory attributes and microbiological analysis during storage. There was marginal increase in FFA at both the storage conditions. The initial (0 day) FFA was 0.28% oleic acid and was increased to 0.34% oleic acid and 0.33% oleic acid at ambient (30±2°C) and refrigerated (5±2°C) conditions respectively at the end of 3 months.

There were minor variations of pH of the product during study period at both storage temperature. The pH value was decreased from 6.42 to 6.20 and from 6.42 to 6.12 for ambient and refrigerated conditions during storage

During storage period of 3 months, negligible changes in textural characteristics viz. hardness, adhesiveness and cohesiveness at both storage temperatures were observed. We can predict that pumpkin seed spread can be stored without textural variation up to three months of storage.

There was a gradual decrease in colour and appearance (8.37 to 7.93), flavor (8.53 to 7.01), odour (8.53 to 6.98) and overall acceptability (8.80 to 7.42) respectively for the product stored at ambient condition, while the corresponding values for the product stored in refrigerated condition were 8.77 to 8.00, 8.51 to 7.17, 8.45 to 6.98 and 8.76 to 7.46 respectively. It was observed that the product remained acceptable even at the end of storage period of 3 months at both temperatures.

Standard plate count was marginally increased with the increase in storage period. The initial count was found to be 2 x 10^3 log cfu/g and it was increased to 46 x 10^3 log cfu/g at refrigerated storage condition while for the sample stored in ambient conditions, it increased from 2 x 10^3 log cfu/g to 55 x 10^3 log cfu/g at the end of 3 months. Coliforms and yeast and molds count were not observed throughout the storage period for both the storage temperatures, indicating the safety of the product throughout storage.

16. Sprouted pumpkin seeds were found to be best for preparation of defatted pumpkin seed flour. The flour was found with protein content of 66.91%, fat content of 2.75% and water absorption capacity of 19.05%.

    The proximate composition of optimized defatted pumpkin seed flour was found to be 1.84%, 66.91%, 3.32%, 8.83%, 6.92% and 14.42% moisture, crude protein, crude fat, ash, crude fibre, total carbohydrate respectively.

    Low phytic acid content (0.589%) in defatted pumpkin seed flour was noticed and this might be due to the sprouting process of pumpkin seed prior to defatting.

    The In-vitro protein digestibility, particle size and bulk density of defatted pumpkin seed flour was found to be 59.32%, 43.758 microns and 1.74 ± 1.02 g/ml respectively.

    Water absorption capacity of defatted pumpkin seed flour was found to be 19.5% and peroxide value and free fatty acid content were found to be 0.23 meq/kg oil and 0.15 % oleic acid respectively. The L*, a*, b* colour values were 95.8, 2.5 and 12 respectively.

The most mineral contents were found to be phosphorus (1983 mg/g), Magnesium (769.1 mg/g) and Potassium (758.3 mg/g) while the other minerals cobalt (1.0 mg/g) and copper (3.6 mg/g) were present in trace levels.

The thermal properties viz. onset temperature (T_o), peak temperature (T_p) and enthalpy, (ΔH) of pumpkin seed flour were found to be 104.04^{o}C, 66.31^{o}C and 116.5383 J/g respectively.

It was observed that coliforms and yeast and mold count were not found and standard plate count was found to be 10 x 10^2 cfu/g.

17. The defatted pumpkin seed flour was analyzed for changes in various physicochemical and microbiological parameters during storage. A marginal decrease in moisture content (1.84% to 1.65%) during storage was observed.

The initial mean value of FFA was 0.15% oleic acid and it was marginally increased to 0.19% oleic acid at the end of 3 months.

The mean values showed that there was a marginal decrease in water absorption capacity (20.51 to 20.15) of defatted pumpkin seed flour during storage.

Standard plate count was marginally increased with the increase in storage period. The initial count was found to be 10 x 10^2 log cfu/g and it increased to 280 x 10^2 log cfu/g at the end of storage period of 3 months. No coliforms and yeast and molds count were observed throughout the storage period, which indicates the sterility of the product throughout storage.

