STUDIES ON THE PRODUCTION OF MICROWAVE BAKED POTATO CHIPS

BY

P.NAGA DEEPTHI YADAV

B.Tech (Food Technology)

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CHAIRPERSON: Dr.L.EDUKONDALU

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COLLEGE OF AGRICULTURAL ENGINEERING, BAPATLA – 522101

ACHARYA N.G. RANGA AGRICULTURAL UNIVERSITY

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CERTIFICATE

Ms**. PESALA NAGA DEEPTHI YADAV** has satisfactorily prosecuted the course of research and that thesis entitled "**STUDIES ON THE PRODUCTION OF MICROWAVE BAKED POTATO CHIPS**" submitted is the result of original research work and is of sufficiently high standard to warrant its presentation to the examination. I also certify that neither the thesis nor its part thereof has been previously submitted by her for a degree of any university.

Date:

(Dr. L. EDUKONDALU)
Chairperson
Assistant Professor
Dept. of AP & FE
CAE, Bapatla

CERTIFICATE

This is to certify that the thesis entitled **"STUDIES ON THE PRODUCTION OF MICROWAVE BAKED POTATO CHIPS"** submitted in partial fulfillment of the requirements for the degree of "**MASTER OF TECHNOLOGY IN AGRICULTURAL ENGINEERING"** in the major field of **"PROCESSING AND FOOD ENGINEERING"** of the Acharya N.G. Ranga Agricultural University, Hyderabad is a record of the bonafide original research work carried out by **Ms. P. NAGA DEEPTHI YADAV** under our guidance and supervision.

No part of the thesis has been submitted by the student for any degree or diploma. The published part and all the assistance received during the course of the investigations have been duly acknowledged by the author of the thesis.

Thesis is approved by Student Advisory Committee

CHAIRPERSON **Dr. L. EDUKONDALU** ____________________
Assistant Professor
Dept. of Agricultural Process
& Food Engineering,
CAE, Bapatla.

MEMBER **Dr. SIVALA KUMAR** ____________________
Professor & Head,
Department of Agricultural Process
& Food Engineering,
CAE, Bapatla.

MEMBER **Dr. LAKSHMI.J** ____________________
Associate Dean,
College of Home Science,
Guntur.

Date of final viva-voce:

DECLARATION

I, **PESALA NAGA DEEPTHI YADAV,** hereby declare that the thesis entitled **“STUDIES ON THE PRODUCTION OF MICROWAVE BAKED POTATO CHIPS”** submitted to the **Acharya N.G. Ranga Agricultural University** for the degree of **MASTER OF TECHNOLOGY IN AGRICULTURAL ENGINEERING** is the result of original research work done by me. I also declare that the thesis or any part has not been published earlier in any manner.

Place : Bapatla (**P.NAGA DEEPTHI YADAV**)

Date : **I.D.NO. BEM-12-005**

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Date: **(P. NAGA DEEPTHI YADAV)**

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LIST OF SYMBOLS AND ABBREVIATIONS

APR	:	Adequate Precision Ratio
ANOVA	:	Analysis of variance
Ca	:	Calcium
CCRD	:	Central Composite Rotatable Device
R^2	:	Coefficient of determination
CLSM	:	Confocal laser scanning microscopy
CV	:	Co-variance
^0C	:	Degree centigrade
df	:	Degrees of freedom
db	:	Dry basis
g	:	grams
Hz	:	Hertz
HDPE	:	High Density Polyethylene
HTST	:	High Temperature Short Time
h	:	Hour
HCl	:	Hydrochloric acid
Fe	:	Iron
kPa	:	Kilo Pascal
<	:	Less than
l	:	Litre
LDPE	:	Low Density Polyethylene
$MgCl_2$	:	Magnesium chloride
Mg	:	Magnisium
MHz	:	Mega Herz
mm	:	Milli meter
mg	:	Milligram
ml	:	Millilitre
MT	:	Million Tonnes

min	:	Minute
M	:	Molarity
nm	:	Nanometre
NEB	:	Non-enzymatic browning
N	:	Normality
ppm	:	Parts per million
PSO	:	Penetrated surface oil
%	:	Percent
±	:	Plus or minus
PE	:	Polyethylene
P	:	Poshphorous, Probability
K	:	Potassium
RSM	:	Response Surface Methodology
SEM	:	Scanning Electron Microscopy
s	:	seconds
Na	:	Sodium
NaCl	:	Sodium Chloride
SS	:	Sum of squares
W	:	Watts
Wt	:	Weight

ABSTRACT

Title of thesis	**:**	**“Studies on the Production of Microwave Baked Potato Chips”**
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Deep fried potato chips fried in oils add fat and calories to the product, which may increase risk of gaining weight that may increase risk of obesity and insulin resistance. Manufacturers often use trans-fats in producing processed foods, including potato chips. Currently, there are demands for low-fat or fat-free snack products, which have been the driving force of the snack food industry. Use of microwave baking for food products may be considered as a new way of improving the quality of the foods. The present work was undertaken to study the development of microwave baked potato chips. The effect of microwave baking time and power levels on the physic-chemical characteristics (Moisture, ash, proteins, fats, carbohydrates, browning index and hardness) of baked potato chips was studied. The baked potato chips were compared with the traditional and microwave deep fat fried chips. Response Surface Methodology was used to investigate the optimum operation conditions of microwave baked potato chips and to analyze the effects of microwave baking processing variables, including microwave power, baking time and potato slice thickness. By superimposing individual contour plots of the different responses, regions meeting the optimum conditions were derived. Quadratic regression equations describing the effects of these factors on the physic-chemical attributes were developed. The predicted models were adequate based on the lack-of-fit test and coefficient of determination obtained. At the constant slice thickness and power level, the process parameters namely moisture, fat, protein, carbohydrate and browning index decreased with increased baking time. Under the similar conditions ash and hardness increased. At the constant power level and baking time, the process parameters namely ash, hardness and protein content decreased with increased thickness. Under the similar conditions moisture, fat, carbohydrates and browning index increased. At the constant slice thickness and baking time, the process parameters namely moisture, fat, protein and carbohydrates decreased with increased power levels. Under the similar conditions ash and hardness increased. The optimum values obtained by substituting the respective coded values are 1.5mm, 600 Watts, 8 min. At these optimum conditions, moisture, ash, hardness, fat, protein, carbohydrate and browning index were calculated as 6.12%, 4.12%, 4.40%, 0.44%, 2.53%, 82.5g/100g and 0.43% respectively. The sensory evaluation of the optimized samples was conducted using 9-point hedonic scale. When compared, the microwave baked potato chips contained less moisture, ash, browning index and fat than the traditional and microwave deep fat fried chips. Microwave baked potato chips had lower fat content (0.44%) than microwave fried (28.32%) and conventionally fried (40.02%) potato chips. The baked chips exhibited more proteins, carbohydrates and hardness compared to the other fried samples. The best sample obtained in optimization was kept for storage in polyethylene and aluminium lined polyethylene and stored. It was observed that the aluminium lined polyethylene had retained the quality parameters of baked potato chips when compared with polyethylene packs.

Keywords: Microwave baking, potato chips, response surface methodology, storage.

Chapter I

INTRODUCTION

The history of Potato has its roots in the windswept Andes Mountains of South America. The tough pre-Columbian farmers first discovered and cultivated the potato 7,000 years ago. They were impressed by its ruggedness, storage quality and its nutritional value. And it was even later, about 1570, that the first potato made its way across the Atlantic to make a start on the continent of Europe.

It took three decades for the potato to spread to the rest of Europe. Europe waited until the 1780's before the potato gained prominence anywhere. About 1780, the people of Ireland adopted the rugged food crop. The primary reason for its acceptance in Ireland was its ability to produce abundant, nutritious food. Unlike any other major crop, potatoes contain most of the vitamins needed for sustenance. Soon the potato gained wide acceptance across Europe and eventually made its way back over the Atlantic to North America. As time passed, the potato became one of the major food stuffs of the world.

Potato is most widely grown vegetable crop in the country with a share of 25.7%. The area under potato cultivation is 1.28 Million ha with total production of 22.49 MT. The main varieties of potato grown in the country are Kufri Chandramukhi, Kufri Jyoti, Kufri Badshah, Kufri Himalani, Kufri Sindhuri, Kufri Lalima etc. Uttar Pradesh is the leading potato growing state in country with a production of 9.53 million tone followed by West Bengal and Bihar.

Potato *(Solanum tuberosum*) is a starchy, tuberous crop of the *solanaceae* family. It is semi perishable in nature, containing about 80% water and 20% dry matter. A major portion of dry matter is starch and sugar that constitute 16% on fresh wet basis, crude protein content is 2% and fat is very low at 0.3% (Singh *et al.*, 2007). India stands third in potato production in the world. Potato is world’s most widely grown tuber crop and fourth largest food crop in terms of fresh produce after rice, wheat and maize for its contribution towards securing the food and nutrition, and eradicating malnutrition and hunger, especially in developing world (Marwaha *et al.*, 2010).

Potatoes are considerably richer source of nutrient than of energy. They are virtually free of fat, although they are quite easily turned into fatty foods. Nutritionally potatoes are best known for their carbohydrate content. The predominant form of the carbohydrate present in it is starch. The starch provides bulk, offers protection against colon cancer, improves glucose intolerance and insulin sensitivity, lowers plasma cholesterol and triglycerides concentration, and reduces fat storage (Tamaki *et al.*, 2003).

Processing of potato into various processed products is a viable option which can help to extend the shelf-life, save the wastage of precious food during gluts, solve the problem of storage, and also serve as a means to increase the supply in off seasons. It adds value to potatoes and therefore gives better returns. Processed products have an attractive color, acceptable texture and good flavour (Marwaha *et al.,* 2010).

Potatoes are processed into many types of products such as dehydrated products, frozen products, puffed products, French fries, patties, dice, powders, flakes and canned products like chips/wafers *etc.*, in which potato chips are very popular and highly consumed product (Nath *et al.*, 2007). For 150 years potato chips have enjoyed high popularity in different countries due to their specific sensory properties, characteristic color, taste, flavor, and crispy texture.

Thin slice of potato which are deep fried or baked until crisp are referred as potato chips. It serves as an appetizer, side dish. The simplest chips are cooked and salted but manufactures can add wide variety of flavouring herbs, spices, cheese, color and artificial additives. The prepared potato chips are fried in edible oils. These oils could be mustard oil, palm oil, rice bran oil and blended oil (Jagoba and Rosana, 2002)**.** Frying of potato slices in hot oil are characterized by relatively high content of fat (36.8-38.1%) (Singh *et al.,* 2007) and low amount of water (<2%) (Franco *et al.,* 2008)**.**

The Semi-products, as well as ready to eat potato products, contain the same nutritive components as potato itself, but in different amounts depending on the products. Apart from nutritive components there are two primary types of toxins associated with potatoes: acrylamide and glycoalkaloids. The level of acrylamide depends upon the cultivar as well as processing methods (Peksa *et al.,* 2006).

The heat intensity and cooking method are directly related to the formation of acrylamide. Boiled and baked potatoes generally have less acrylamide; where as french fries and potato chips have higher acrylamide content. Acrylamide formed when potatoes cooked at high temperatures, causing a chemical reaction between sugars and an amino acid called asparagine that is both present in potatoes (Friedman and Levin, 2008).

Potatoes are a nutritious root vegetable that is naturally free of fat, cholesterol and sodium, low in calories and a good source of vitamin C, antioxidants, potassium and fiber. Yet, when potatoes are sliced and deep fried in oil and processed with other ingredients to enhance their flavor and extend their shelf life, they become unhealthy. Deep fried potatoes in oils add fat and calories to the product, which may increase risk of gaining weight. Each gram of fat supplies 9 calories, more than twice the amount of calories per gram of carbohydrate or protein which each supply 4 calories per gram. Increasing body weight may increase risk of obesity and insulin resistance. Manufacturers often use trans-fats in producing processed foods, including potato chips. Consuming trans-fats may clog arteries, block the flow of oxygenated blood to heart and increase risk of coronary heart disease, heart attack and death (Saguy and Dana, 2003). Acrylamide is a chemical in potato chips that may increase risks of cancer and nerve damage. Research by scientists at the National Institute of Food and Nutrition in Warsaw, Poland, published in "The American Journal of Clinical Nutrition" in 2009 discovered that chronic ingestion of acrylamide-containing potato chip products induces a pro-inflammatory condition which increases the risk for progression of atherosclerosis, hardening of the arteries (Sumnu, 2009).

Potato chips have been popular snacks for more than a century and its production is indeed a more competitive industry than other snack products. Currently, there are demands for low-fat or fat-free snack products, which have been the driving force of the snack food industry. In conventional heating, employing a direct flame, heated air, infrared elements, direct contact with a hot plate, and so on, the heat source causes food molecules to react largely from the surface inward, so that successive layers heat in turn. This produces a temperature gradient which can burn the outside of piece of food long before the temperature within has risen appreciably.

Microwaves are electromagnetic waves of radiant energy, differing from such other electromagnetic radiations as light waves and radio waves only in wavelength frequency. They fall between radio waves and infrared radiations, with wavelength in the range of about 25 million to 0.75 billion nanometers, which is equivalent to about 0.025-0.75m. Microwave wavelengths of about 0.025-0.75m correspond to frequencies of about 20KHz-400MHz (1Hz=1cycle/second) for food application the most approved & most commonly used microwave frequencies are 2450MHz and 915 Hz (Chandrasekaran *et al.,* 2013).

Microwave energy is made up of electromagnetic waves that vibrate at billions of times per second. Polar molecules like molecules of water, that contain areas of both positive and negative charge, will rotate to align themselves with an applied electromagnetic field. When microwaves are applied to food these polar molecules attempt to rotate, and since the field vibrates so rapidly they are in constant motion. These molecular movements cause heat. Therefore, microwave energy is an efficient form of heating for foods which contain a high percentage of water. Heat is generated inside the food product and moves toward the surface. The internal steam pressure also forces moisture towards the surface, which is the opposite of how conventional heating works (Chavan and Chavan, 2010)**.**

Microwave food processes offers a lot of advantages such as less start-up time, faster heating, energy efficiency, space savings, precise process control, selective heating and food with high nutritional quality (Marra *et al.*, 2010). There are a number of advantages of microwave baking in food processing technology like significant reduction in the thermal processing time while making food safe for consumption is the major advantage of microwave sterilization processing. Reduction in processing time results in more fresh-like taste and texture, and improves visual appeal of the food. The reduction of processing time may also potentially increase retention of nutrients in the thermally processed foods. Instantaneous turn-on and off of the process allows for a more precise process control, better energy usage, and cleaner working environment in food processing facilities. Deep-fat fried products contain a substantial amount of oils because the foods with low fat content absorb large amount of oil during deep fat frying (Oztop *et al.*, 2006). So the main advantage of baking is that oil free chips can be produced when compared with the traditional potato chips.

Keeping in view the importance of fat free chips, the present work was taken up with the following specific objectives:

1. To study the effect of baking time and microwave power levels on physico-chemical characteristics of baked potato chips.

2. To Optimization the process parameters.

3. To compare the microwave baked potato chips with traditional and microwave deep fat fried chips.

4. To study the shelf life of baked potato chips using polyethylene and aluminium lined polyethylene.

Chapter II

REVIEW OF LITERATURE

This chapter deals with the processing methods of potato chips, blanching treatments, microwave processing, response surface methodology and storage of potato chips. The various findings by different researchers in these areas of work have been reviewed and presented. The past research findings were critically examined with reference to the objectives of the present investigation.

2.1 PROCESSING OF POTATO CHIPS

Forough *et al.* (2013) study the effect of Linseed (*Linum usitatissimum* L.) hydrocolloid on physico-chemical properties of fried potato chips (moisture content, oil uptake, acidity, peroxide value, texture and colour). The slices of potato were immersed in 1.5%, 2% and 2.5% aqueous solution of Linseed hydrocolloids at room temperature for five minutes. A control treatment was immersed in water and a Xanthan treatment was immersed in aqueous solution of Xanthan hydrocolloid. The results showed that the treatment with 1.5% Linseed hydrocolloid was the best in decreasing oil uptake, acidity and peroxide value of extracted oil, increasing moisture content of potato chips with no changes in texture compared to control sample. Sensory evaluation of treated potato chips did not show significant differences compared to Control samples.

Basuny *et al.* (2012) studied the effect of different frying process (atmospheric and vacuum) on physical and sensory properties of potato chips and to evaluate frying oil quality. In six consecutive days, sunflower oil was fried under atmospheric condition (at 180 ^{0}C ± 5 ^{0}C and vacuum frying (at 120 ^{0}C, 5.37kPa absolute pressure) for 20 min each hour in a 4 hour shift. Physical properties (oil uptake and moisture content), Organoleptic tests were performed on fried potato chips and quality limits (acid value, peroxide value, polar content, polymer content and oxidized fatty acids) of the sunflower oil samples were measured. The results showed that vacuum frying at 120 ^{0}C under pressure of 5.37 kpa night produce potato chips with acceptable quality and improved quality of frying oil.

Yagua and Moreira (2011) estimated the kinetics of oil absorption and oil distribution in the potato chips. Non-linear regression model was used to describe the oil absorption in potato chips with time. Moisture content, oil content, microstructure, diameter and thickness expansion, bulk density, true density, and porosity of chips fried at different temperatures (120, 130 and 140 ^{0}C) was performed to evaluate the effect of process temperature on the product. The results revealed that the final oil content of the potato chips was 0.072 ± 0.004, 0.062 ± 0.003, and 0.059 ± 0.003 g/g solid for frying temperatures of 120, 130, and 140 ºC, respectively. These values are lower (80–87% less) than the not de-oiled potato chips. A significant difference ($P < 0.05$) was observed in oil content and oil distribution within temperatures. The rate of change in product quality attributes was greatly affected by temperature but moisture content, bulk density, true density, porosity, diameter shrinkage, and thickness expansion were not affected. The convective heat transfer coefficient changed considerably as frying progressed; it increased with temperature reaching a maximum between 2200 and 2650 W/ m^2 K depending on frying temperature.

Elfaki and Abbsher (2010) evaluated the nutritive value of potato (alpha variety) which was subjected to three different cooking methods (boiling, frying and Sudanese home cooking style, stew). Proximate analysis, minerals, amino acids content and sensory evaluation were determined. Protein was found to decrease insignificantly by boiling while frying caused a significant increase in protein. The stew has higher significant increase in protein, ash, fat and fiber content but high significant increase in fat was caused by frying. CHO showed a significant decrease in stew and by boiling while frying showed a significant increase in CHO. The starch content was significant decreases by boiling and stew while significantly increased by frying. Boiling was found to decrease insignificantly the amount of Na and Ca, while significantly decreased K, P and Mg and increased insignificantly the Fe. Amino acid, argnine and methionine were destructed by the three methods of cooking. Sensory evaluation showed that the texture was not significantly affected by the three methods of cooking. There is no significant difference was observed in flavour, colour, taste and overall quality in stew and fried potato.

Basuny *et al.* (2009) determined the relationship between the sensory evaluation of potato chips and chemical composition of six potato varieties (Osina, Sponta, Glactica, Valour, Ledy valour and Hana). Sunflower oil was fried at 180± 5^{0}C, 4hr every day for five consecutive days. The results revealed that organoleptic properties for

Osina, Sponta and Glactica potato varieties obtained from fried sunflower oil were categorized as good and also they were effective in improving the overall quality of sunflower oil. It also concluded that Osina, Sponta and Glactica potato varieties were more suitable for frying processes.

Kita and Figiel (2008) studied the effect of different drying methods on fat content, texture, color and sensory properties of potato chips. The material for investigation were potato chips fried in palm oil at temperature of 175^0C to range 20%, 15% and 5% of moisture and then post dried using different methods to moisture level below 2%. Control sample were potato chips fried to less than 2% moisture. Investigations proved that shortening frying time and post-drying decreases fat content in chips lighter color.

Mai *et al.* (2007) studied the reducing of oil content of fried potato crisps considerably using a ‘sweet’ pre-treatment technique. Potato crisps were blanched, pre-dried, and dipped in the solution of sugar (23.07 wt %) 2s before frying at 180 ^{0}C. The results revealed that crisps that had been treated had about 30% less oil than the samples that were not treated. The treatment did not affect the final moisture content of crisps. A linear oil–moisture relationship of samples during frying was obtained. The potato crisps with dipping had more shrinkage compared with the non-dipping ones.