The present research generated data on physicochemical characteristics of pumpkin seeds and different roasters for roasting pumpkin seeds. The technologies optimized in the present investigation viz. roasting in halogen oven, roasted salted pumpkin seed kernels, pumpkin seed spread and defatted pumpkin seed flour can be explored for commercial applications.

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APPENDICES

APPENDIX-I

Observation table of dimensions for whole pumpkin seeds and kernels

Sr. No	Length (mm)	Breadth (mm)	Thickness (mm)	Length (mm)	Breadth (mm)	Thickness (mm)
1	17.669	9.23	2.842	12.51	5.733	3.065
2	16.993	8.576	2.38	11.652	5.916	1.99
3	16.625	8.893	2.436	12.267	5.743	2.457
4	15.746	8.776	2.698	11.116	5.809	2.205
5	16.251	8.764	2.436	11.064	6.708	2.754
6	17.136	8.715	2.942	12.792	6.325	2.596
7	17.381	9.022	2.92	11.132	6.125	2.594
8	16.993	9.28	2.837	11.939	5.996	2.441
9	15.35	8.4	2.768	10.811	5.685	2.458
10	17.144	9.424	2.869	11.233	5.805	2.667
11	18.3	9.177	2.839	11.38	5.91	2.436
12	17.612	9.366	2.755	12.3	5.93	2.942
13	17.151	9.825	3.155	11.15	5.63	2.92
14	18.003	10.628	2.703	12.65	5.89	2.837
15	17.735	9.295	2.682	12.9	5.77	2.768
16	17.618	9.337	2.851	10.87	5.7	2.869
17	18.494	10.03	3.104	11.73	5.53	2.839
18	17.565	9.132	2.92	11.74	5.85	2.755
19	16.514	9.028	3.035	12.04	6.27	3.155
20	17.34	8.935	2.892	11.29	5.65	2.703
21	16.652	8.854	2.662	12.06	5.75	2.682
22	17.056	8.622	2.861	12.1	5.38	2.851
23	16.656	8.555	2.91	11.48	6.2	2.723
24	15.168	8.896	2.74	11.4	5.77	2.848
25	16.444	8.883	2.7114	10.87	5.9	2.801
26	16.522	8.45	2.485	12.2	5.65	2.629
27	16.486	8.322	2.438	12.67	5.98	2.372
28	16.463	8.679	2.956	11.06	6.11	2.464
29	14.735	7.556	2.61	12.21	5.76	2.704
30	14.049	7.514	2.714	12.96	6.01	2.867
31	17.993	9.275	2.527	11.03	4.76	2.64

32	17.044	8.992	2.627	12.94	4.89	2.722
33	16.599	8.019	2.799	12.03	5.01	2.673
34	16.101	7.798	2.789	11.94	4.99	2.619
35	16.132	8.749	2.539	11.21	4.98	2.971
36	15.729	8.478	2.694	11.81	5.6	2.566
37	17.566	9.34	2.647	12.42	4.85	2.464
38	17.642	9.606	2.852	11.9	5.75	2.758
39	16.822	8.373	2.841	10.65	4.98	2.825
40	16.671	8.371	2.853	10.79	5.04	2.508
41	17.296	9.009	2.356	11.6	4.99	2.577
42	16.751	8.699	2.506	12.06	5.28	2.098
43	15.883	9.523	2.809	11.86	4.88	2.766
44	17.802	7.276	2.877	12.19	4.96	2.565
45	15.329	8.83	2.796	10.83	4.99	2.629
46	17.538	9.452	2.612	10.96	5.67	2.559
47	17.766	8.652	2.719	12.19	4.84	2.543
48	16.756	9.007	3.026	11.83	5.95	2.629
49	16.557	8.538	2.594	10.96	4.67	2.721
50	16.452	9.266	2.681	10.98	5.79	2.619
51	17.34	8.935	2.892	11.33	5.81	2.712
52	16.652	8.854	2.662	11.95	5.97	2.675
53	17.016	8.422	2.841	11.94	4.78	2.107
54	16.756	8.555	2.91	12.87	4.72	2.146
55	15.168	8.896	2.74	12.12	4.75	2.545
56	16.444	8.783	2.7114	12.01	4.96	2.515
57	16.522	8.45	2.485	12.34	4.93	2.453
58	16.586	8.322	2.438	12.03	4.99	2.144
59	16.463	8.689	2.956	11.75	4.94	2.107
60	14.635	7.556	2.61	12.49	6.67	2.791
61	14.049	7.514	2.614	11.55	5.19	2.76
62	17.893	9.275	2.527	12.75	5.83	2.435
63	17.044	8.992	2.627	12.55	5.96	2.141
64	16.589	8.019	2.799	12.02	5.98	2.141
65	16.101	7.798	2.789	11.73	6.33	2.509
66	16.132	8.749	2.539	12.08	6.95	2.146
67	15.729	8.478	2.694	11.7	5.94	2.571
68	17.566	9.34	2.647	10.86	5.87	2.487
69	17.642	9.606	2.852	10.99	5.12	2.596
70	16.822	8.373	2.841	11.7	5.01	2.53