Namtip *et al.* (2006) introduced the Drying kinetics and quality of potato chips undergoing different drying techniques. The Potato slices were dried using both low-pressure superheated steam drying (LPSSD) and hot air drying techniques. The effects of blanching as well as the drying temperature on the drying kinetics as well as various quality attributes of potato slices viz. color, texture, and brown pigment accumulation were also investigated. The results revealed that LPSSD took shorter time to dry the product to the final desired moisture content than that required by hot air drying when the drying temperatures were higher than 80°C. Longer blanching time and lower drying temperature resulted in better color retention and led to chips of lower browning index. Blanching also reduced the hardness and shrinkage of the product. The use of different blanching periods did not significantly affect the product hardness.

Granda *et al.* (2005) studied the effect of potato components (reducing sugars and asparagine) on acrylamide content during frying in a traditional fryer. A model system was developed by infusing leached potato slices with predetermined amounts of glucose and asparagine. The results revealed that increasing glucose and asparagines content in the slices increased the acrylamide content in the potato chips. It also revealed that color could not be used as an indication of acrylamide content because potato chips with similar color had very different acrylamide concentration.

Bouchon and Pyle (2004) estimated the oil absorption capacity of different restructured potato chips during frying. Low leach potato flakes was chosen as ingredient while native and pregelatinized potato were taken as complementary ingredients. The results revealed that oil absorption increased significantly when reducing the thickness of the product. It was also found that the product containing native potato starch as an ingredient picked up the lowest amount of oil when sheeted in to a thick chip and larger amounts of oil when sheeted in to a thin chip.

Nema and Prasad (2004) developed potato chips using 'Kufri Chandramukhi' variety using edible refined oil for frying. The experiment was conducted to observe the variations in moisture content, oil content and yield at different temperature and duration of frying. The results revealed that frying at 170^{o}C for 6 min gave potato chips of most acceptable qualities with 1.1% moisture and 38.5% oil content.

Phillippy *et al*. (2004) studied the phytate (myo-inositol hexakisphosphate) contents of eight varieties of potato (Solanum tuberosum) stored at 4^{o}C for approximately 3 months ranged from 0.111% to 0.269% of dry weight. There were no significant differences in phytate content between raw russet potatoes and those which had been boiled, baked or microwaved until fully cooked. French fries, potato chips and dehydrated potato flakes contained 0.174%, 0.095% and 0.205% phytate, respectively, on a dry weight basis. Only phytate was detected in raw russet potatoes, but smaller amounts of inositol pentakisphosphate were also present in the fries, chips and flakes.

Bouchon *et al*. (2003) determined the oil-absorption process in deep-fat fried potato cylinders (frying temperatures of 155 °C, 170 °C, and 185 °C) allowed to distinguish 3 oil fractions: structural oil (absorbed during frying), penetrated surface oil (suctioned during cooling), and surface oil. Results showed that a small amount of oil penetrates during frying because most of the oil was picked up at the end of the process. After cooling, oil was located either on the surface of the chip or suctioned into the porous crust microstructure, with an inverse relationship between them for increasing frying times.

Jagoba and Rosana (2002) studied the effect of oil temperature (118, 132, 144°C) and vacuum pressure (16.661, 9.888, and 3.115 kPa) on the drying rate, oil absorption and product quality attribute (shrinkage, color, and texture) of potato chips. Furthermore, the characteristics of the vacuum fried potato chips (3.115 kPa and 144°C) were compared to potato chips fried under atmospheric conditions (165°C). Potato chips fried at lower vacuum pressure and higher temperature had less volume shrinkage while potato chips fried under vacuum (3.115 kPa and 144°C) had more volume shrinkage, slightly softer, and lighter in color than the potato chips fried under atmospheric conditions (165°C). Hardness values increased with increasing oil temperature and decreasing vacuum levels.

Kita (2002) determined the relationship between the texture of potato crisps and starch, nitrogen compounds, non-starch polysaccharides and lignin content. Analyses of five different potato varieties-''Aster'', ''Karlena'', ''Ania'', ''Saturna'', ''Panda'' harvested in 1996 and 1997, were conducted on potato tubers, before and after peeling, and the crisps produced. Crisps were characterised by proper colour, odour, flavour and texture. The results showed that texture were good for both ''Saturna'' and ''Panda'' varieties, while the least were ''Ania''. The texture of crisps depended on the content of starch in potato tubers and nitrogen substances and non-starch polysaccharides. Among non-starch polysaccharides, protopectins had the most important influence on crisp texture.

Wang and Brennan (1995) studied the Structural changes in potato during drying by using light microscopy. The results showed that the degree of shrinkage of potato during low temperature drying is greater than at high-temperature drying. The density and porosity are affected by shrinkage. In the initial stage of drying the density increased as the moisture content decreased, reaching a peak and then decreased with further decrease in moisture content. The density at given moisture content decreased with increasing drying temperature. The percentage changes in thickness, length and width of the potato samples during drying increased linearly with decreasing moisture content.

2.2 BLANCHING PRETREATMENT

Samir *et al.* (2013) studied the Impact of pre-treatments on the acrylamide formation and organoleptic evolution of fried potato chips. The results revealed that blanching process caused significant decreases in acrylamide content of fried potato. The highest decrease was observed for those samples blanched in $MgCl_2$ (0.1 M), L-cysteine (0.05 M) and 0.01 M of citric acid solutions, 97.97, 97.17 and 93.43%, respectively. Soaking of potato slices in water or different solutions significantly reduced the formation of acrylamide. The decreases in acrylamide content ranged from 61.61 to 97.47%. Addition of fresh leaves into frying oil significantly influenced acrylamide formation. Oregano, rosemary, bamboo, guava and olive leaves caused the greatest reductions. Potato slices blanched in distilled water at 65°C, NaCl, $MgCl_2$ and 0.1 M glutamine had significantly the highest scores of overall acceptability.

Elfnesh *et al.* (2011) investigated the influence of growing environment and blanching on chips quality of five improved potato cultivars (Chiro, Zemen, Bedassa, Gabissa and Harchassa). In the blanching treatment, sliced potatoes were blanched at 90°C for about 5 min. Both blanched and unblanched slices were fried at 175°C for about 5 min using vegetable oil. Blanching improved chips color, texture, sweetness, and crispness while reducing sourness and bitterness, ultimately increased the overall acceptability.

Elizabeth and Franco (2009) determine the kinetics of water loss and oil uptake during frying of pre-treated potato slices under vacuum and atmospheric pressure. Potato slices (diameter- 30 mm; width- 3 mm) were pre-treated in the following ways: (i) raw potato slices ‘‘control’’; (ii) control slices were blanched in hot water at 85 °C for 3.5 min; (iii) blanched slices were dried in hot air until reaching a moisture content of 0.6 g water/g dry basis. The slices were fried under vacuum (5.37 kPa, absolute pressure, at 120, 130 and 140°C) and atmospheric conditions (at 180 °C). The results revealed that control and blanched vacuum fried potato chips increased their final oil contents to 57.1% and 75.4% respectively, when compared with those fried at atmospheric pressure.

Franco *et al.* (2008) established the kinetics of oil absorption and distribution in the structure of potato slices during frying, considering the effects of three oil temperatures and a blanching pre-treatment. Either raw or blanched potato slices

(Desiree variety, diameter: 30 mm, thickness: 3.0 mm) were fried at three constant (±1ºC) oil temperatures: 120, 150 and 180ºC. Potatoes were blanched in hot water at 85ºC for 3.5 min and raw potato slices were used as the control. The amount of oil absorbed was quantified during frying at four time intervals. The following fractions of the total oil (TO) content of potato slices were determined: (i) structural oil (STO); (ii) penetrated surface oil (PSO); and (iii) surface oil (SO). The results revealed that PSO constituted the highest fraction of the total oil content. The blanched potato chips absorbed more oil than the control chips. The higher the frying temperature, the lower the oil absorbed by chips. Confocal laser scanning microscopy (CLSM) and scanning electron microscopy (SEM) were used to study the surface topography of potato chips.

Mestdagh *et al*. (2008) added several components to the blanching water of potato crisps and studied the impact of chemical pre-treatments on the acrylamide formation and sensorial quality of potato crisps. The results revealed that Calcium ions, sodium acid pyrophosphate, citric, acetic and L-lactic acid significantly reduced the final acrylamide, glycine and L-lysine contents. The acids, NaCl and calcium-containing additives also lowered acrylamide contamination in the final product. The sensory analyses of these crisps have shown a successful combination between acrylamide mitigating treatments and crisps of acceptable or even superior product quality, compared to control crisps blanched in water.

Marisol *et al*. (2007) reported the effect of some pre-treatments and oil temperatures in the kinetics of oil absorption and distribution in the structure of potato. Pre-treated potato slices (Desire´e variety, diameter: 30 mm, thickness: 3.0 mm) were fried at four constant oil temperatures (±1ºC): 120, 140, 160 and 180ºC. The tested pre-treatments were: (i) blanching in hot water at 85ºC per 3.5 min (control); (ii) blanching as in (i) and then immersion in a NaCl solution of 20 g/L per 5 min and at 200 rpm of agitation and 25ºC (salt impregnation); (iii) blanching as in (i) and then covering with an edible film solution of hydroxypropylmethylcellulose – HPMC – (16 g/L per 20 min at 70ºC). Potato chips absorbed during frying at 180ºC nearly 38% of the total oil content, and almost 62% of the total oil content remained at the chip surface without penetrating into the microstructure (average values for the three pre-treatments tested). This situation reverses during the cooling stage and 65% of the total oil content was absorbed by potato chips and only 35% remained at the chip surface. The results revealed that potato chips coated with the edible film HPMC absorbed more oil than control and salt impregnated potato chips ($P<0.05$).

Franco *et al*. (2007) studied the development of color formation in pre-dried potato slices during frying and acrylamide formation in the potato chips. Prior to frying the potato slices (Desiree variety, diameter: 37mm and width 2.2mm) were blanched in hot water at 85°C for 3.5min. Unblanched slices are air dried to reach 60% moisture content (wet basis). Later slices were fried at 120, 140, 160 and 180°C until reaching the moisture content 1.8% for color qualification. Acrylamide concentration was determined only in finally fried chips and these are compared with that of two brands of commercial chips (Moms and Lays). Then color measurement was done by using an computer vision techniques and color value in L*a*b* units were recorded by using colour difference parameters (ΔE). Pre-dried potato chips presented acrylamide content much lower than those of control and commercial chips.

Marisol *et al*. (2007) reported the effect of some pre-treatments and oil temperatures in the kinetics of oil absorption and distribution in the structure of potato chips during the frying process and also during the posterior cooling. Pre-treated potato slices (Desiree variety, diameter: 30 mm, thickness: 3.0 mm) were fried at four constant oil temperatures (±1°C): 120, 140, 160 and 180°C. The pre-treatments were: (i) blanching in hot water at 85°C per 3.5 min (control); (ii) blanching as in (i) and then immersion in a NaCl solution of 20 g/L per 5 min and at 200 rpm of agitation and 25°C (salt impregnation); (iii) blanching as in (i) and then covering with an edible film solution of hydroxypropylmethylcellulose – HPMC – (16 g/L per 20 min at 70°C). It was absorbed that Potato chips frying at 180°C nearly 38% of the total oil content, and almost 62% of the total oil content remained at the chip surface without penetrating into the microstructure. This situation reverses during the cooling stage and 65% of the total oil content was absorbed by potato chips and only 35% remained at the chip surface. It was also shown that potato chips coated with the edible film HPMC absorbed more oil than control and salt impregnated potato chips ($P<0.05$).

Severini *et al*. (2005) studied the combined treatments of blanching and dehydration on potato cubes. Blanching was alternatively performed in hot distilled water, hot sugary-saline solution, by microwaves in distilled water or by microwaves in saline solution. Drying was alternatively carried out in an air cabinet, a microwave oven or a belt drier. In terms of process speed, colour retention and water absorption capacity, the best results were obtained combining microwave blanching with dehydration on the belt drier.

Suzana *et al.* (2004) investigated the influence of oil origin (sunflower oil, vegetable oil, palm oil) and pre-frying treatment (blanching in water solutions of calcium chloride or citric acid, immersion in some carboxymethyl cellulose derivatives solutions) on the oil absorption in fried potato strips. The results revealed that the oil origin has no significant influence on the potato fat uptake. The pre-frying treatments considerably decreased the oil absorption. The lowest oil absorption was found for the potato blanched in calcium chloride solution, and the greatest for the potato blanched in water. Immersion in hydrocolloid solution affected the fried potato fat uptake. The best result was observed for the potato strips blanched in 0.5% calcium chloride solution following immersion in 1% solution of carboxymethyl cellulose, where the reduction of oil content reached 54%.

Severini *et al.* (2003) studied the Prevention of enzymatic browning in sliced potatoes by blanching in boiling saline solutions. The response surface methodology was applied to investigate the way in which variables, such as time of treatment, sodium or calcium chloride concentrations and lactic acid concentration, affect the blanching of potato slices in boiling solutions. Two 3 factor-5 level, second order central composite designs were developed to analyse the considered variables. Results showed that all the considered blanching treatments allowed polyphenoloxidase inactivation. With regard to colour, the use of calcium chloride, at low concentrations, was better than the sodium chloride. Under the applied operative conditions, the best results were revealed with short times of treatment and low lactic acid concentrations.

Joshi and Nath (2002) studied the effect of pre-treatments on quality and shelflife of fried chips from sprouted tubers of potato variety ‘Kufri Chandramukhi’. The results revealed that dipping 1.5-2.0 mm thick slices from unpeeled sprouted tubers for 3 min in hot (85°C) solution of 0.5% citric acid + NaCl + 0.25% $CaCl_2$ was the best pre-treatment and 17sec-195°C was the best condition for deep oil frying of chips. Residual moisture and oil contents of fried chips for peeled potatoes (moisture: 3.5-4.7%, oil: 23.4-34.8%) and unpeeled potatoes (moisture: 3.5-4.8%, oil: 24.6-35.5%) did not differ significantly. It also showed that loss of acceptability of fried chips during storage were primarily due to oxidative rancidity. Addition of 0.02% tertiary butyl hydroquinone to frying oil reduced the rate of changes in peroxide value during storage.

Karki and Maskey (2001) observed the effect of pre-frying dehydration on the potato chips. The potato slices of 1.5 mm thick were blanched in boiling water for 1.5 min, dipped in to 1000 ppm sulphur dioxide solution containing 2%NaCl and 0.2% citric acid for 15 min and dehydrated to 72%, 58%, 44% and 26% moisture content at 50°C in a cabinat dryer. The fresh slices were taken as a control. Slices were fried in refined soya bean oil, packed in polyethylene bag and analysed for appearance, texture and oil content. The results concluded that the potato chips of better texture and appearance with minimum oil content of 29.45% could be prepared by partial dehydration of slices to 44% before frying.

Truong *et al*. (1998) studied the Textural Properties and Sensory Quality of Processed Sweet potatoes as Affected by Low Temperature Blanching. Sweet potatoes stored for 9-12 months after harvest were cut in to cylindrical pieces and were blanched at 50°and 80°C for 15-274 min. samples of selected blanching treatments were canned in syrup for textural and sensory evaluations. Textural properties were measured by uniaxial compression and textural profile analysis. The results revealed that the optimal temperature for maximal firmness retention was about 62°C. For canned SP, the 62°C blanched samples were more intact (2-3 fold) and firmer (2-7 fold) than controls. Sensory texture and overall acceptability were greatest for samples blanched at 62°C for 30 or 45 min before canning.

2.3 MICROWAVE PROCESSING

Murali and Lakshmi (2013) studied the effects of microwaves on quality of fried potatoes (moisture content, oil content, color and hardness) and also the process was optimized by using Taguchi Technique. Microwave power level (400W, 600W & 800W), frying time (2.0, 2.5 & 3.0 minutes) and oil type (sunflower, corn and ground nut oil) were the parameters used in the study. Moisture content of potatoes decreased whereas oil content, hardness and ΔE values of the potatoes increased with increasing frying time and microwave power level. The potatoes with the highest oil content were found for ground nut oil. The optimum condition was found as frying at 600W power level, for 2.5 minutes in sunflower oil.

Tomasz *et al.* (2013) studied the optimization of process parameters for microwave-vacuum puffing of black radish slices using the response surface method. The best values of process parameters were found using the RSM. The processing parameters values were determined to be 0.39 $kg \cdot kg^{-1}$ (wet basis) moisture content of pre-dehydrated radish slices, 14.5 kPa vacuum absolute pressure and 80 s of microwave heating time during puffing (for the 650 W power output of the microwave generator).

Sezin *et al.* (2010) studied the effect of microwave pre-thawing of frozen potato strips on acrylamide level and quality of french fries. The objective was to reduce frying time, and acrylamide level of french fries by microwave pre-thawing of frozen potato strips. Frozen par-fried potato strips (8.5x8.5x70mm) were thawed in a microwave oven prior to final frying in sunflower oil at 170, 180, and 190°C. Potato strips that were final fried without pre-thawing were considered as the control. Acrylamide analysis was performed by liquid chromatography-mass spectrometry (LC-MS) method. Microwave pre-thawing of frozen strips reduced the acrylamide level of French fries by 10% (from 17.7 to 15.9 ng/g), 89% (from 72.1 to 8.0 ng/g), and 64% (from 50.5 to 18.4ng/g) for frying at 170, 180, and 190°C respectively, in comparision to the control sample.

Yan *et al.* (2009) studied the influence of drying conditions of the spouted bed microwave drying on puffing characteristics of potato cubes and compared them with the direct microwave and hot air drying methods. Results of response surface analysis showed that expansion ratio and breaking force were significantly ($P < 0.05$) affected by conversion point, size of potato cubes, and microwave power, only the size of potato size had a non significant effect ($P > 0.05$) on expansion ratio. Using expansion ratio and breaking force as indicators of puffing characteristics, the optimum conditions were moisture content of conversion point of about 60%, size of potato cubes of 10–12 mm, and microwave power at 2–2.5Wg^{-1}.

Oztop *et al*. (2007) studied the microwave frying of osmotically dehydrated potato slices by using response surface methodology. Moisture content, oil content, hardness and color of the fried potatoes were used as quality parameters. Microwave power level (400, 550 & 700 W), frying time (1.5, 2.0 & 2.5min) and osmotic dehydration (20%W/W at 30°C) time (15, 30 & 45 min) were the independent variables. The optimum condition was found as frying at 400 W microwave power levels for 1.5 min after 39 min of osmotic dehydration time.

Xian-Ju Song *et al*. (2007) studied the effects of vacuum microwave pre-drying and vacuum frying conditions on the quality of vacuum-fried potato chips. The results showed that both the moisture content and oil content of potato chips decreased with increasing vacuum microwave pre-drying time. During vacuum frying, the moisture content of potato chips decreased with increasing frying temperature and time, while the oil content increased. Statistical analysis with response surface regression showed that the moisture content, oil content, and breaking force of potato chips were significantly ($P<0.05$) correlated with vacuum microwave pre-drying time, frying temperature, and frying time. Based on surface responses and contour plots, optimum conditions were vacuum microwave pre-drying time of 8–9 min, vacuum frying temperature of 108-110 ºC, and vacuum frying time of 20–21 min.

Oztop *et al*. (2006) studied the effects of microwaves on quality of fried potatoes (moisture content, oil absorption, color and hardness) and the process was optimized by using Taguchi Technique. Microwave power level (400 W, 550 Wand 700 W), frying time (2.0, 2.5 & 3.0 min) and oil type (sunflower, corn and hazelnut oil) were the parameters used. Moisture content decreased whereas oil content, hardness and colour of potatoes increased with increasing frying time and microwave power level. The potatoes with the highest oil content were found to be the ones that were fried in the hazelnut oil. The optimum condition was found as frying at 550W microwave power level, for 2.5 min in sunflower oil. At this condition, the oil content of fried potatoes was lower than that of conventionally fried ones.

2.4 RESPONSE SURFACE METHODOLOGY

Yadav *et al.* (2012) optimized osmotic dehydration of peach slices using response surface methodology (RSM) with respect to sucrose concentration (50-70°B), immersion time (2-4 h) and process temperature (35-55 °C) for maximum water loss (WL), minimum solute gain (SG) and maximum rehydration ratio (RR) as response variables. A central composite rotatable design (CCRD) was used as experimental design. The results revealed that optimized conditions were sucrose concentration-69.9°B, time 3.97 h and temperature 37.63 °C in order to obtain WL of 28.42 (g/100 g of fresh weight), SG of 8.39 (g/100 g of fresh weight) and RR of 3.38.