71	16.671	8.371	2.853	11.82	5.29	2.3
72	17.296	9.009	2.356	11.86	5.03	2.723
73	16.751	8.699	2.506	12.01	4.75	2.148
74	15.883	9.523	2.809	11.81	5.49	2.101
75	17.802	7.276	2.877	11.75	5.06	2.629
76	16.329	8.83	2.796	11.76	5.19	2.372
77	17.538	9.452	2.612	10.98	4.89	2.464
78	17.766	8.652	2.719	10.85	6.98	2.704
79	16.976	9.907	3.026	10.935	4.93	2.867
80	16.987	9.938	2.894	10.854	5.97	2.64
81	16.452	9.266	2.681	10.422	6.73	2.522
82	16.868	8.896	2.84	10.555	6.82	2.173
83	16.444	8.983	2.7114	10.896	6.82	2.119
84	16.699	8.995	2.485	11.783	6.42	2.171
85	16.986	8.922	2.538	12.45	6.31	2.566
86	16.853	8.679	2.956	12.322	6.04	2.464
87	16.935	9.556	2.81	11.689	5.91	2.158
88	17.949	7.814	2.814	11.556	6.12	2.125
89	17.993	9.575	2.927	11.514	6.65	2.498
90	17.844	8.992	2.627	11.275	6.87	2.54
91	16.899	8.919	2.999	10.992	6.84	2.185
92	16.201	8.798	2.789	12.019	6.54	2.278
93	16.522	9.945	2.785	10.798	6.81	2.332
94	17.486	8.922	2.838	11.749	6.84	2.169
95	17.463	8.899	2.956	11.478	6.97	2.162
96	18.044	9.992	2.827	11.34	6.83	2.592
97	17.599	9.889	2.799	10.7114	6.82	2.174
98	16.557	8.938	2.794	11.485	5.96	2.599
99	16.652	9.266	2.881	10.538	6.73	2.51
100	16.663	9.234	2.882	10.956	6.92	2.184

APPENDIX-II

(a) Scorecard for Sensory Evaluation for pumpkin seed snacks

Name of Panelist: Date:

Name of Product: Time:

Sensory Attributes	Sample number									
	1	2	3	4	5	6	7	8	9	10
Color and appearance										
Taste										
Odour										
Overall Acceptability										

Evaluation guidance:

Hedonic rating	**Score**
Like extremely	9
Like very much	8
Like moderately	7
Like slightly	6
Neither like nor dislike	5
Dislike slightly	4
Dislike moderately	3
Dislike very much	2
Dislike extremely	1

Comments:

Signature

(b) Scorecard for Sensory Evaluation for pumpkin seed spread

Name of Panelist: Date:

Name of Product: Time:

Sensory Attributes	Sample number									
	1	2	3	4	5	6	7	8	9	10
Color and appearance										
Flavour										
Body and Texture										
Overall Acceptability										

Evaluation guidance:

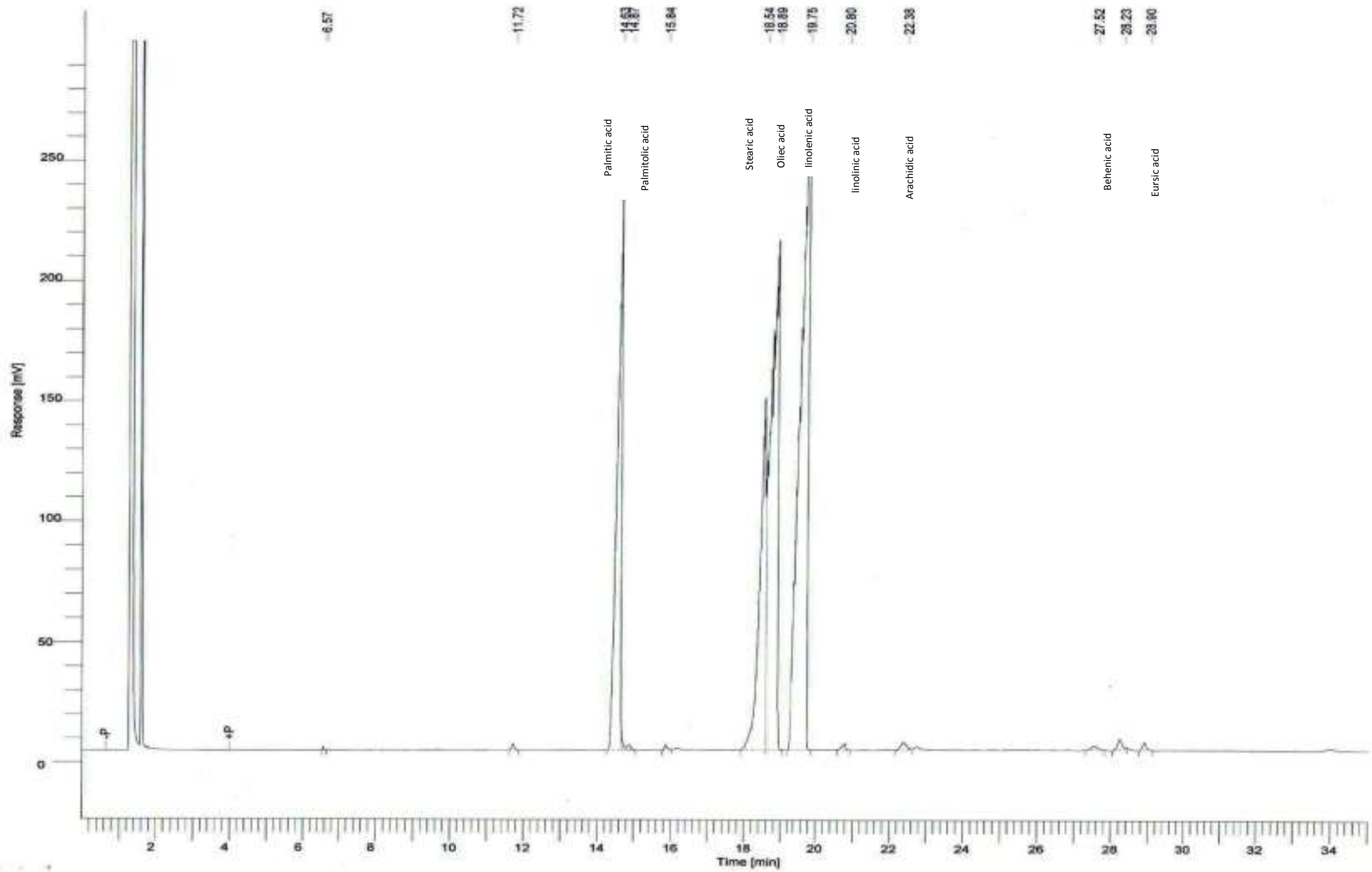
Hedonic rating	**Score**
Like extremely	9
Like very much	8
Like moderately	7
Like slightly	6
Neither like nor dislike	5
Dislike slightly	4
Dislike moderately	3
Dislike very much	2
Dislike extremely	1

Comments:

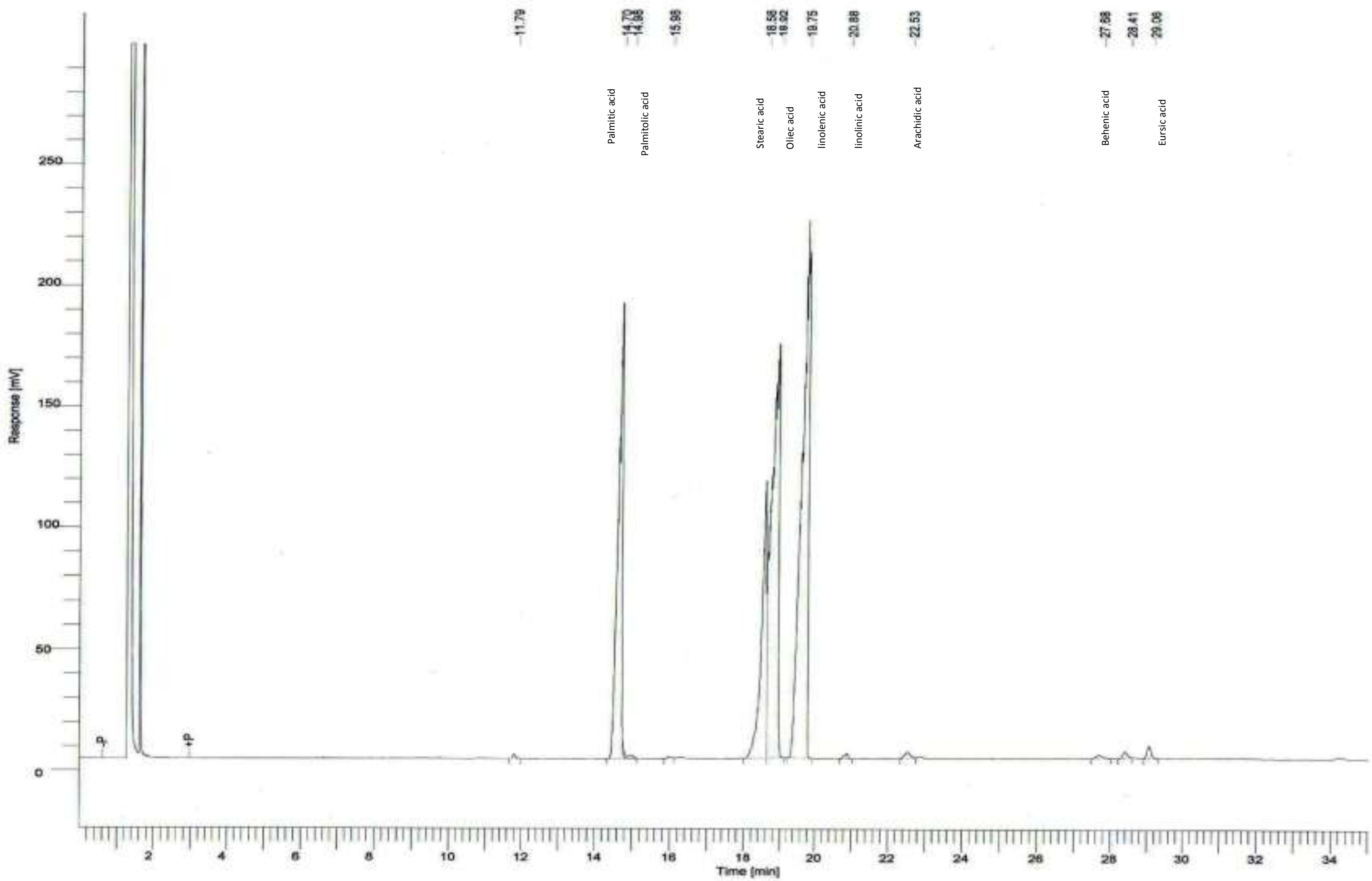
Signature

APPENDIX- III

(a). Free fatty acid profile of pumpkin seed kernels

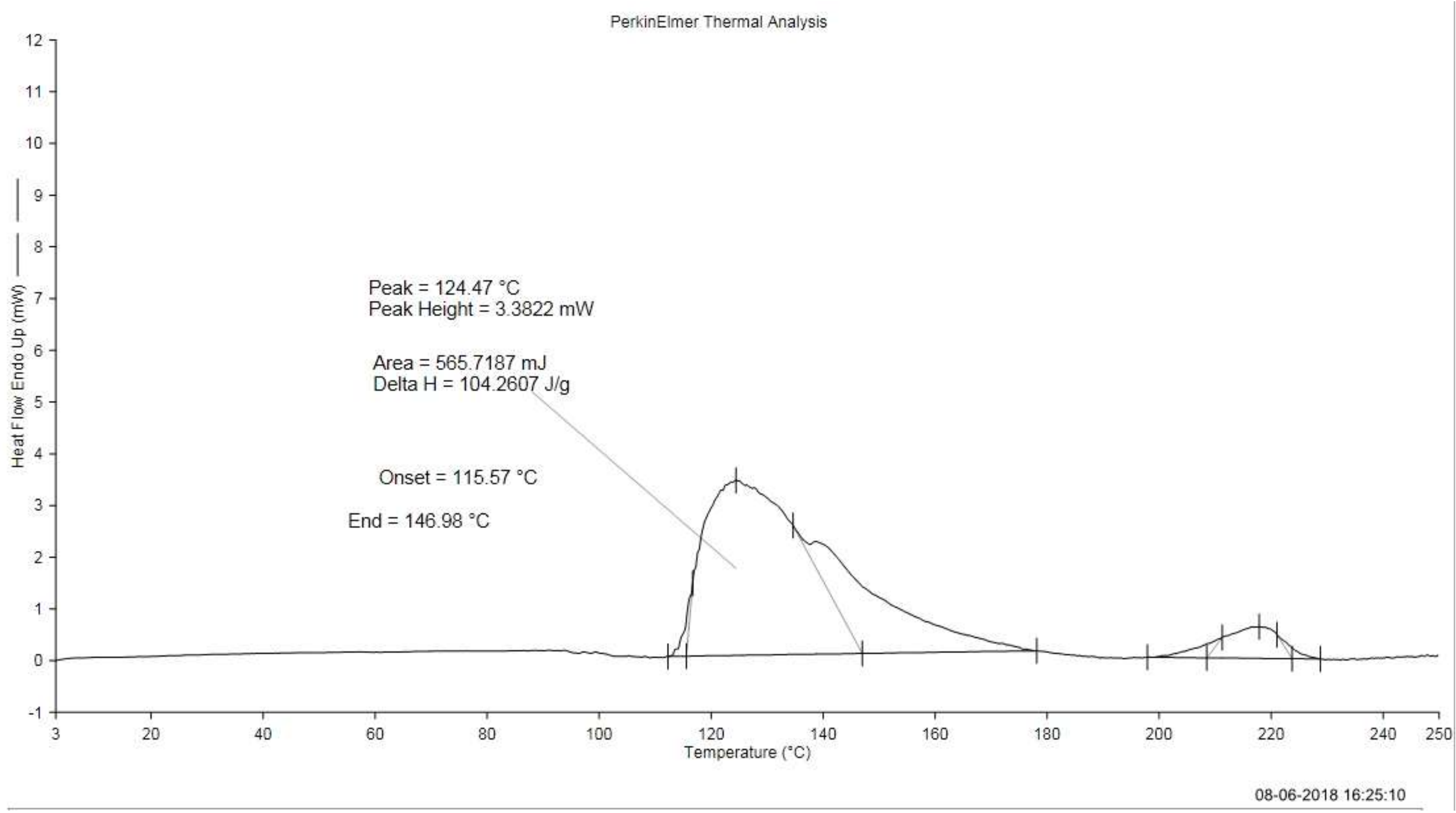


(b). Free fatty acid profile of optimized pumpkin seed snacks



APPENDIX- IV

(a). Thermal properties graph of Pumpkin seed kernels



(b). Thermal properties graph of Optimized pumpkin seed flour