Ismail Eren and Figen (2007) determine the optimum processing conditions that yield maximum water loss and weight reduction and minimum solid gain and water activity during osmotic dehydration of potatoes. Temperature (20-60 °C), processing time (0.5–8 h), sucrose (40–60% w/w) and salt (0–15% w/w) concentrations were the factors investigated with respect to water loss (WL), solid gain (SG), weight reduction (WR) and water activity (aw). Experiments were designed according to Central Composite Rotatable Design with these four factors each at five different levels, including central and axial points. Experiments were conducted in a shaker (Thermoshake-Gerthardt) with constant agitation of 200 rpm and solution to sample ratio of 5/1 (w/w). The results showed that optimum operating conditions were found to be temperature of 22°C, sucrose concentration of 54.5%, salt concentration of 14% and treatment time of 329 min. At this optimum point, water loss, solid gain, weight reduction and water activity were found to be 59.1 (g/100 g initial sample), 6.0 (g/100 g initial sample), 52.9 (g/100 g initial sample) and 0.785, respectively.

Nath *et al*. (2007) studied on Ready-to-eat (RTE) potato snacks were developed with high temperature short time (HTST) air puffing process based on centre composite RSM design. The effects of process parameters viz. puffing temperature (175-275°C), puffing time (15-75 s), initial moisture content (30-40%) and air velocity (2.4-4.8 m/s) on quality attributes such as expansion ratio, hardness, ascorbic acid loss and overall acceptability of the products were investigated. The optimum product qualities in terms of expansion ratio (4.7 times), hardness (1120.83 g), ascorbic acid loss (17.53%, db) and overall acceptability (7.56) were obtained at puffing temperature of 235.46°C, puffing time of 51.11 s, initial moisture content of 36.74% and air velocity of 3.99 m/s.

Varnalis *et al*. (2004) evaluated the Optimisation of high temperature puffing of potato cubes using response surface methodology. One cubic centimetre potato cubes were blanched, sulfited, dried initially for between 40 and 80 min in air at 90°C in a cabinet drier, puffed in a high temperature fluidised bed and then dried for up to 180 min in a cabinet drier. The results revealed that the final moisture content was 0.05 dwb. Later the product was optimised using response surface methodology, in terms of volume and colour (L*, a* and b* values) of the dry product, as well as rehydration ratio and texture of the rehydrated product. The operating conditions resulting in the optimised product were found to be blanching for 6 min in water at 100°C, dipping in

400 ppm sodium metabisulfite solution for 10 min, initially drying for 40 min and puffing in air at 200°C for 40 s, followed by final drying to a moisture content of 0.05 db.

2.5 STORAGE OF PROCESSED POTATO

Shweta *et al.* (2014) prepared Potato flour from two locally available varieties (Kufri Pukhraj and Kufri Jyoti), packed in four packaging materials (HDPE, LDPE pouches, aluminium laminate and glass bottles) and then stored for three months at room temperature. Quality parameters like colour, NEB (non enzymatic browning), flavor and moisture content were investigated at regular interval of 15 days during storage. The results revealed that significant differences occurred in all the quality parameters measured. However, storage of potato flour for 3 months did not result in any significant changes in the flavor, except that moisture and NEB increased and color (L value) decreased.

Saranya and Barathi (2012) attempted to produce potato chips in different oils (Sunflower oil, Gingelly oil, Rice bran oil, Corn oil, Palm oil, Groundnut oil and Coconut oil) and evaluated the keeping quality of potato chips during the storage period of 45 days. The quality parameters such as Sensory analysis, Microbiological analysis, Nutrient analysis, Rancidity and Trans fat changes were performed on 7th day, 14th day, 24th day, 34th day and 45th day of the storage period. The results revealed that potato chips prepared in corn oil and rice bran oil holds good in all quality parameters and there was an excellent sensory scores, decreased microbial count, decreased nutrient change, absence of rancidity and trans fatty acid changes during the storage period of 45 days.

Abong *et al.* (2011) observed the effect of packaging and storage temperature on the shelf life of crisps from four Kenyan potato cultivars. Potato tubers were processed in to crisps of 1.5mm thickness at a frying temperature of 70°C for 3.5 min. Then the crisps were packed into aluminium foil pack and polyethylene bags and stored at 25, 30 and 35°C for 24 weeks. The results revealed that aluminium lined foil pack was the most effective in controlling increase in moisture content, peroxides values and free fatty acid levels. Crisps stored at 35°C had significantly ($P < 0.05$) shorter life compare to those stored at 25 and 30°C. The flavour, aroma and acceptability scores of the crisps significantly ($P < 0.05$) decreased and varied with cultivar and storage temperature.

Sandhu *et al*. (2002) conducted Studies with the four commercially grown potato cultivars ('Kufri Jawahar', 'Kufri Jyoti', 'Kufri Badshah' and 'Kufri Chandramukhi') and six frying media (refined cottonseed oil, refined groundnut oil, extra refined sunflower oil, refined soybean oil, palm oil and Dalda) to find out their suitability for potato chip manufacture. Physico-chemical characteristics (total solids, total soluble solids, reducing sugars and specific gravity of potato cultivars and moisture content, oil uptake, peroxide value, free fatty acids, colour) and sensory quality of chips were studied. Shelf-life studies were conducted in three different packages (polythene, laminated paper and aluminium foil bags) under ambient conditions at temperature 14°-34°C and relative humidity 45-77%. The results revealed that 'Kufri Jawahar' had the most desirable quality characteristics and produced the best quality chips. The highest consumer preference for potato chip frying medium was for cottonseed oil followed by sunflower oil. Packaging in aluminium foil was found to be the most suitable with minimum increase in peroxide value and free fatty acid content and maximum retention of sensory scores during storage. Potato chips fried in sunflower oil and packed in aluminium foil bags stored under ambient conditions retained better quality than those fried in cottonseed oil and had a shelf-life of 90 days and was highly acceptable.

Chapter III

MATERIALS AND METHODS

This chapter deals with the process and techniques employed for preparation and physico-chemical testing of baked potato chips. The present investigation was conducted in the Process Engineering Laboratory, Department of Agricultural Process and Food Engineering, College of Agricultural Engineering, Bapatla and at the Department of Food Chemistry and Nutrition, College of Food Science and Technology, Bapatla.

The details of materials and experimental procedures followed and the techniques adopted during the course of present investigation have been elaborated in this chapter under the following heads.

3.1 PROCUREMENT OF RAW MATERIAL

Good quality potatoes were procured from the local market of Guntur. Care was taken that potatoes were not affected by any damage and spoilage.

3.2 EQUIPMENTS USED

3.2.1 Minor Equipments

Minor equipments used are weighing balance, potato peeler, slicer, microwave oven, sealing machine, hot air oven, desiccators and muffle furnace

3.2.2 Major Equipments

3.2.2.1 Soxhlet apparatus

A soxhlet type of apparatus (Plate 3.1) which allows for near 100% active material recovery was used for the purpose of determining fat content. The basic components of soxhlet apparatus include condenser (function is to cool the solvent vapour and cause it condense), porous container (function is to hold the solid sample and allow for the condensed solvent to saturate and pass through thereby extracting the material) and distillation beaker (function is to hold the solvent pool and serve as a reservoir for the concentrated material).

Plate 3.1: Soxhlet apparatus

3.2.2.2 Micro- Kjeldahl apparatus

The Micro-Kjeldahl apparatus as shown in Plate 3.2 was used for the determination of the protein in the samples. The Nitrogen content was estimated by this apparatus which is based on the determination of the amount of reduced nitrogen present in the sample. The Micro-Kjeldahl apparatus consists of the digestion flask and the distillation apparatus.

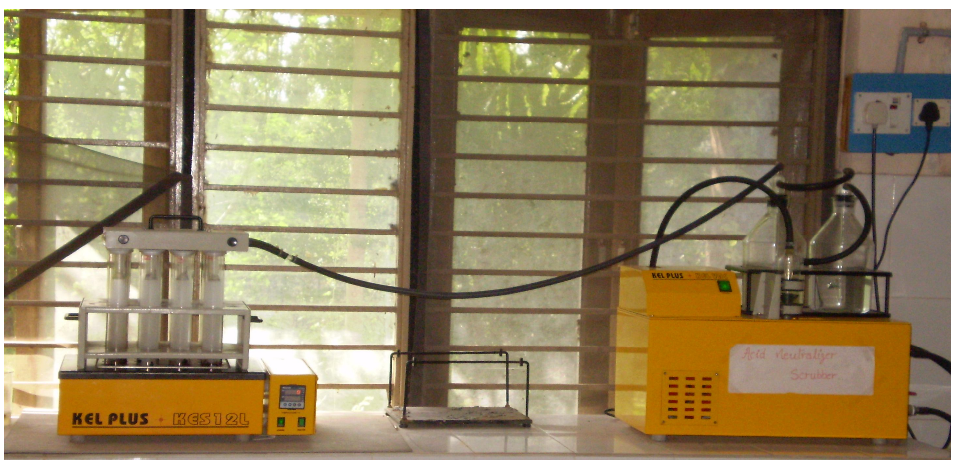

Plate 3.2: Micro-Kjeldahl apparatus

3.2.2.3 Spectrophotometer

A spectrophotometer (Plate 3.3) was used for measuring the absorption of the radient energy. In the visible spectrum, white light emanating from a tungsten lamp split in to its component wavelength by a grating (or by a prism). The latter is oriented through variois positions, so that only the desired wavelength passes through an exit split in to the sample area. The absorbing solution was placed in to a glass cuvette and lowered in to the light path. The transmitted light was measured by means of a phototubes and recorded on a digital meter.

Plate 3.3: Spectrophotometer

3.2.2.4 Calorimeter

The Colorimeter (Plate 3.4) was used to determine the concentration of a solution by analyzing its color intensity. Monochromatic light from a LED light source passes through a cuvette containing a sample solution and some of the incoming light is absorbed by the solution. As a result, light of a lower intensity strikes a photodiode which can recorded on a digital meter. The Colorimeter consists of LEDs for red (635 nm), green (565 nm) and blue (470 nm) lights.

Plate 3.4: Calorimeter

3.3 EXPERIMENTAL DESIGN

3.3.1 Independent Variables

The independent variables namely, slice thickness, microwave power level and baking time each of 5 levels were selected to conduct the experiment.

1) Thickness, mm : 0.5, 1, 1.5, 2.0 and 2.5
2) Power level, Watts : 300, 450, 600,750 and 900
3) Baking time, min : 4, 6, 8,10 and 12

3.3.2 Dependent Variables

The following quality parameters were considered as the dependent variables of the experiment. The dependent variables are as follows;

1) Moisture content
2) Ash content
3) Protein content
4) Browning index
5) Hardness
6) Carbohydrate content
7) Fat content

To reduce a large number of experiments, with three independent variables, a Central Composite Rotatable Design (CCRD) and Response Surface Methodology (RSM) has been successfully applied to optimize operational parameters. CCRD experiment was conducted with three process variables keeping optimized values of process parameters. For each experiment 1kg of potato sample was used. For optimization of independent operational parameters (thickness (mm), power levels (watts) and time (min)), 14 experiments were carried out according to CCRD and their combined effects were studied. Experiments were conducted immediately after preparation of baked chips. The CCRD was used to show interactions of power levels over thickness and time on the responses of quality parameters.

3.3.3 CCRD for Optimization of Process Parameters

A CCRD experiment was made with three independent variables viz., thickness of slice (X_1), power level (X_2) and baking time (X_3). In the design, the coded values of independent variables viz., x_1, x_2 and x_3 were converted into their real form as X_1, X_2, and X_3 respectively by using equations 3.1 to 3.4.

$$x_i = \frac{X_i - X_m}{X_D} \quad \text{(Here i =1, 2 and 3)} \qquad \dots \quad (3.1)$$

$$X_D = \frac{X_{max} - X_m}{a_m} \qquad \dots \quad (3.2)$$

$$X_m = \frac{X_{max} + X_{min}}{2} \qquad \dots \quad (3.3)$$

$$a_m = 2^{0.25K} \qquad \dots \quad (3.4)$$

Where, X_{max} = maximum value of independent variable, X_{min} = minimum value of independent variable, a_m = extreme coded value, k = number of independent variables considered for optimization and X_D = interval difference of the independent variable. Non linear second order regression equations were developed of the form equation (3.5).

$$Y = a_0 + \sum_{i=0}^{3} a_i x_i + \sum_{i=1}^{3} a_{ii} x_i^2 + \sum_{i=1}^{2} \sum_{j=i+1}^{3} a_{ij} x_i x_j \qquad \dots \quad (3.5)$$

The goodness of fit of the developed nonlinear equations was tested by F value for lack of fit (F_{lof}). The value of F_{lof} was calculated using equation 3.6.

$$F_{lof} = \frac{\sum_{i=1}^{n} (Y_{ai} - Y_a)^2 - \sum_{i=1}^{nc} (Y_{ai} - \overline{Y}_a)^2}{N - no.\,of\ coefficients\ in\ regression\ equation} \qquad \dots \quad (3.6)$$

Independent process variables, coded values and their real values are given in Table 3.1. The experiments were conducted in random order. In this study, the optimization was carried out using Design Expert 9.0.2.0 software (Design Expert, 2014), which gave optimum values based on predicted conditions given in Table 3.1. Appendix- A gives complete experimentation in coded and real values given by Design Expert 9.0.2.0 software.

Table 3.1: Coded values and corresponding real values used in experimentation

Independent Variables	Data levels					
	Code levels	-α (-1.682)	-1	0	+1	+α (+1.682)
Thickness, mm	Actual levels	0.5	1	1.5	2	2.5
Power level, watts		300	450	600	750	900
Time, min		4	6	8	10	12

3.4 PROCEDURE FOR PREPARATION OF BAKED POTATO CHIPS

3.4.1 Washing

Potatoes were washed under the tap water in order to remove the dust and some other adhered foreign particle on its surface.

3.4.2 Shortening/ Grading

Infected and spoiled potatoes were carefully discarded in order to produce a good quality of potato chips.

3.4.3 Slicing

Cleaned potatoes were then made in to slices of 0.5, 1.0, 1.5, 2.0 and 2.5mm thickness.

3.4.4 Blanching

Sliced potatoes were blanched in hot water at 85 ± 5^0C for 3 minutes. Then the blanched samples were drained and surface moisture was removed by blotting paper (Plate 3.5).

Plate 3.5: Blanched potato slices

3.4.5 Microwave Baking

The blanched potato slices were kept in a microwave chip maker and baked at different power levels (300, 450, 600, 750 and 900 watts) with a different baking times (4, 6, 8, 10 and 12 min). Finally the baked chips (Plate 3.6) were cooled and packed for conducting physic-chemical analysis and shelf life studies.

Plate 3.6: Microwave baked potato chips

The following flow chat (Figure 3.1) depicts different unit operations involved in the production of baked potato chips.

Potatoes (fully matured)

↓

Washing

↓

Sorting

(Removal of small and defective timbers)

↓

Peeling

↓

Trimming

(Removal of residual skin, discolored area, green)

↓

Slicing

(At thickness 0.5, 1, 1.5, 2, 1.5 mm)

↓

Blanching

(In hot water at 85 ± 5^{0}C for 3 min.)

↓

Microwave baking

(At powers of 300, 450W, 600W, 750 and 900W for 4, 6, 8, 10, 12 min)

↓

Cooling

↓

Packaging

Figure: 3.1 Process flow Chart for Preparation of baked Potato Chips

3.5 PHYSIOCHEMICAL ANALYSIS

Physico-chemical properties namely, moisture content, ash content, fat content, protein content, carbohydrate, hardness and browning index required for the present investigation were determined as follows:

3.5.1 Determination of Moisture Content

Standard procedure of AOAC, 1984 was followed to estimate the moisture content of microwave baked potato chips.

3.5.1.1 Procedure

Moisture content was determined by weighing 3g sample accurately and subjected to oven drying at 105^{o}C for 4-5 h. Oven dried samples were cooled in desiccator and weighed. The drying was repeated until the constant weights were obtained or until the difference between two successive weights was not more than 0.002g. The resultant loss in weight was calculated as percent moisture content (d.b).

3.5.1.2 Calculation

$$\text{Moisture Content (\% db)} = \frac{W1-W2}{W1-W} X\ 100$$

Where

W = Weight of dish (g)

W_1 = Weight of dish with sample before drying (g)

W_2 = Weight of dish + sample after dying (g)

3.5.2 Determination of Ash Content

Standard procedure of AOAC, 1984 was followed to estimate the ash content of microwave baked potato chips. Ash is the residue remaining after all the combustible material has been burned off (oxidized completely).

3.5.2.1 Procedure

5 g sample was weighed into crucible and ignited at low flame till all the material was completely charred. Then it was kept in muffle furnace for 6h at 600^{o}C and further cooled in desiccators and weighed. This process was repeated till two consecutive weights were constant and percent ash was calculated.

3.5.2.2 Calculation

$$\text{Ash Content (\%)} = \frac{W1-W2}{\text{Weight of sample}} X\ 100$$

Where,

W_1 = Initial Weight of the dish with sample (g)

W_2 = Weight of (dish + sample) after removing from muffle furnace (g)

3.5.3 Estimation of Fat (Soxhlet Apparatus Method)

Fat content of baked potato chips was determined by Soxhlet apparatus according to AOAC, 1984 procedure.

3.5.3.1 Principle

Fats are characterized by their readiness with which they are extracted by ethyl ether, petroleum products-Hexane. Hence the organic solvents are used for extracting fats from the samples. These solvents also extracts small amount of substance other than fat and the result is generally designated as “crude fat” or “ether extract”.

3.5.3.2 Procedure

The moisture free baked potato sample was transferred in to the thimble and the top was plugged with a fat-free cotton. Then the thimble was dropped into the fat extraction tube of Soxhlet apparatus and the tube was attached to a Soxhlet flask. Later 75-80 ml of petroleum ether was poured into the flask and the top of the fat extraction tube was attached to the condenser and the sample was extracted for 3-4 hours. Later the thimble was removed, dried for 1h to eliminate the organic solvent present in the thimble. Petroleum ether extract was filtered and transferred into 250 ml beaker, then the soxhlet flask containing the ether was washed 2 to 3 times with 5 ml of petroleum ether and the washings were also transferred to the beaker. Finally the Petroleum ether was evaporated completely and the residue was dried completely in an oven at 60-80 ^{0}C, cooled in a desiccator and the weight of beaker was noted.

3.5.3.3 Calculation

$$\text{Fat (\%)} = \frac{\text{Weight of the ether extract}}{\text{Weight of the sample}} \times 100$$

3.5.4 Determination of Protein

The protein content of samples was determined by Micro kjeldhal method according to AOAC, 1984 procedure.

3.5.4.1 Procedure

Protein was estimated by microkjeldhal method (Plate 3.7) using 0.5 g of ground sample by digesting with concentrated sulphuric acid at 100^{o}C. Then it was distilled with 40% NaOH and liberated ammonia was trapped in 4% boric acid, using mixed indicator (methyl red and bromocresol green (1:5)). Then it was titrated with 0.1N hydrochloric acid, the percent of nitrogen was estimated and protein percentage was calculated by multiplying percent nitrogen with factor 6.25.

Plate 3.7: Distillation process of microwave baked potato chips

3.5.4.2 Calculation

$$\text{Percent Nitrogen} = \frac{(\text{Sample titer value - blank titre value}) \times \text{Normality of Hcl} \times 14 \times 100}{\text{Sample weight (g)} \times 1000}$$

Protein %= Nitrogen% × 6.25

3.5.5 Determination of Total Carbohydrates by Anthrone method (Sadasivam and Manickam, 2008.)

Carbohydrates exist in the food materials as free sugars and polysaccharides. The basic units of carbohydrates are the monosaccharide. The carbohydrate content can be measured by hydrolyzing the polysaccharides into simpler sugars by acid hydrolysis and estimating the resultant monosaccharide**.**

3.5.5.1 Principle

Carbohydrates are first hydrolyzed into simple sugars using dilute hydrochloric acid. In hot acidic medium glucose was dehydrated to hydroxymethyl furfural. This compound forms a green colored solution with anthrone reagent, with a maximum absorption at 630nm.

3.5.5.2 Materials Required:

1) 2.5N HCl

2) Anthrone reagent**:** 100mg anthrone was dissolved in 50ml of ice cold H_2SO_4.

3) Standard glucose:

- Stock standard-100mg of glucose was dissolved in 100ml.
- Working standard- 10ml of stock standard solution was diluted with 100ml distilled water. It was stored in refrigeration after adding a few drops of toluene.

3.5.5.3 Procedure:

100mg of sample was taken into a 100ml of volumetric flask and then hydrolyzed it by keeping in a boiling water bath for 3 hours with 5ml of 2.5N HCl and cooled to room temperature. It was then neutralized with solid sodium carbonate until the effervescences ceases. The volume was then made up to 100ml and centrifuged. The supernatant was collected and 0.1ml, 0.2ml, 0.5ml and 1ml aliquots were taken for the analysis. The standards were prepared by taking 0, 0.2, 0.4, 0.6, 0.8 and 1ml of the working standard. ‘0’serves as blank. The volume was made up to 1ml in all the tubes including the sample tubes by adding distilled water. Then 4ml of anthrone reagent was added and heated for 8 min in a boiling water bath and cooled rapidly. Finally the green to dark green color of the solution was read at 630nm by using colorimeter (Plate 3.8). A standard graph was drawn by plotting concentration of the standard on the x-axis versus absorbance on the y-axis. From the graph the amount of carbohydrate present in the sample tube was calculated.

Plate 3.8: Colorimeter to Read the Green to Dark Green Color at 630nm for the Estimation of Carbohydrates

3.5.5.4 Calculation

$$\text{Amount of carbohydrates present (\%)} = \frac{\text{mg of glucose}}{\text{sample weight}} \text{x100}$$

3.5.6 Determination of Hardness

The hardness of the baked potato chips was measured by using tablet testing apparatus (Plate 3.9). Initially the reading of the apparatus was set to zero and the chip was placed between the two jaws and then the handle of the tester was pressed. The reading showed by the tester is taken as hardness in kilograms.

Plate 3.9: Measurement of hardness of chips using tablet tester

3.5.7 Determination of Browning Index

The sample (5g) was soaked in 15 ml of water and 30 ml of ethanol for 2h. The soaked sample was ground with a pestle and mortar and "filtered through Whatman No. 1" filter paper. The optical density of the filtrate was measured at 420 nm by using spectrophotometer and expressed as an index for non enzymatic browning (Ranganna 1986).

3.6 SENSORY ANALYSIS

Sensory evaluation of samples was carried out for consumer acceptance and preference using 10 panelists selected at random from the College of Agricultural Engineering, ANGRAU, Bapatla. For the analysis of color, taste, texture, flavour, and overall acceptability of the samples were rated using a 9-point hedonic scale where 9 and 1 represent like extremely and dislike extremely respectively (Appendix-B). Sensory evaluation was carried out at ambient conditions in a comfortable and quiet area without disturbance under fluorescent lighting. Water was supplied to cleanse the palate between samples. The sensory score given by the panel have been evaluated for the sensory result.

3.7 PREPARATION OF TRADITIONAL AND MICROWAVE DEEP FAT FRIED CHIPS

The traditional method of obtaining potato chips involved the deep fat frying of sliced potato chips in sunflower oil at a temperature of 170°C for 2-3min. For the production of microwave fried chips, initially the required amount of sunflower oil was heated in micro oven. Once the required oil temperature was reached, the potato slices were immersed in the oil. The micro oven was set at a power level of 600Watts for 4min.

3.8 PACKAGING MATERIALS

The samples were kept in polyethylene and aluminum lined polyethylene and then sealed with a sealing machine.

Chapter IV

RESULTS AND DISCUSSION

This chapter deals with the results of investigations carried out to determine the effect of baking time and microwave power levels on the physico-chemical characteristics of baked potato chips in micro oven. Optimization of process parameters for the production of microwave baked potato chips *vis-a-vis* the physico-chemical quality parameters is also presented. A comparison of the microwave baked potato chips with traditional and microwave deep fat fried chips was carried out. The studies on the storage of the baked chips in polyethylene and aluminium lined polyethylene were also presented.

4.1 EFFECT OF SLICE THICKNESS, MICROWAVE BAKING TIME AND POWER LEVELS ON THE QUALITY PARAMETERS OF BAKED POTATO CHIPS

The complete data on the quality parameters of microwave baked potato chips baked at different baking conditions is presented in Appendix-B. The effect of microwave baking time on the quality parameters like moisture, ash, hardness, fat, protein, carbohydrates and browning index was studied. At the constant slice thickness and power level, the process parameters namely moisture, fat, protein and browning index decreased with increased baking time. Under the similar conditions carbohydrate, ash and hardness increased (Figure 4.1 to 4.3).

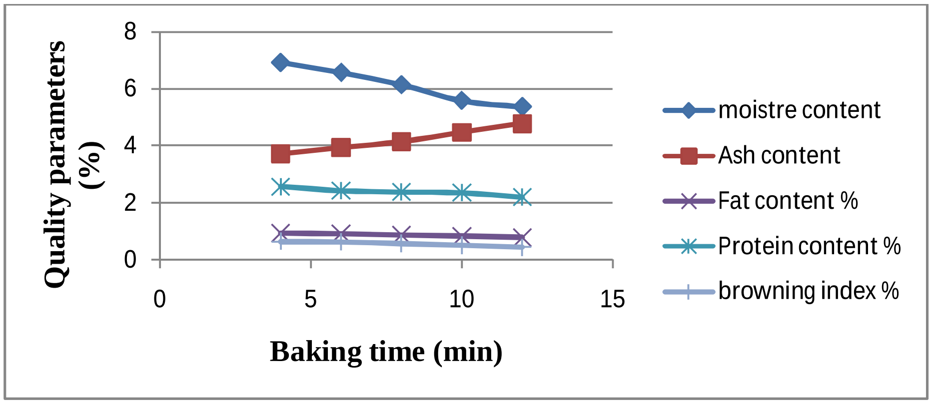

Figure 4.1: Effect of baking time on the quality parameters of baked potato chips

The carbohydrate content of potato chips was increased with increased baking time. The reason behind the increase in carbohydrate content with increase in baking time may be due to the fact that increase in the fat content will lead to decrease in the carbohydrate content (Ramasawmy *et al.*, 1999).

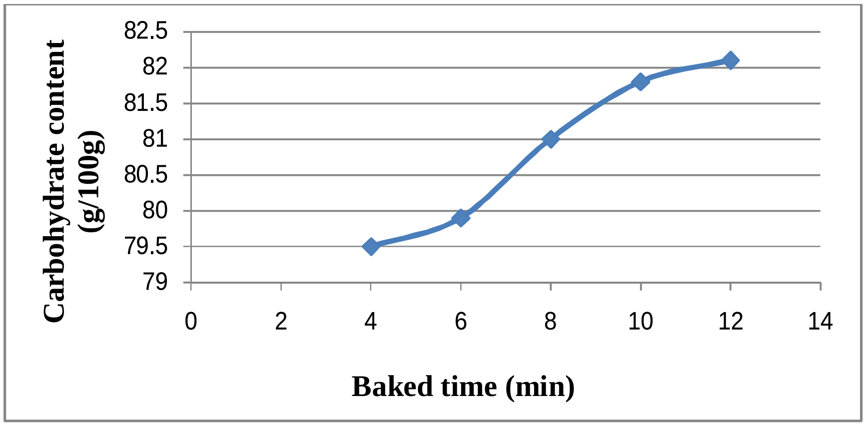

Figure 4.2: Effect of baking time on carbohydrate content of baked potato chips

The hardness content of potato chips was increased with increased baking time. The reason behind the increase in hardness with baking time might be due to the fact that during higher temperatures all the water evaporated quickly leading to the hardness of the slices. Similar findings were reported by Murali and Lakshmi, 2013.

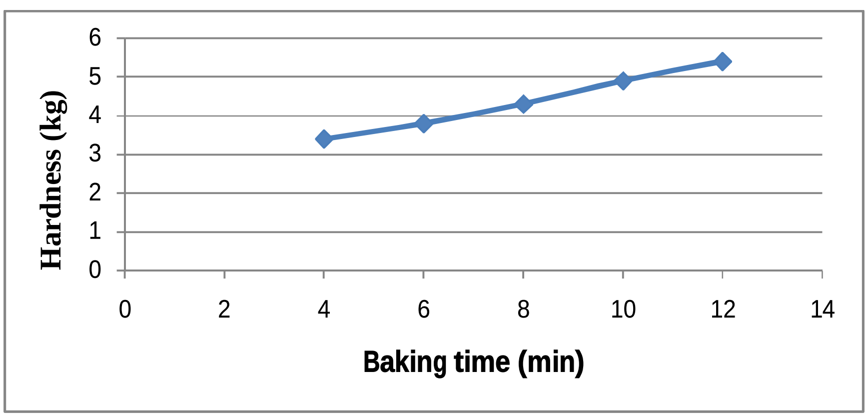

Figure 4.3: Effect of baking time on hardness of baked potato chips

The effect of microwave power level on the quality parameters like moisture content, ash, hardness, fat, protein, carbohydrates and browning index was studied. At constant slice thickness and baking time, the process parameters namely moisture, fat and protein decreased with increased power levels. Under the similar conditions ash, carbohydrates and hardness increased (Figure 4.4 to 4.6). The reason behind the decrease in moisture content with increase in power level may be due to rapid conversion of moisture within the potato slice into steam which escaped from the slices and prevented the gelatinization resulting in hardening exterior surfaces of the slice. Similar observations were reported by Anjineyulu *et al*., 2013.

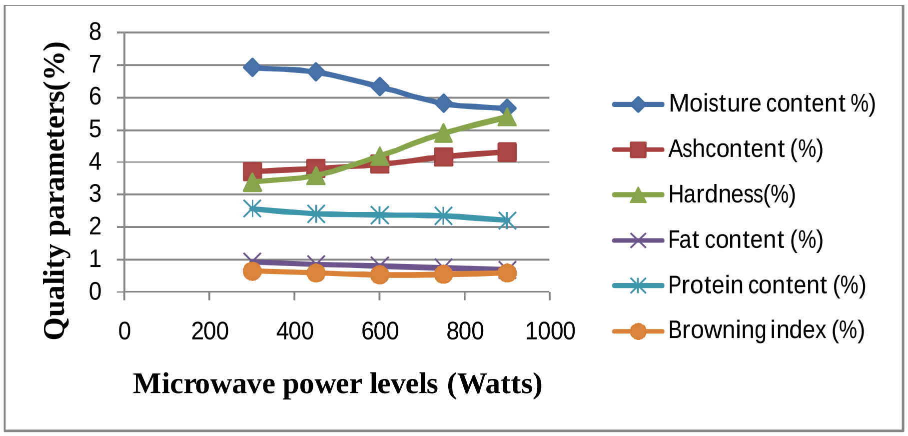

Figure 4.4: Effect of microwave power level on the quality parameters of baked potato chips

The carbohydrate content of potato chips was increased with increasing the power level. The reason behind the increase in carbohydrate content with increase in power level may be due to the fact that increase in the fat content will lead to decrease in the carbohydrate content (Ramasawmy *et al*., 1999).

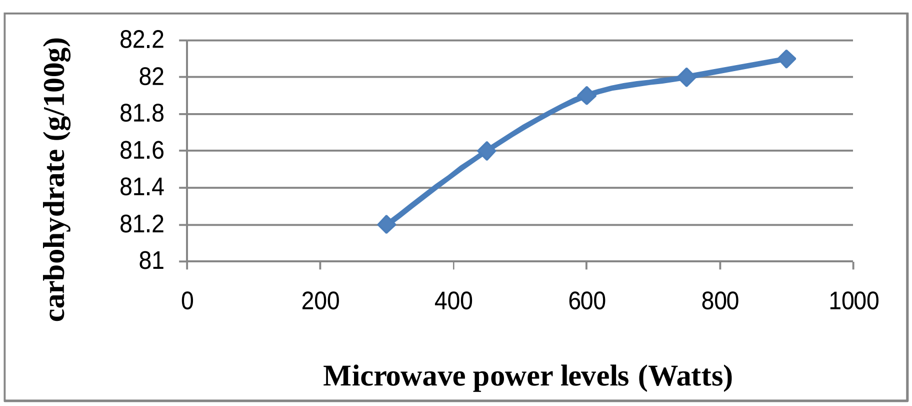

Figure 4.5: Effect of microwave power levels on the carbohydrate content of baked potato chips

The hardness content of potato chips was increased with increase in power level. The reason behind the increase in hardness with power levels was may be due to the fact that during higher temperatures all the water evaporated quickly leading to the hardness of the slices. Similar findings were reported by Murali and Lakshmi, 2013.

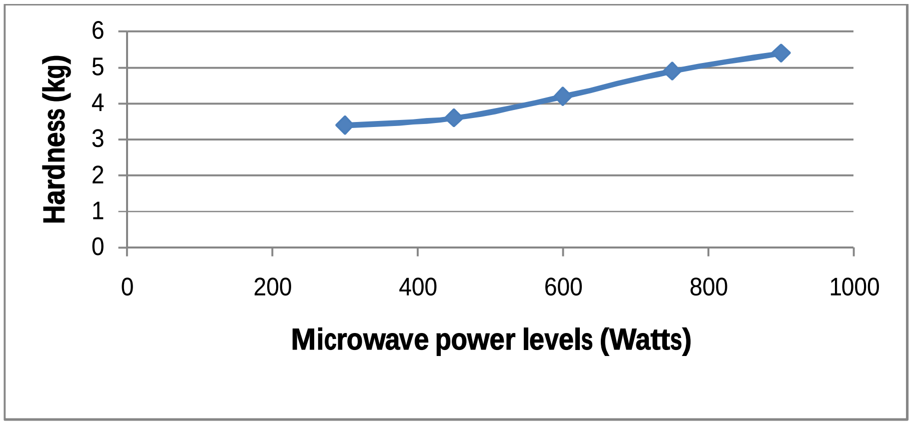

Figure 4.6: Effect of microwave power levels on the hardness of baked potato chips

The effect of slice thickness on the quality parameters like moisture content, ash, hardness, fat, protein, carbohydrates and browning index was studied. At the constant power levels and baking time, the process parameters namely hardness and ash content decreased with increased slice thickness. Under the similar conditions moisture, protein, fat, carbohydrates and browning index increased with increased slice thickness (Figure 4.7 to 4.9). The ash content was decreased with increase in slice thickness due the reason that increase in moisture content lead to decrease in ash content. Similar observations were reported by Chichester *et al.*, 1986.

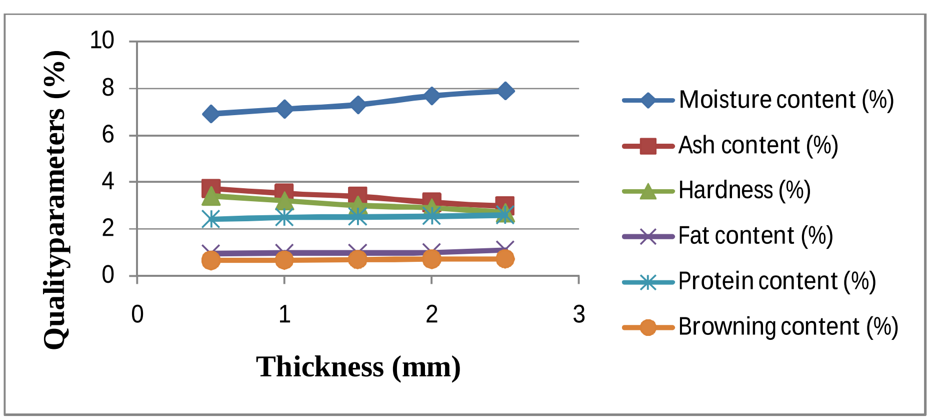

Figure 4.7: Effect of slice thickness on the quality parameters of baked potato chips

The carbohydrate content of potato chips was increased with increased thickness of the slice. The reason behind the increase of carbohydrate content is due to the fact that the increase in the surface area could have lead to the increase of carbohydrates (Ramasawmy *et al.*, 1999).

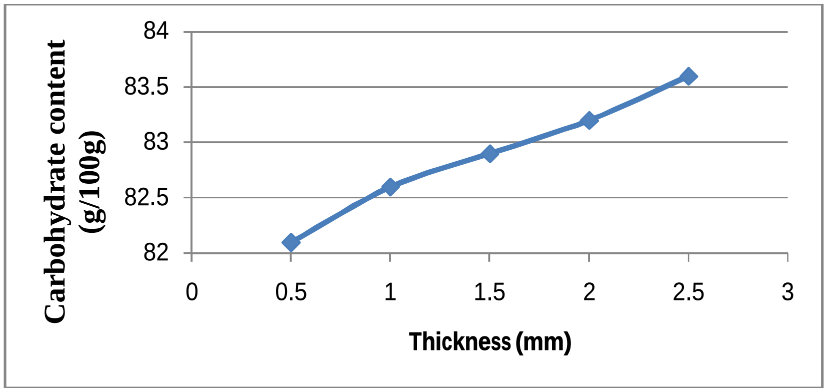

Figure 4.8: Effect of slice thickness on the carbohydrate content of baked potato chips

The hardness content of potato chips was decreased with increased slice thickness. The reason behind the decrease in hardness with slice thickness was may be due to the facts that increase in the moisture content should have lead to the lesser hardness of chips (Kite and Figiel, 2008).

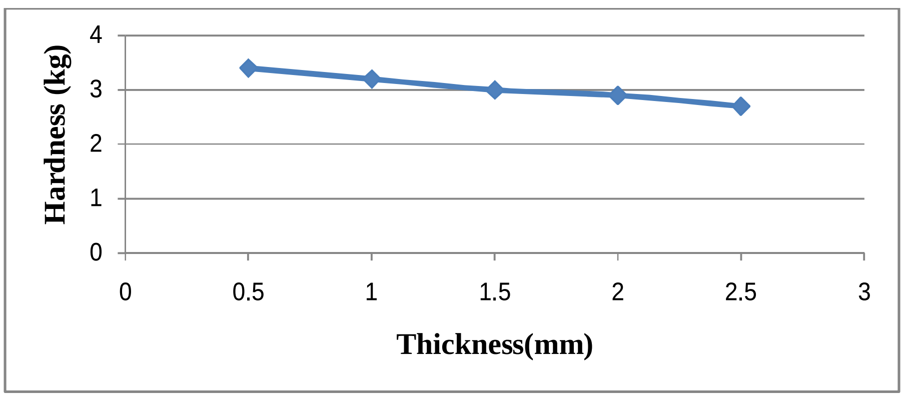

Figure 4.9: Effect of slice thickness on the hardness (kg) content of baked potato chips

4.2 OPTIMIZATION OF OPERATIONAL PARAMETERS

To reduce a large number of experiments, with three independent variables, a central composite rotatable design (CCRD) and response surface methodology (RSM) has been successfully applied to optimize operational parameters. CCRD experiment was conducted with three process variables keeping optimized values of process parameters.

Variations of responses of microwave baked chips with independent variables are shown in Appendix-C. Complete second order models were tested for their adequacy to decide the variation of responses with independent variables. To aid visualization of variation in responses with respect to processing variables, series of three dimensional response surfaces were drawn using Design Expert 9.0.2.0 software (Design Expert, 2014). The estimated regression coefficients of the quadratic polynomial models for the response variables are given in Appendix-D

The estimated regression coefficients of the quadratic polynomial models for the response variables, along with coefficient of variation (CV) and Adequate Precision Ratio (APR) are given in Appendix-D. Carbohydrate content has high intercept estimated coefficient value (82.50) compared to moisture content (7.99), ash (4.12), hardness (4.40), fat (0.44), protein (2.53) and browning index (0.45). Single and interaction effects of thickness mm (x_1), temperature °C (x_2) and baking time min (x_3) has less estimated coefficient values. Coefficient of determination (R^2) of hardness (1.00) is slightly higher than moisture content (0.9997), ash (0.9998), fat (0.9999), protein (0.9999), carbohydrates (0.9993) and browning index (0.9995).

4.2.1 Moisture Content

The model predicted response surface for the interaction of independent variables on moisture is shown in Figure 4.10(a) to 4.10(c).

At constant baking time (8 min), the moisture content increased with increase in thickness, whereas the moisture content decreased with increase in power level at the constant baking time (Figure 4.10(a)).

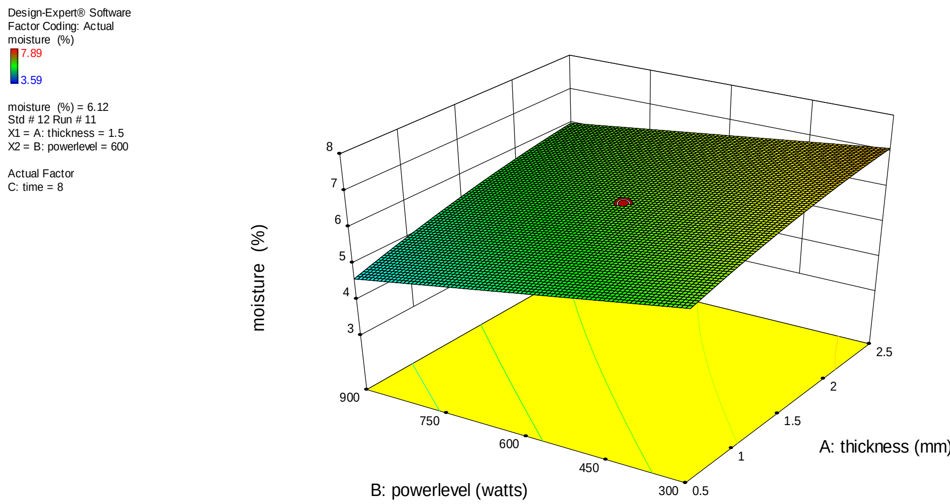

Figure 4.10(a): Response surface plot of moisture content (%) of potato chips as a function of thickness and microwave power level at constant baking time (8min)

At constant power level (600W), the moisture content increased with increase in slice thickness, whereas the moisture content decreased with increase in baking time (Figure 4.10(b)).

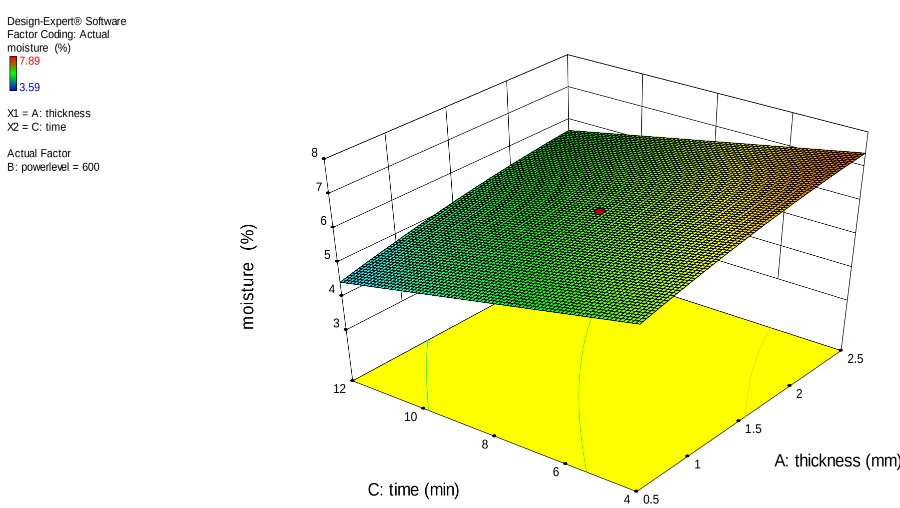

Figure 4.10(b): Response surface plot of moisture content (%) of potato chips as a function of thickness and baking time at constant microwave power level (600 watts)

At constant thickness (1.5mm) the moisture content decreased with increase in power level and baking time (Figure 4.10(c)).

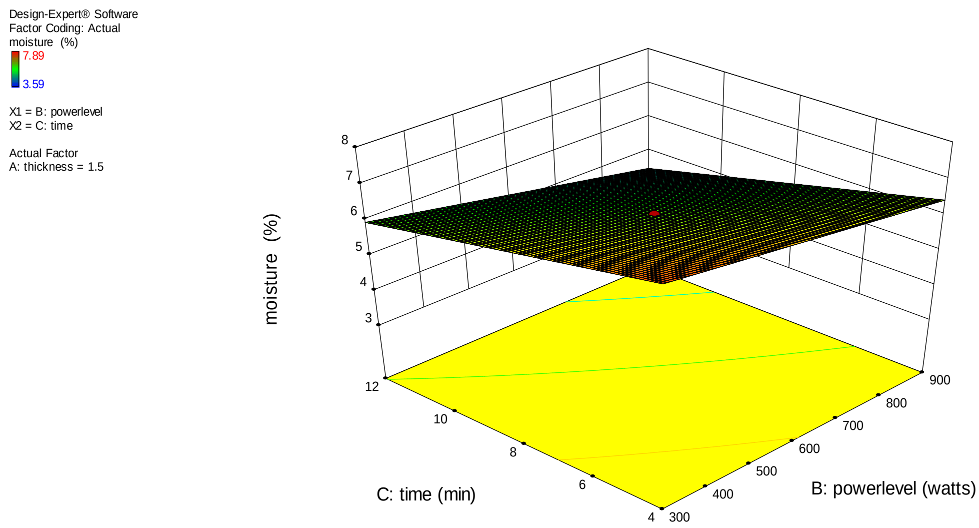

Figure 4.10(c): Response surface plot of moisture content (%) of potato chips as a function of microwave power level and baking time at constant thickness (1.5mm)

The reason behind the decrease in moisture content with increase in power level may be due to rapid conversion of moisture within the potato slice into steam which escaped from the slices and prevented the gelatinization resulting in hardening of a starch layer on the exterior surfaces of the slice. Similar observations were reported by Anjineyulu *et al.*, 2013.

The analysis of variance (ANOVA) of moisture content is presented in Appendix-E. The ANOVA data shows very high model F value (2192.38) suggesting that the quadratic model can be successfully used to fit the experimental data ($p<0.001$). F–values indicated that the linear terms of independent variable such as thickness, power level, time and interaction terms of variables thickness and time had significantly affected the moisture content ($p<0.001$). The quadratic term of thickness affected the moisture content ($P<0.01$). However, the interaction terms of variable thickness and time affected the moisture content at 5 per cent level of significance ($p<0.05$). The nonlinear second order regression equation was developed as a function of real values of independent variables viz., x_1, x_2 and x_3 for the dependent variable moisture. The developed relation with actual values (after deleting non-significant terms) has been given in equation 4.1.

$$M=7.99+0.74x_1-2.05x_2-0.18x_3+3.66x_1x_2+7.50x_1x_3-8.12x_2x_3-0.14x_1^2 \quad (R^2=0.9997)..... (4.1)$$

The high value of coefficient of determination (R^2) and difference of predicted R^2 (0.9496) and adjusted R^2 (0.9993) less than 0.20 indicated that the developed model was well fitted. The value of CV (0.47) less than 10, and APR (177.071) greater than 4 shows the adequate precision and reliability of the experiment and model. It was observed that model on moisture content was fitted well with values of sum of square (12.53), degrees of freedom (7), mean square (1.79) and F value of 2192.38.

4.2.2 Ash content

The model predicted response surface for the interaction of independent variables on ash content is shown in Figure 4.11(a) to 4.11(c).

At constant baking time (8 min), the ash content decreased with increase in thickness, whereas the ash content increased with increase in power level at the constant baking time (Figure 4.11(a)).

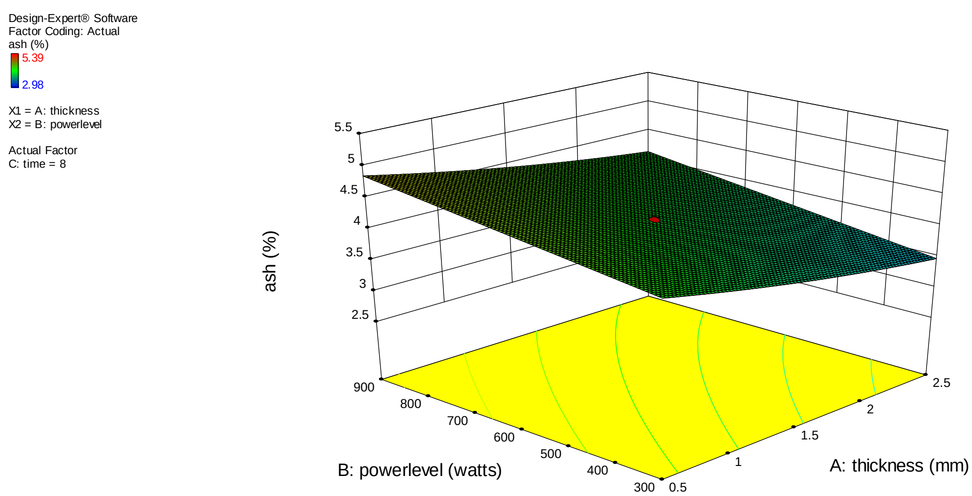

Figure 4.11(a): Response surface plot of ash content (%) of potato chips as a function of microwave power level and thickness at constant baking time (8mim)

At constant power level (600W), the ash content decreased with increase in slice thickness, whereas the ash content increased with increase in baking time (Figure 4.11(b)).

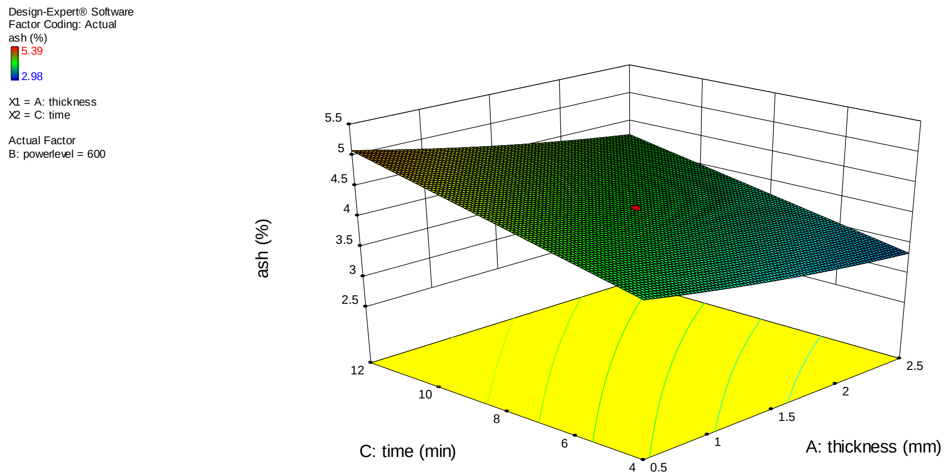

Figure 4.11(b): Response surface plot of ash content (%) of potato chips as a function of baking time and thickness at constant power level (600 watts)

At constant thickness (1.5mm) the ash content increased with increase in power level and baking time (Figure 4.11(c)).

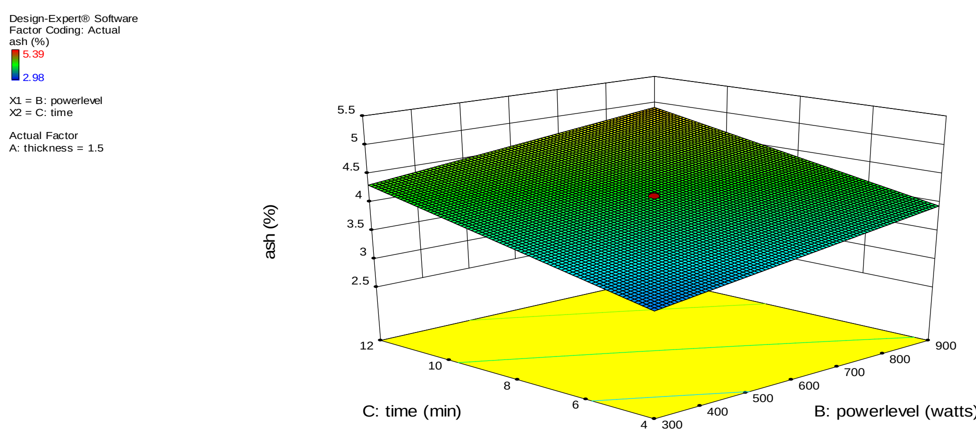

Figure 4.11(c): Response surface plot of ash content (%) of potato chips as a function of baking time and power level at constant thickness (1.5 mm)

The increase in ash content with increase in temperature may be attributed to the fact that during heating inorganic residue increases with evaporation of water content in the form of vapours. The ash content decreased with increase in thickness due the reason that increase in moisture content lead to decrease in ash content. Similar observations were reported by Chichester *et al.*, 1986.

The analysis of variance (ANOVA) of ash content of baked potato chips is presented in Appendix-F. The ANOVA data set shows very high model F value (2388.73) suggesting that the quadratic model can be successfully used to fit the experimental data ($p<0.001$). F-values indicated that the linear terms of independent variables thickness, power level and time significantly affected the ash content ($p<0.001$). The interaction terms of thickness-time variables and quadratic terms of thickness affected the ash ($p<0.01$). However, the interaction terms of thickness-power and time-power affected the ash content at 5 per cent level of significance ($p<0.05$). The nonlinear second order regression equation was developed as a function of real values of independent variables viz., x_1, x_2 and x_3 for the dependent variable ash. The developed relation with actual values (after deleting non significant terms) has been given in equation 4.2.

$$A=4.12-0.37x_1+0.32x_2+0.5x_3+0.01x_1x_2-0.036x_1x_3-0.019x_2x_3+0.064x_1^2 (R^2=0.9998) \quad (4.2)$$

The high value of coefficient of determination (R^2) and difference of predicted R^2 (0.9993) and adjusted R^2 (0.9993) less than 0.20 indicated that the developed model was correct. The value of CV (0.37), less than 10, and APR (185.296), greater than 4, shows the adequate precision and reliability of the experiment and model. It was observed that model on ash content was fitted significantly well with values of sum of square (3.92), degrees of freedom (7), mean square (0.56) and F-value (2388.73) at $P<0.0001$.

4.2.3 Hardness

The model predicted response surface for the interaction of independent variables on hardness value is shown in Figure 4.12(a) to 4.12(c).

At constant baking time (8 min), the hardness value decreased with increase in thickness, whereas the hardness value increased with increase in power level at the constant baking time (Figure 4.12(a)).

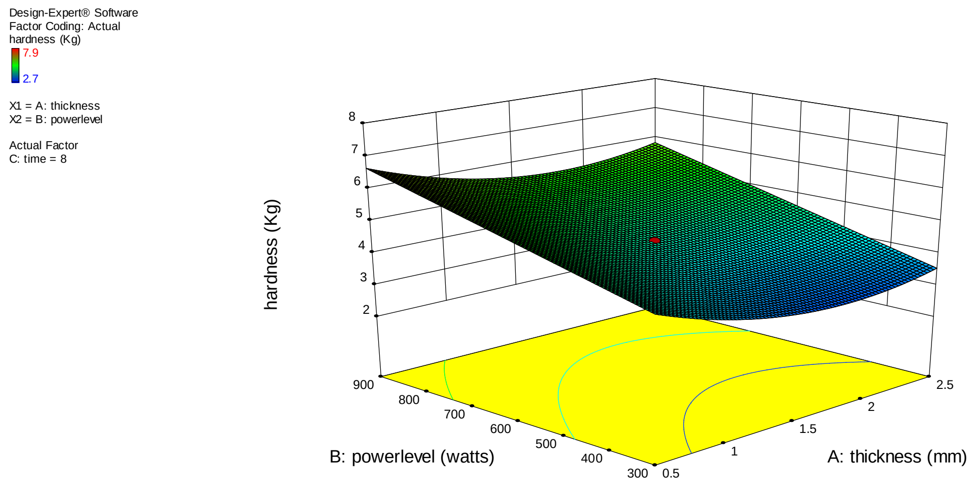

Figure 4.12(a): Response surface plot of hardness (kg) of potato chips as a function of thickness and power level at constant baking time (8mim)

At constant power level (600W), the hardness value decreased with increase in thickness, whereas the hardness value increased with increase in baking time at the constant power level (Figure 4.12(b)).

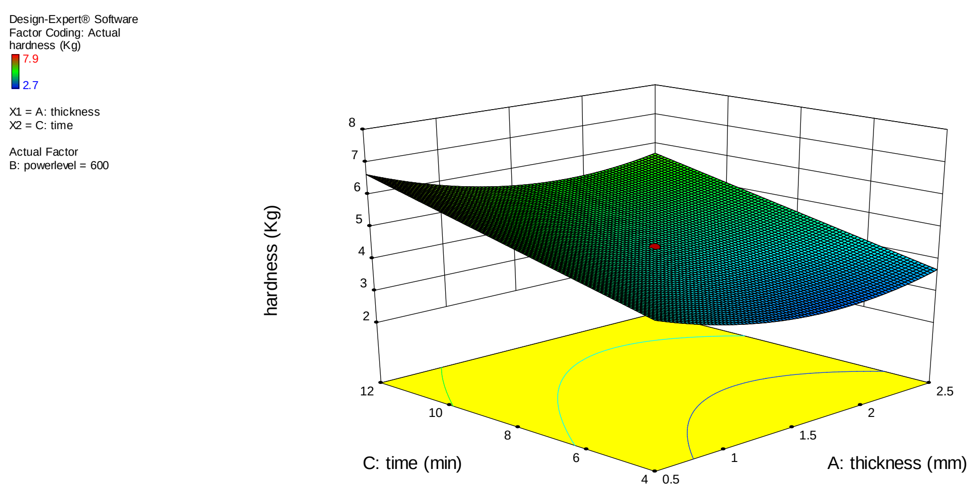

Figure 4.12(b): Response surface plot of hardness (kg) of potato chips as a function of baking time and thickness at constant power level (600 watts)

At constant thickness (1.5mm) the hardness value increased with increase in power level and baking time (Figure 4.12(c)).

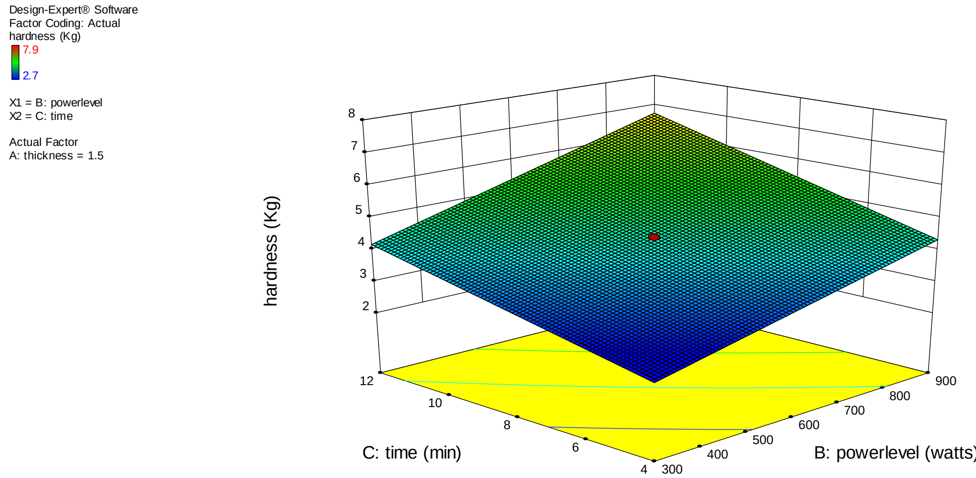

Figure 4.12(c): Response surface plot of hardness (kg) of potato chips as a function of baking time and power level at constant thickness (1.5mm)

The reason behind the increase in hardness with baking time and power levels was may be due to the fact that during higher temperatures all the water evaporated quickly leading to the hardness of the slices. Similar findings were reported by Murali and Lakshmi, 2013.

The analysis of variance (ANOVA) of hardness of baked potato chips is presented in Appendix-G. The ANOVA data set shows very high model F value (30557.14) suggesting that the quadratic model can be successfully used to fit the experimental data ($p<0.001$). F-values indicated that the linear terms of independent variables (thickness, power level, time), interaction terms of thickness-time, power – time and quadratic terms of thickness significantly affected the ash content ($p<0.001$). The interaction terms of thickness-power variables affected the ash content at 5 per cent level of significance ($p<0.05$). The nonlinear second order regression equation was developed as a function of real values of independent variables viz., x_1, x_2 and x_3 for the dependent variable hardness. The developed relation with actual values (after deleting non significant terms) has been given in equation 4.3.

$$H=4.40-0.41x_1+1.14x_2+1.06x_3+0.01x_1x_2-0.062x_1x_3+0.14x_2x_3-0.71x_1^2 \quad (R^2=1.000)\ldots(4.3)$$

The high value of coefficient of determination (R^2) and difference of predicted R^2 (0.9964) and adjusted R^2 (0.9999) less than 0.20 indicated that the developed model was correct. The value of CV (0.21), less than 10, and APR (603.807), greater than 4, shows the adequate precision and reliability of the experiment and model. It was observed that model on hardness was fitted significantly well with values of sum of square (22.28), degrees of freedom (7), mean square (0.19) and F-value (30557.14) at P<0.0001.

4.2.4 Fat Content

The model predicted response surface for the interaction of independent variables on fat content is shown in Figure 4.13(a) to 4.13(c).

At constant baking time (8 min), the fat content increased with increase in thickness, whereas the fat content decreased with increase in power level at the constant baking time (Figure 4.13(a)).

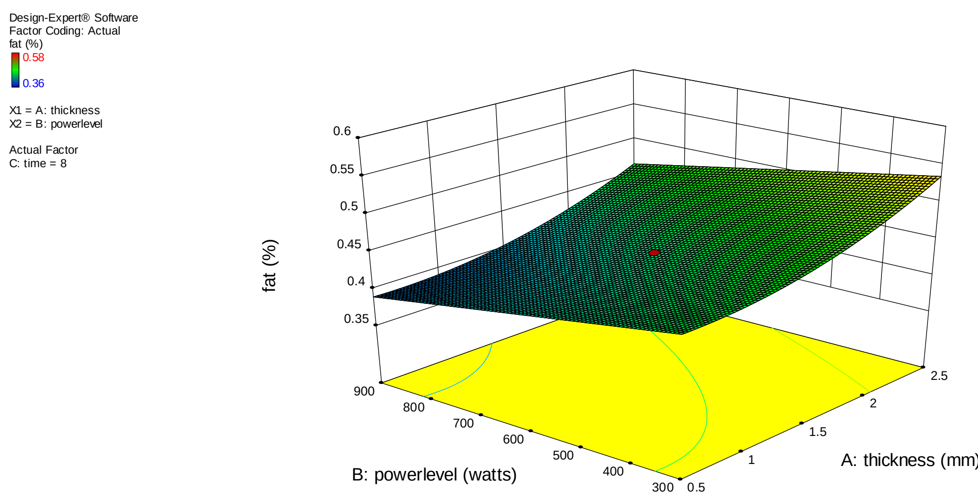

Figure 4.13(a): Response surface plot of fat content (%) of potato chips as a function of thickness and power level at constant baking time (8 min)

At constant power level (600W), the fat content increased with increase in thickness, whereas the fat content decreased with increase in baking time at the constant power level (Figure 4.13(b)).

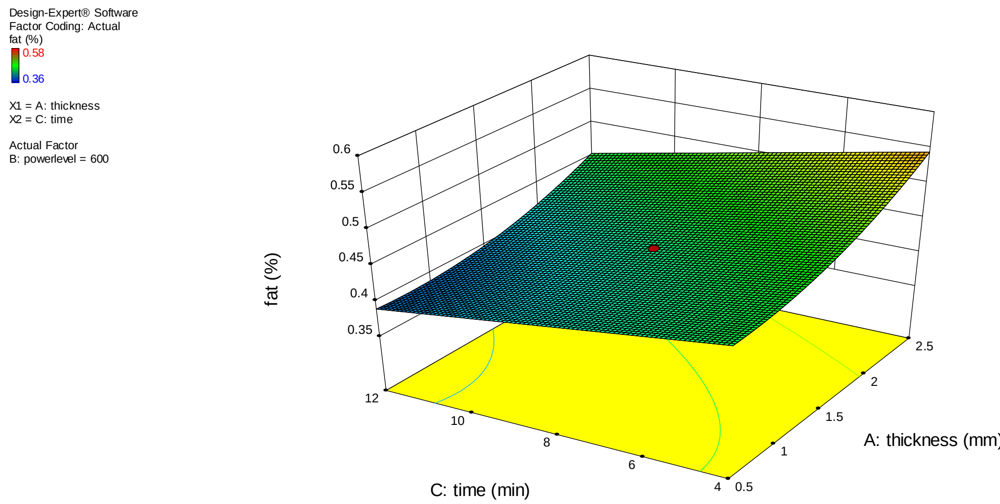

Figure 4.13(b): Response surface plot of fat content (%) of potato chips as a function of thickness and baking time at constant power level (600 Watts)

At constant thickness (1.5mm) the fat content decreased with increase in power level and baking time (Figure 4.13(c)).

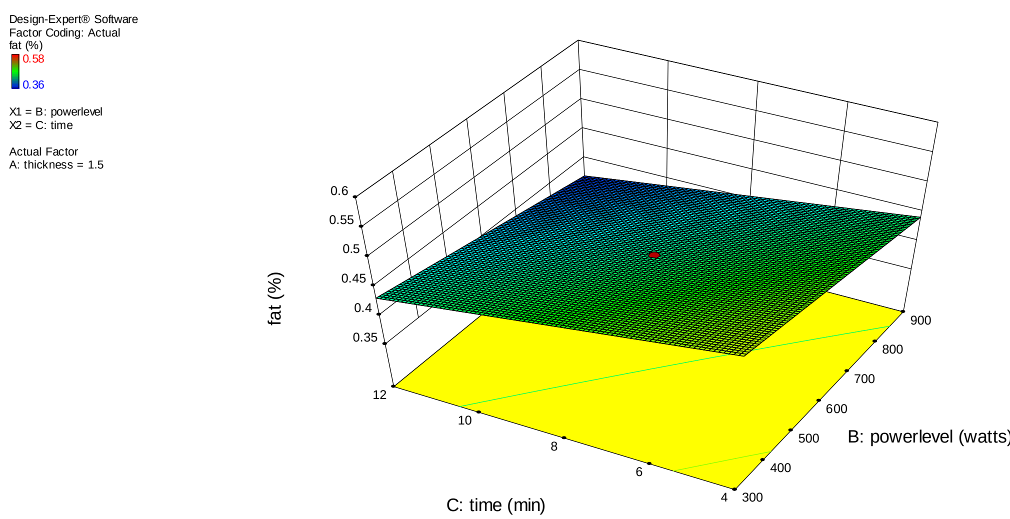

Figure 4.13(c): Response surface plot of fat content (%) of potato chips as a function of power level and baking time at constant thickness (1.5 mm)

The analysis of variance (ANOVA) of fat content of baked potato chips is presented in Appendix-H. The ANOVA data set shows very high model F value (4756) suggesting that the quadratic model can be successfully used to fit the experimental data ($p<0.001$). F-values indicated that the linear terms of independent variables (thickness, power level and time), the interaction term of thickness-time variable and as well as quadratic terms of thickness affected the fat content ($p<0.001$). However, the interaction terms of variable thickness- power level and thickness-time affected the fat content at 5 per cent level of significance ($p<0.05$). The nonlinear second order regression equation was developed as a function of real values of independent variables viz., x_1, x_2 and x_3 for the dependent variable fat. The developed relation with actual values (after deleting non significant terms) has been given in equation 4.4.

$$F=0.44+0.039x_1+0.034x_2-0.039x_3-6.25x_1x_3+0.021x_1^2 \quad (R^2=0.9999)\text{……….}(4.4)$$

The high value of coefficient of determination (R^2) and difference of predicted R^2 (0.9768) and adjusted R^2 (0.9997) less than 0.20 indicated that the developed model was correct. The value of CV (0.23), less than 10, and APR (256.014), greater than 4, shows the adequate precision and reliability of the experiment and model. It was observed that model on fat content was fitted significantly well with values of sum of square (0.035), degrees of freedom (7), mean square (4.954) and F-value (4756.00) at $P<0.0001$.

4.2.5 Protein Content

The model predicted response surface for the interaction of independent variables on protein content is shown in Figure 4.14(a) to 4.14(c).

At constant baking time (8 min), the protein content decreased with increase in thickness and power level at the constant baking time (Figure 4.14(a)).

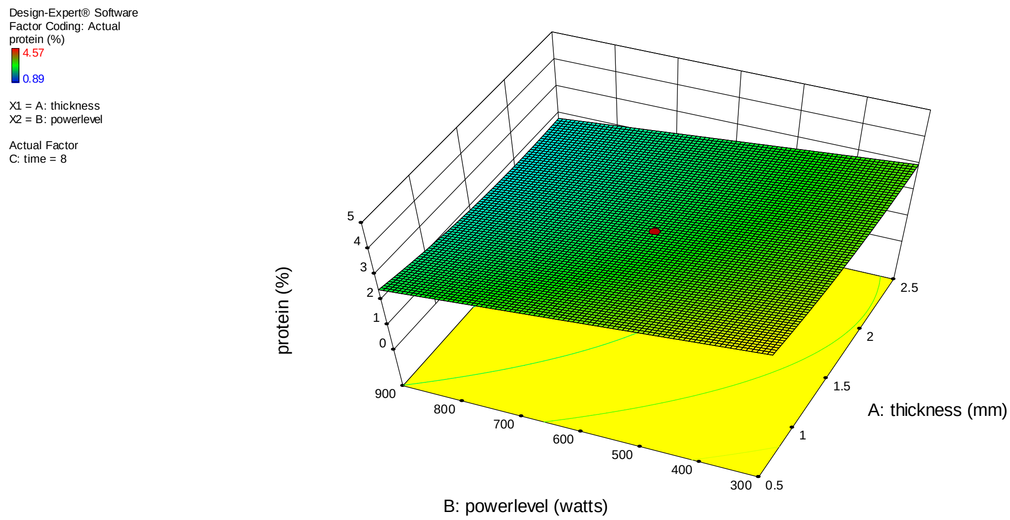

Figure 4.14(a): Response surface plot of protein content (%) of potato chips as a function of power level and thickness at constant baking time (8min)

At constant power level (600W), the protein content decreased with increase in thickness, whereas the protein content decreased with increase in baking time at the constant power level (Figure 4.14(b)).

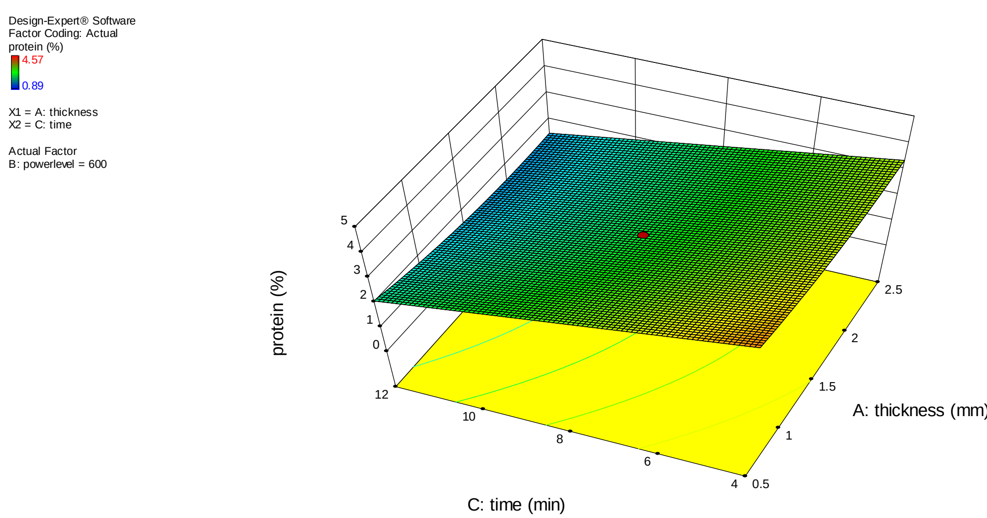

Figure 4.14(b): Response surface plot of protein content (%) of potato chips as a function of baking time and thickness at constant power level (600watts)

At constant thickness (1.5mm) the protein content decreased with increase in power level and baking time (Figure 4.14(c)).

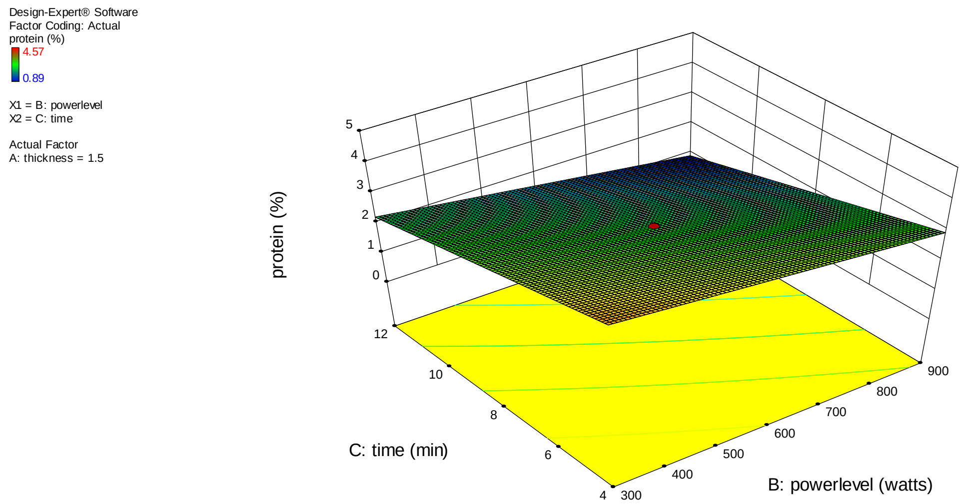

Figure 4.14(c): Response surface plot of protein content (%) of potato chips as a function of baking time and power level at constant thickness (1.5mm)

The leaching loss of soluble proteins might have resulted in decrease of protein content with baking time.

The analysis of variance (ANOVA) of protein content of baked potato chips is presented in Appendix-I. The ANOVA data set shows very high model F value (5228.33) suggesting that the quadratic model can be successfully used to fit the experimental data ($p<0.001$). F-values indicated that the linear terms of independent variables (thickness, power level and time), interaction terms of power-time variables and quadratic terms of thickness affected the protein content ($p<0.001$). No significant effect was observed in interaction terms of thickness-time and thickness-power variables on protein content. The nonlinear second order regression equation was developed as a function of real values of independent variables viz., x_1, x_2 and x_3 for the dependent variable protein content. The developed relation with actual values (after deleting non significant terms) has been given in equation 4.5.

$$P=2.53-0.32x_1-0.59x_2-0.94x_3-0.081x_2x_3+0.26x_1^2 (R^2=0.9999).......(4.5)$$

The high value of coefficient of determination (R^2) and difference of predicted R^2 (0.9789) and adjusted R^2 (0.9997) less than 0.20 indicated that the developed model was correct. The value of CV (0.65), less than 10, and APR (251.923), greater than 4, shows the adequate precision and reliability of the experiment and model. It was observed that model on protein content was fitted significantly well with values of sum of square (11.02), degrees of freedom (7), mean square (1.57) and F-value (5228.33) at P<0.0001.

4.2.6 Carbohydrate Content

The model predicted response surface for the interaction of independent variables on protein content is shown in Fig. 4.15(a) to 4.15(c).

At constant baking time (8 min), the carbohydrate content decreased with increase in thickness, whereas the carbohydrate content increased with increase in power level at the constant baking time (Figure 4.15(a)).

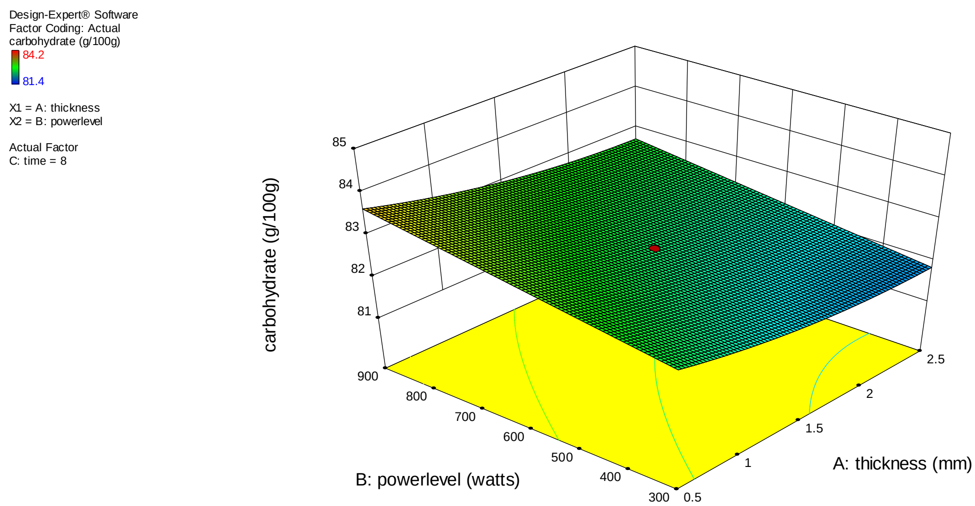

Figure 4.15(a): Response surface plot of carbohydrate content (g/100g) of potato chips as a function of thickness and power level at constant baking time (8mim)

At constant power level (600W), the carbohydrate content decreased with increase in thickness, whereas the carbohydrate content increased with increase in baking time at the constant power level (Figure 4.15(b)).

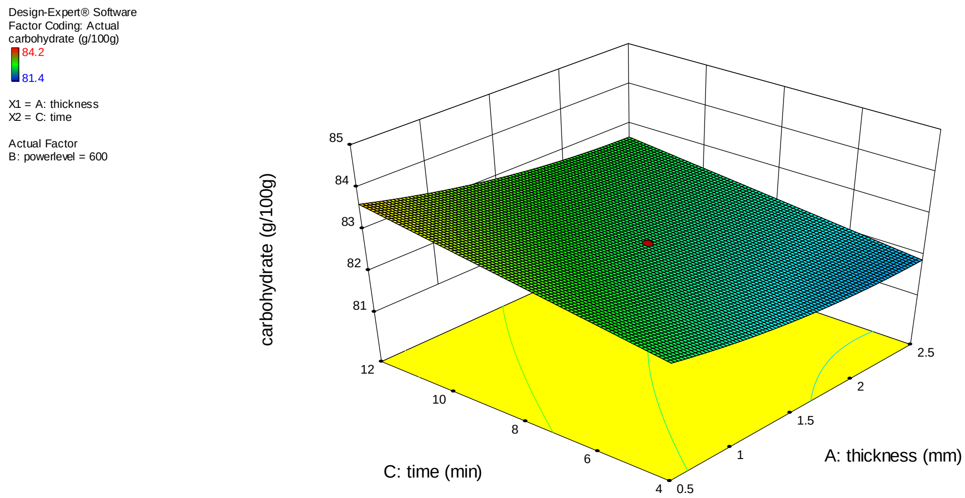

Figure 4.15(b): Response surface plot of carbohydrate content (g/100g) of potato chips as a function of thickness and baking time at constant power level (600 Watts)

At constant thickness (1.5mm) the carbohydrate content increased with increase in power level and baking time (Figure 4.15(c)).

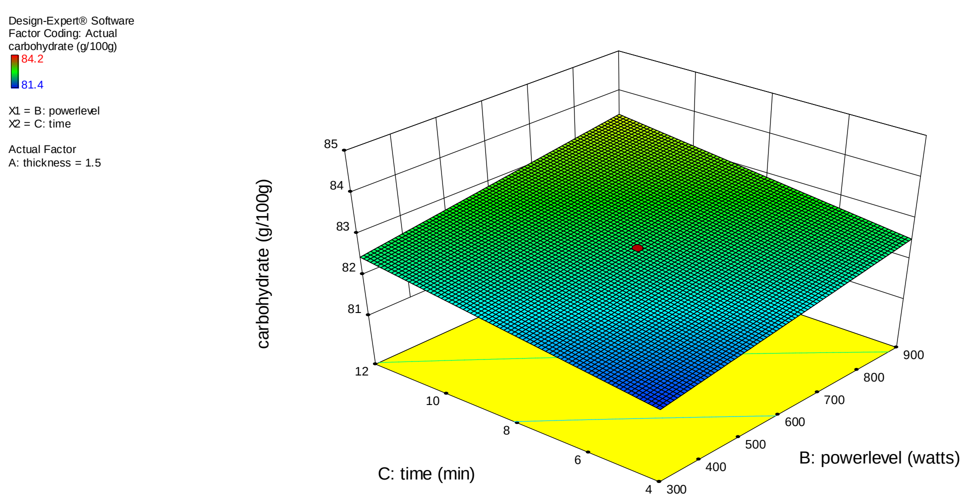

Figure 4.15(c): Response surface plot of carbohydrate content (g/100g) of potato chips as a function of power level and baking time at constant thickness (1.5 mm)

The reason behind the increase in Carbohydrate content with increase in time and power level may be due to the fact that increase in the fat content will lead to decrease in the carbohydrate content because as the increase in the surface area could lead to loss of carbohydrates (Ramasawmy *et al*., 1999).

The analysis of variance (ANOVA) of carbohydrate content of baked potato chips is presented in Appendix-J. The ANOVA data set shows very high model F value (782.92) suggesting that the quadratic model can be successfully used to fit the experimental data ($p<0.001$). F-values indicated that the linear terms of independent variables (thickness, power level and time) and the quadratic terms of thickness affected the protein content ($p<0.001$). The interaction terms of thickness-time affected the protein content ($p<0.01$).

However, the interaction terms of variable thickness-power level affected the moisture content at 5 per cent level of significance ($p<0.05$). No significant effect was observed in interaction term of power-time variables on protein content. The nonlinear second order regression equation was developed as a function of real values of independent variables viz., x_1, x_2 and x_3 for the dependent variable protein content. The developed relation with actual values (after deleting non significant terms) has been given in equation 4.6.

$$C=82.50-0.41x_1+0.49x_2+0.46x_3-0.037x_1x_2-0.062x_1x_3+0.21x_1^2 (R^2=0.9993) .....(4.7)$$

The high value of coefficient of determination (R^2) and difference of predicted R^2 (0.8589) and adjusted R^2 (0.9980) less than 0.20 indicated that the developed model was correct. The value of CV (0.037), less than 10, and APR (107.236), greater than 4, shows the adequate precision and reliability of the experiment and model. It was observed that model on Carbohydrate content was fitted significantly well with values of sum of square (5.14), degrees of freedom (7), mean square (0.73) and F-value (782.92) at $P<0.0001$.

4.2.7 Browning Index

The model predicted response surface for the interaction of independent variables on browning index is shown in Figure 4.16(a) to 4.16(c).

At constant baking time (8 min), the browning index decreased with increase in thickness, whereas the browning index increased with increase in power level at the constant baking time (Figure 4.16(a)).

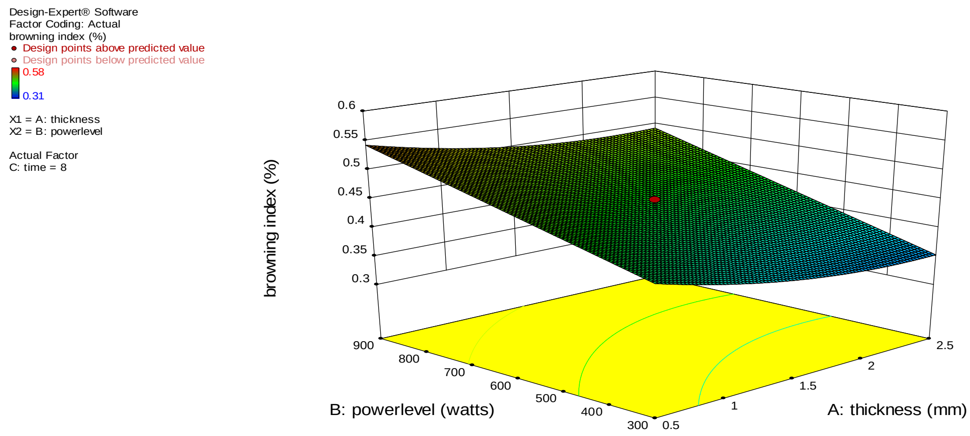

Figure 4.16(a): Response surface plot of browning index (%) of potato chips as a function of thickness and power level at constant baking time (8mim)

At constant power level (600W), the browning index decreased with increase in thickness, whereas the browning index increased with increase in baking time at the constant power level (Figure 4.16(b)).

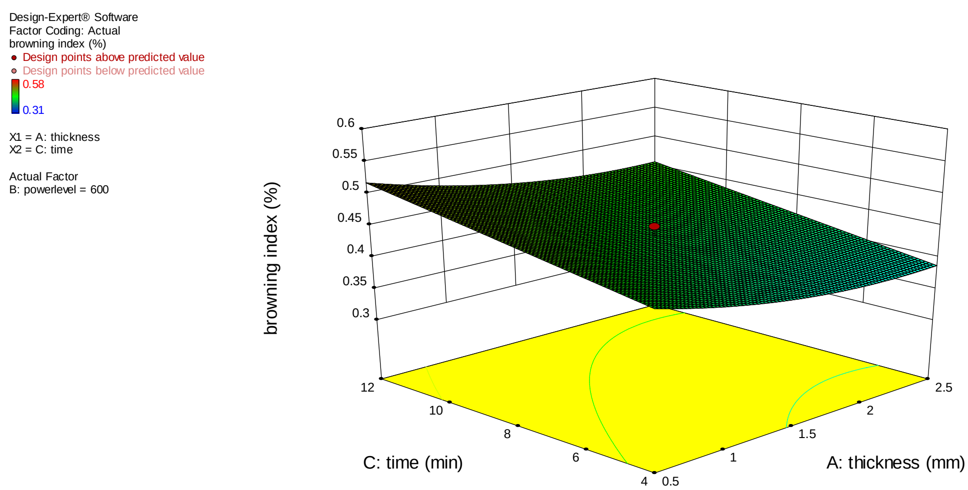

Figure 4.16(b): Response surface plot of browning index (%) of potato chips as function of thickness and baking time at constant power level (600 watts)

At constant thickness (1.5mm) the browning index increased with increase in power level and baking time (Figure 4.16(c)).

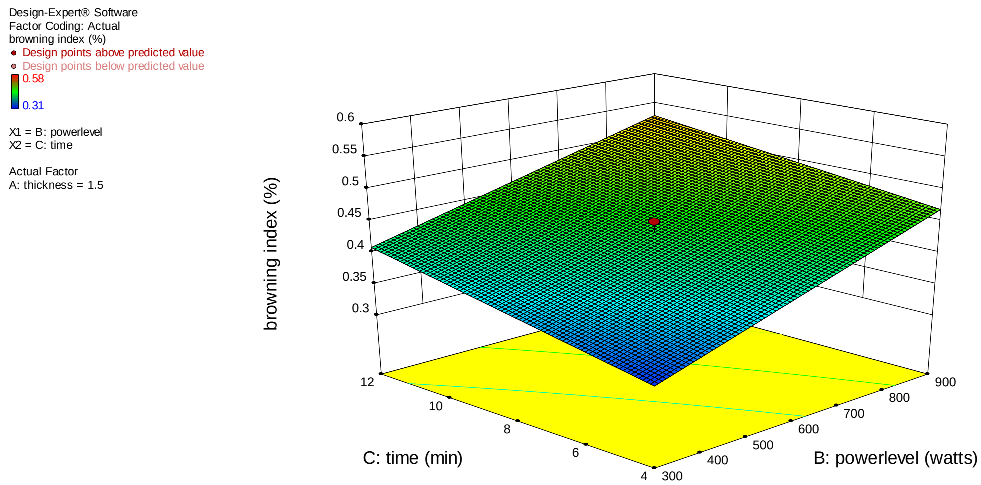

Figure 4.16(c): Response surface plot of browning index (%) of potato chips as a function of power level and baking time at constant thickness (1.5 mm)

The reason behind the increase in browning index with increase in time and power level might be due to the fact that during high temperatures the moisture content was reduced and the colour of the potatoes increased. Similar observations were reported by Franco and Zuniga, 2009.

The analysis of variance (ANOVA) of browning index of baked potato chips is presented in Appendix-K. The ANOVA data set shows very high model F value (825.59) suggesting that the quadratic model can be successfully used to fit the experimental data ($p<0.001$). F-values indicated that the linear terms of independent variables thickness, power level, time and the quadratic terms of thickness variable affected the browning content ($p<0.001$). However, the interaction terms of variable thickness and power level affected the browning index at 5 per cent level of significance ($p<0.05$). No significant effect was observed in the interaction terms of thickness-time and power level-time variables on browning content. The nonlinear second order regression equation was developed as a function of real values of independent variables viz., x_1, x_2 and x_3 for the dependent variable browning content. The developed relation with actual values (after deleting non significant terms) has been given in equation 4.7.

$$B.I=0.43-0.029x_1+0.066x_2+0.036x_3+3.75x_1x_2 \quad (R^2=0.9995) \qquad (4.7)$$

The high value of coefficient of determination (R^2) and difference of predicted R^2 (0.8662) and adjusted R^2 (0.9981) less than 0.20 indicated that the developed model was correct. The value of CV (0.69), less than 10, and APR (103.372), greater than 4, shows the adequate precision and reliability of the experiment and model. It was observed that model on browning index was fitted significantly well with values of sum of square (0.054), degrees of freedom (7), mean square (7.740) and F-value (825.59) at $P<0.0001$.

4.2.8 Optimum Conditions

Optimum conditions for microwave baked potato chips were determined to obtain maximum carbohydrate and protein content and minimum moisture, ash, fat and browning index. Second order polynomial models obtained in the study were utilized for each response to determine the specified optimum conditions. The sequential quadratic programming in Design Expert 9.0.2.0 was used to solve the second degree polynomial regression equations. Firstly, the range of optimized responses was achieved numerically by putting the values of operational variables following the goal presented in Table 4.1.

Table 4.1 Operational criteria for different operational variables and responses

Variables and responses	Goal	Importance
Thickness, mm	is in range	+++
Power level, Watts	is in range	++++
Time, min	is in range	++++
Moisture content, %	Minimum	++
ash content, %	Minimum	++
Hardness, kg	Minimum	++
Fat, %	Minimum	++
Protein, %	Maximum	++++
Carbohydrate, g/100g	Maximum	++++
Browning index %	Minimum	++

The optimum values obtained by substituting the respective coded values are 1.5mm, 600 Watts, 8 min. At these optimum conditions, moisture, ash, hardness, fat, protein, carbohydrate and browning index were calculated as 6.12%, 4.12%, 4.40kg, 0.44%, 2.53%, 82.5g/100g and 0.43% respectively.

4.2.9 Sensory Evaluation of Baked Potato Chips

The sensory scores of baked potato chips were analyzed as described under section 3.6 of materials and methods. Sensory analysis of baked potato chips is done using 9-point hedonic scale (Appendix-L).

Results of sensory scores of optimised baked samples were presented in Table 4.2 in terms of quality attributes namely, colour, taste, flavour, texture and overall acceptability.

The samples S_3, S_4, S_6, S_7 andS_9 had higher scores for colour; S_3, S_4, S_6 and S_7 for taste; samples S_3, S_5, S_6, S_7 and S_9 for texture; samples S_3, S_4, S_6,S_7, S_8, S_9 and S_7 for Flavour and samples S_3,S_4,S_6,S_7,S_9 (Table 4.2). Finally, the baked chips sample S_3 scores well among nine samples in terms of quality attribute.

Table 4.2 Sensory evaluation scores of baked potato chip samples

Quality attributes	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8	S_9
Colour	6	5	9	7	6	7	8	6	7
Taste	6	5	8	7	6	7	7	6	6
Texture	5	4	8	6	7	8	8	6	6
Flavour	5	4	8	7	6	8	8	7	7
Overall acceptability	5	5	9	7	6	7	8	6	7

Where

$S_{1=}$ Sample of 0.5mm thickness baked at 300 Watts power level for 4min

S_2= Sample of 2.5mm thickness baked at 300 Watts power level for 12min

S_3= Sample of 1.5mm thickness baked at 600 Watts power level for 8min

S_4=Sample of 2.5mm thickness baked at 900 Watts power level for 4min

S_5 =Sample of 0.5mm thickness baked at 900 Watts power level for 12min

S_6 =Sample of 0.5mm thickness baked at 900 Watts power level for 4min

S_7=Sample of 2.5mm thickness baked at 900 Watts power level for 12min

S_8=Sample of 2.5mm thickness baked at 300 Watts power level for 6min

S_9=Sample of 0.5mm thickness baked at 300 Watts power level for 12min

4.3 Comparison of the baked potato chips with deep fat fried potato chips

In this part of the study, the microwave baked potato chips were compared with traditional and microwave frying methods. The comparison was based on the quality parameters of the potato chips.

4.3.1 Moisture Content

As can be seen in Figure 4.17 microwave baked potato chips had lower moisture content (6.12%) than microwave fried (7.45%) and conventionally fried (9.32%) potato chips. The reason behind the lower moisture content of baked potato chips may be due to rapid conversion of moisture within the potato slice into steam which escaped from the slices and prevented the gelatinization resulting in hardening of a starch layer on the exterior surfaces of the slice.

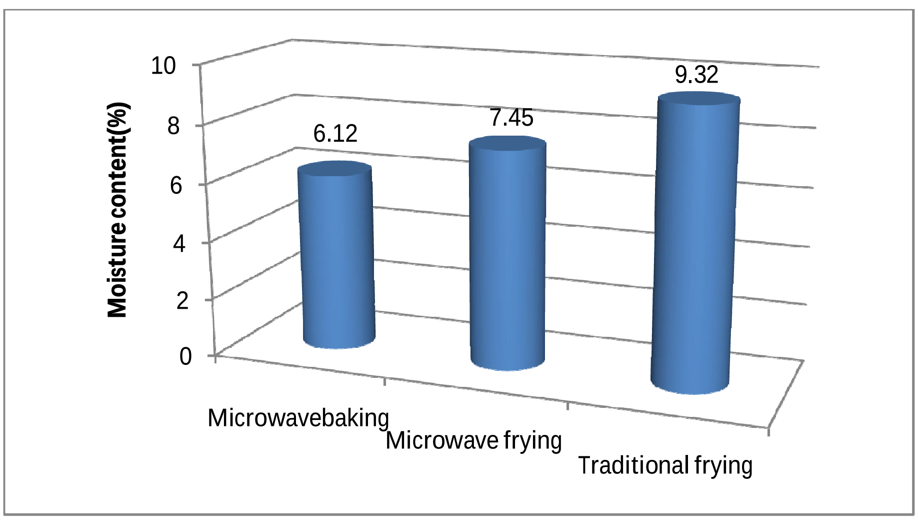

Figure 4.17: Comparison of the moisture content of baked chips with microwave and traditional fried chips

4.3.2 Ash Content

Microwave baked potato chips had lower ash content (4.12%) than microwave fried (8.31%) and conventionally fried (9.74%) potato chips (Figure 4.18). The higher value of ash content in traditionally fried potato chips could probably due to the addition of oils.

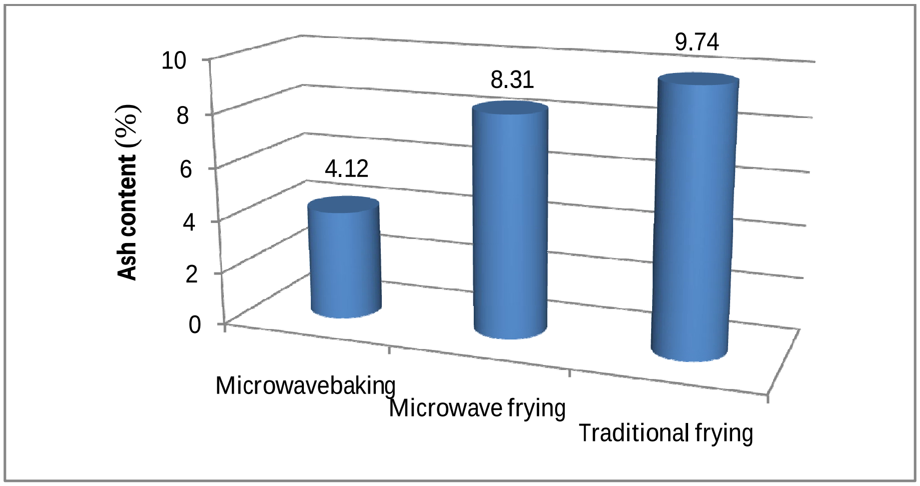

Figure 4.18: Comparison of the ash content of baked chips with microwave and traditional fried chips

4.3.3 Hardness

Figure 4.19 shows that microwave baked potato chips had higher hardness content (4.4kg) than microwave fried (2.9kg) and conventionally fried (2.1kg) potato chips.

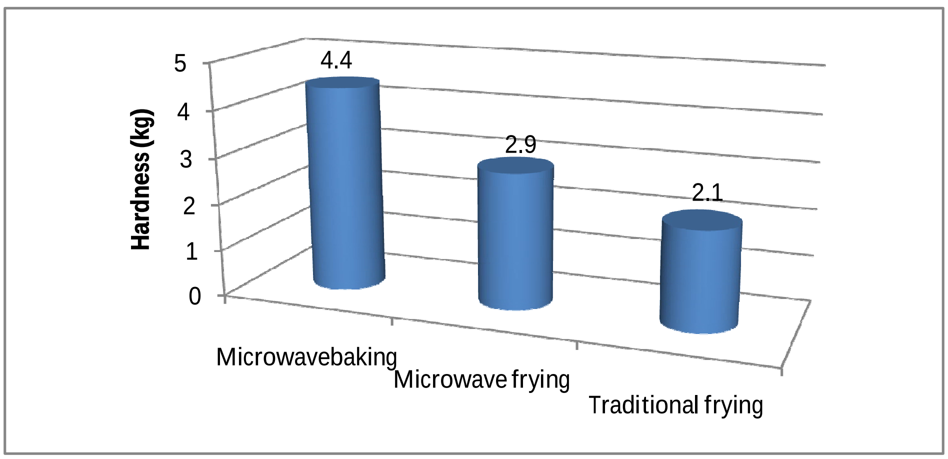

Figure 4.19: Comparison of the hardness of baked chips with microwave and traditional fried chips

4.3.4 Fat Content

Microwave baked potato chips had lower fat content (0.44%) than microwave fried (28.32%) and conventionally fried (40.02%) potato chips (Figure 4.20). Microwave fried potatoes had lower fat content compared to conventional fried ones.

The reason beside the high fat content of traditional chips was when potato slices were fried in oil at high temperature; the substantial amount of moisture present boiled explosively. This resulted in burst cell walls, and consequently, the formation of capillary holes and voids. Oil adhered to the surfaces of the chips and is also absorbed into the holes and voids in the slices. Similar results were obtained by Yanien *et al.*, 1988.

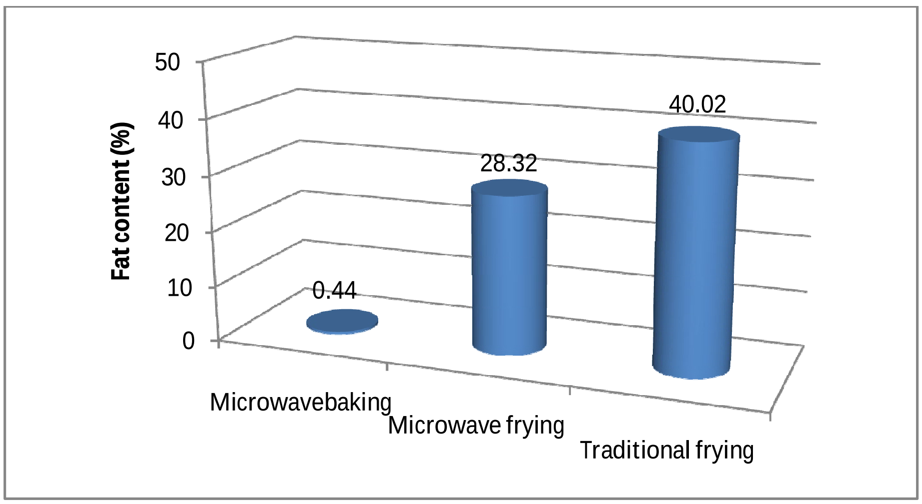

Figure 4.20: Comparison of the fat content of baked chips with microwave and traditional fried chips

4.3.5 Protein Content

Figure 4.21 shows that microwave baked potato chips had higher protein content (2.53%) than microwave fried (2.22%) and conventionally fried (2.01%) potato chips. Application of moist heat to potato slices might have caused the coagulation and shrinkage of proteins and as a result, the protein content of traditionally fried chips was low.

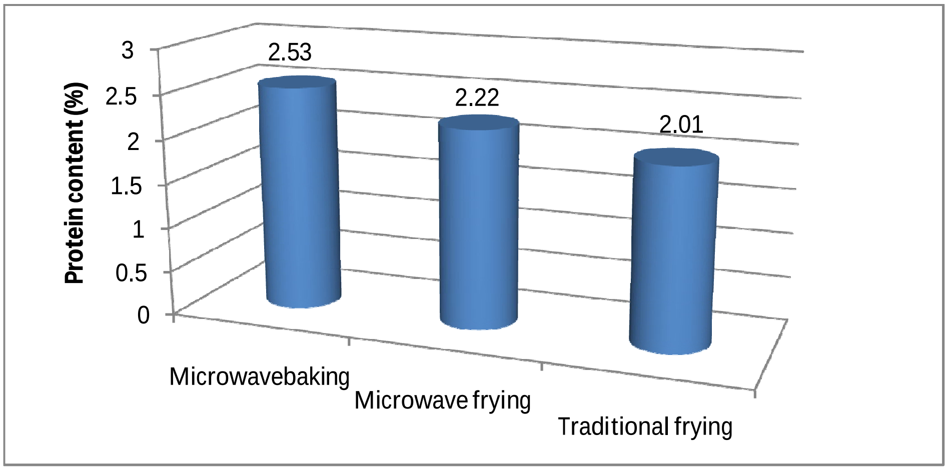

Figure 4.21: Comparison of the protein content of baked chips with microwave and traditional fried chips

4.3.6 Carbohydrate Content

Figure 4.22 shows that microwave baked potato chips had higher carbohydrate content (82.5%) than microwave fried (74.62%) and conventionally fried (61.32%) potato chips.

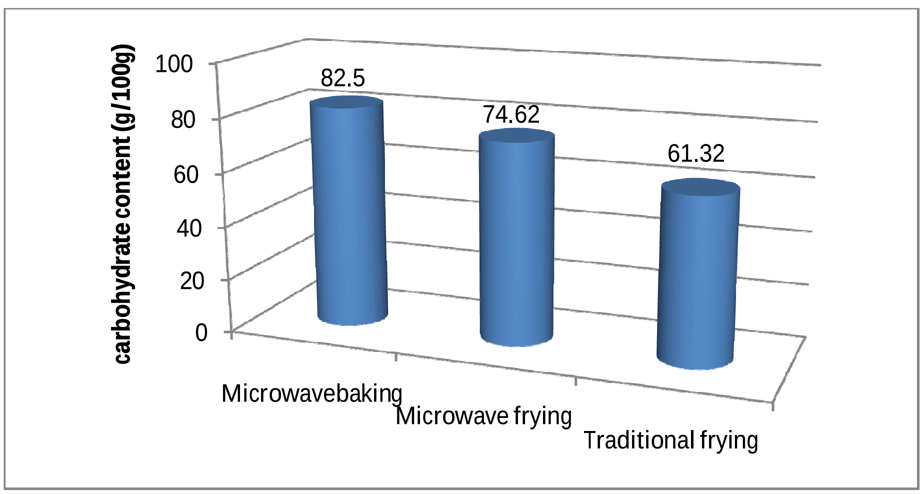

Figure 4.22: Comparison of the carbohydrate content of baked chips with microwave and traditional fried chips

4.3.7 Browning Index

Microwave baked potato chips had lower browning index (0.43%) than microwave fried (0.72%) and conventionally fried (0.91%) potato chips (Figure 4.23). The reason beside the high browning index in traditionally fried chips was due to high temperature of oil and prolonged time of frying.

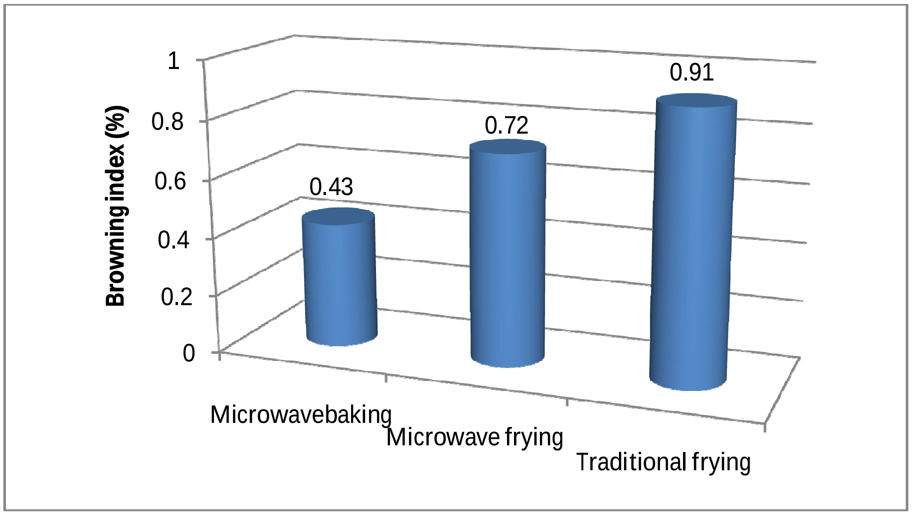

Figure 4.23: Comparison of the browning index of baked chips with microwave and traditional fried chips

4.4 SHELF LIFE OF BAKED POTATO CHIPS STORED IN POLYETHYLENE AND ALUMINIUM LINED POLYETHYLENE

The best sample obtained in optimization (chips of 1.5mm thickness baked at 600 Watts for 8 minutes) was kept for storage in polyethylene and aluminium lined polyethylene. During storage the quality parameters namely moisture, ash, hardness, fat, protein, carbohydrate and browning index of potato chips were studied with 15 days interval from 0-45 days of storage.

4.4.1 Effect of Packaging Material on Moisture Content During Storage

The change in moisture content with respect to storage period for aluminium lined polyethylene and polyethylene (HDPE), was shown in Figure 4.24. It was observed that the moisture content increased with increase in storage days both in aluminium lined polyethylene and polyethylene packs. In case of baked potato chips the moisture content had increased from 6.12% to 7.42% in polyethylene packs where as in aluminium lined polyethylene it had increased from 6.12% to 6.92% during the storage from 0 to 45 days. In the microwave fried chips the moisture content had increased from 7.45% to 9.16% in polyethylene packs where as in aluminium lined polyethylene it has increased from 7.45% to 8.18% during the storage from 0 to 45 days. In traditional fried chips the moisture content for aluminium lined polyethylene was increased from 9.32% to 9.94% and for polyethylene it was increased from 9.32% to 10.34% during the storage period.

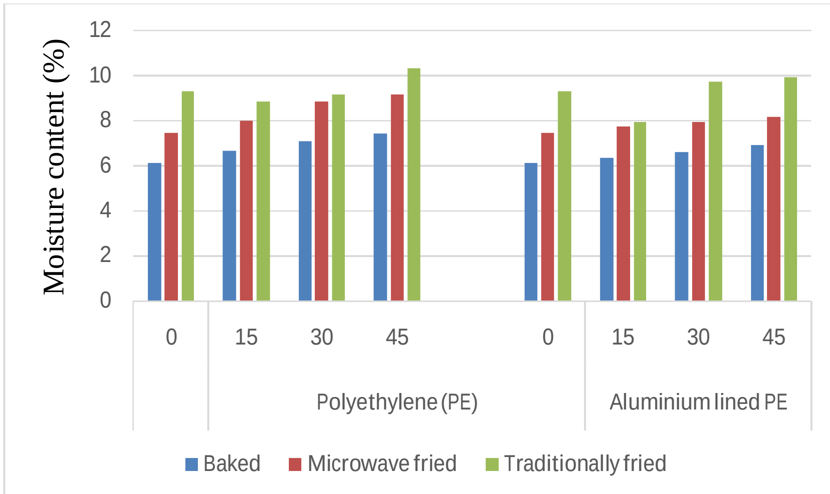

Figure 4.24: Variation of moisture content with storage period and pakaging material

4.4.2 Effect of Storage Conditions and Packaging Material on Ash Content of Different Potato Chips.

The change in ash content with respect to storage period for aluminium lined polyethylene and polyethylene (HDPE), was shown in Figure 4.25. It was observed that the ash content increased with increase in storage days in both aluminium lined polyethylene and polyethylene packs. For baked chips the ash content had increased from 4.12% to 4.31% in polyethylene packs where as in aluminium lined polyethylene it has increased from 4.12% to 4.25% during the storage from 0 to 45 days. In the microwave fried chips the ash content had increased from 8.31% to 8.61% in polyethylene packs where as in aluminium lined polyethylene it had increased from 8.31% to 8.50% during the same period. Whereas for traditional fried chips the ash content for aluminium lined polyethylene was increased from 9.74% to 9.89% and for polyethylene it was increased from 9.74% to 9.99%.

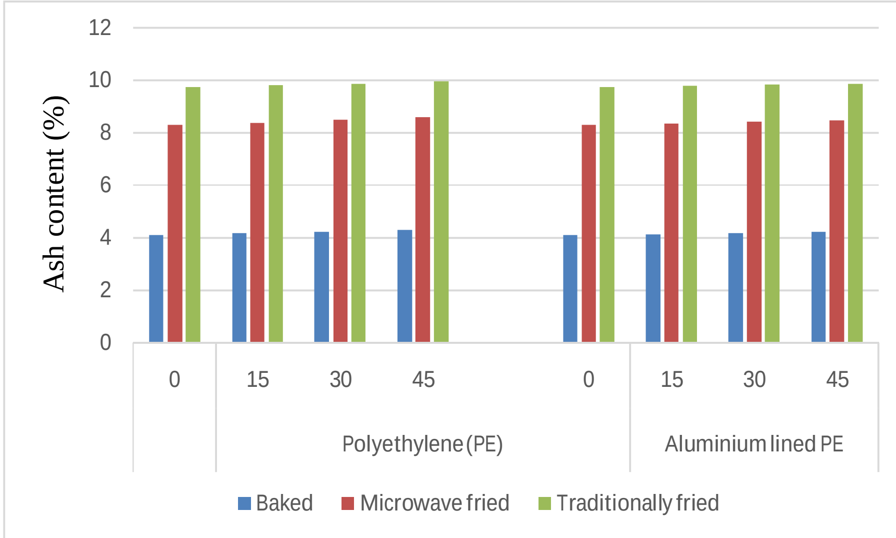

Figure 4.25: Variation of ash content with storage period and pakaging material

4.4.3 Effect of Storage Conditions and Packaging Material on Hardness of Different Potato Chips.

The change in hardness with respect to storage period for aluminium lined polyethylene and polyethylene (HDPE), was shown in Figure 4.26 It was observed that the hardness decreased with increase in storage days in both aluminium lined polyethylene and polyethylene packs. For baked chips the hardness has decreased from 4.4 to 3.6kg in polyethylene packs where as in aluminium lined polyethylene it has decreased from 4.4 to 4.1kg during the storage from 0 to 45 days. In the microwave fried chips the hardness content had decreased from 2.1 to 1.6 kg in polyethylene packs where as in aluminium lined polyethylene it had decreased from 2.1 kg to 1.7 kg during the same period. Whereas for traditional fried chips the hardness content for aluminium lined polyethylene was decreased from 1.7 kg to 1.4 kg and for polyethylene it was increased from 1.7 kg to 1.2 kg.

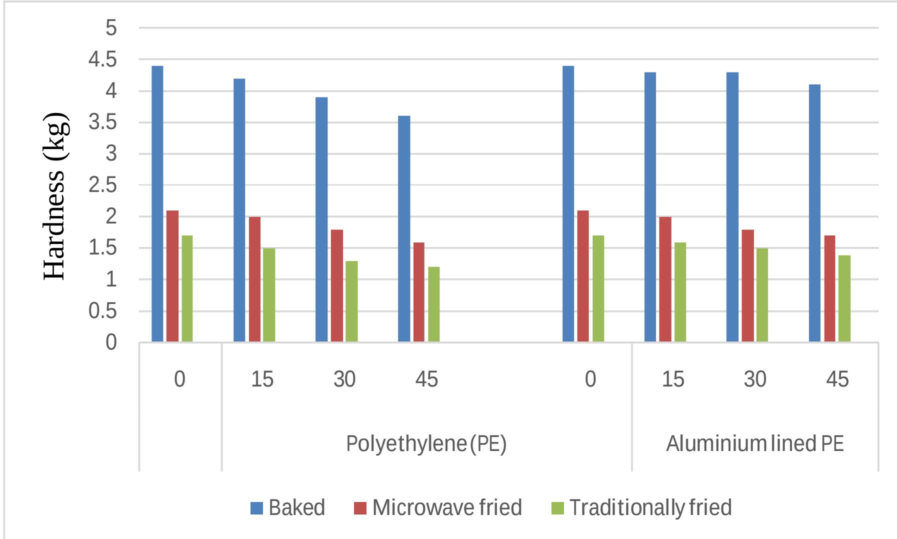

Figure 4.26: Variation of hardness with storage period and pakaging material

4.4.4 Effect of Storage Conditions and Packaging Material on Fat Content of Different Potato Chips.

The change in fat content with respect to storage period for aluminium lined polyethylene and polyethylene (HDPE), was shown in Figure 4.27 It was observed that the fat content increased with increase in storage days in both aluminium lined polyethylene and polyethylene packs. For baked chips the fat content had increased from 0.44% to 0.49% in polyethylene packs where as in aluminium lined polyethylene it has increased from 0.44% to 0.51% during the storage from 0 to 45 days. In the microwave fried chips the ash content had increased from 28.32% to 28.37% in polyethylene packs where as in aluminium lined polyethylene it had increased from 28.32% to 28.36%. For traditional fried chips the ash content for aluminium lined polyethylene was increased from 40.02% to 40.06% and for polyethylene it was increased from 40.02% to 40.08% during same period.

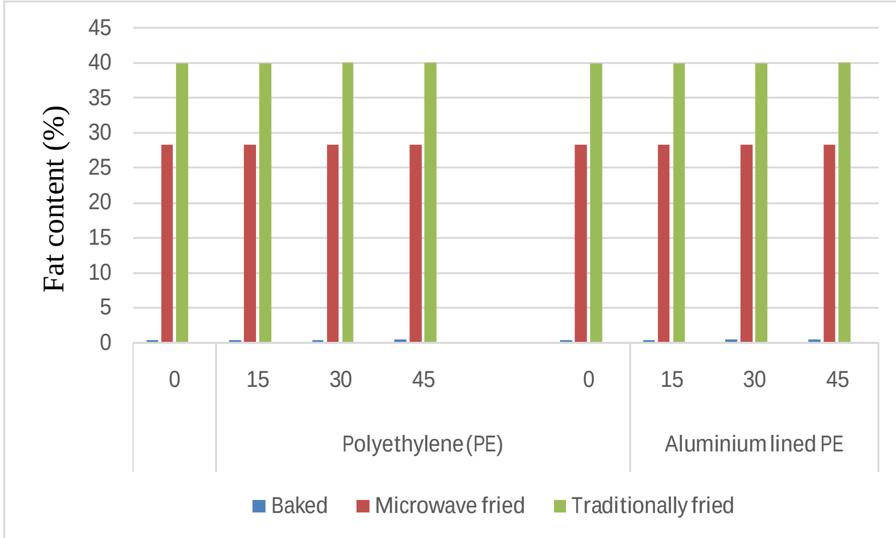

Figure 4.27: Variation of fat content with storage period and pakaging material

4.4.5 Effect of Storage Conditions and Packaging Material on Protein Content of Different Potato Chips

The protein content decreased with increase in storage days in both aluminium lined polyethylene and polyethylene packs (Figure 4.28). For baked chips the protein content has been decreased from 2.53% to 2.44% in polyethylene packs where as in aluminium lined polyethylene it has decreased from 2.53% to 2.47% during the storage from 0 to 45 days. In the microwave fried chips the protein content had decreased from 2.22% to 2.13% in polyethylene packs where as in aluminium lined polyethylene it had decreased from 2.22% to 2.16% during the storage from 0 to 45 days. Whereas for traditional fried chips the hardness content for aluminium lined polyethylene was decreased from 2.01% to 1.95% and for polyethylene it was increased from 2.01% to 1.90% during the storage from 0 to 45 days.

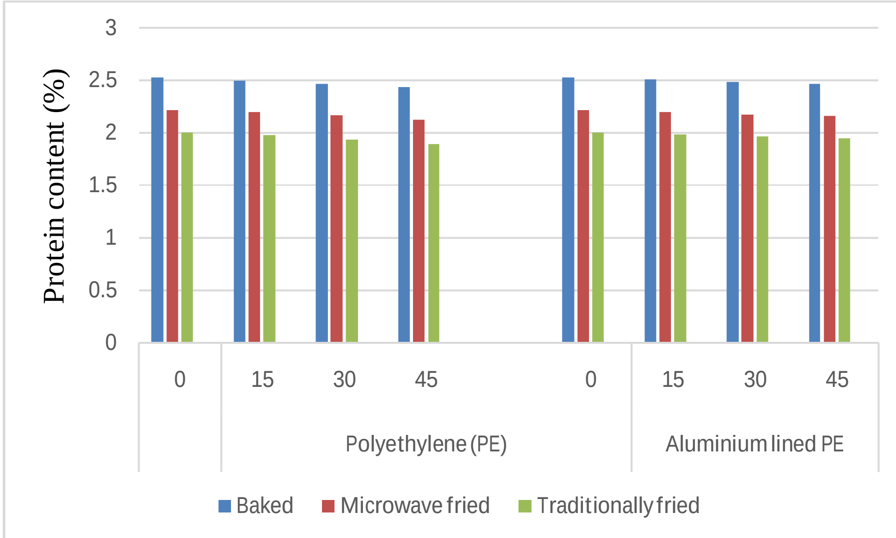

Figure 4.28: Variation of protein content with storage period and pakaging material

4.4.6 Effect of Storage Conditions and Packaging Material on Carbohydrate Content of Different Potato Chips

It was observed that the carbohydrate content decreased with increase in storage days in both aluminium lined polyethylene and polyethylene packs (Figure 4.29). For baked chips the carbohydrate content had decreased from 82.5 to 81.6 g/100g in polyethylene packs where as in aluminium lined polyethylene it has decreased from 82.5 to 81.8 g/100g during the storage from 0 to 45 days. In the microwave fried chips the carbohydrate content had decreased from 74.62 to 74.41g/100g in polyethylene packs where as in aluminium lined polyethylene it had decreased 74.62 to 74.50g/100g during the storage from 0 to 45 days. Whereas for traditional fried chips the hardness content for aluminium lined polyethylene was decreased from 61.32 to 61.20 g/100g and for polyethylene it was increased from 61.32 to 61.17g/100g during the storage from 0 to 45 days.

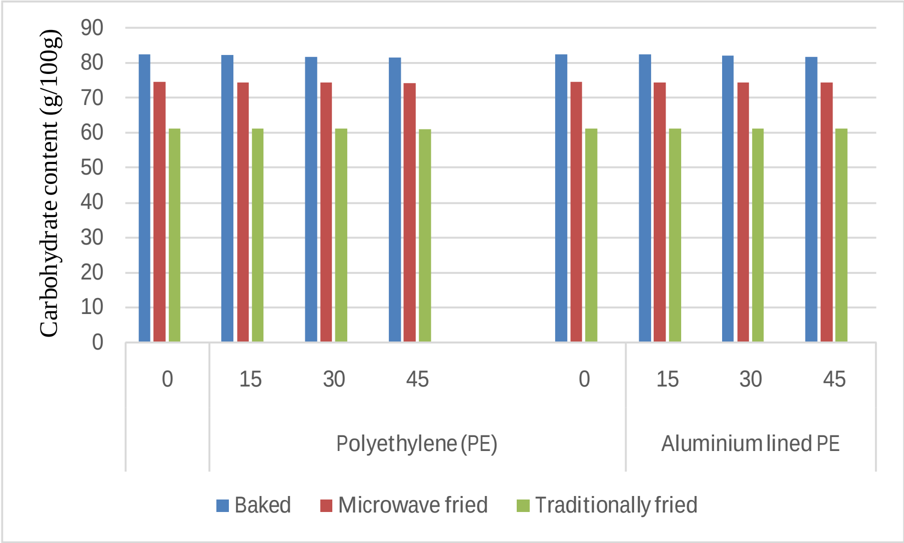

Figure 4.29: Variation of carbohydrate content with storage period and pakaging material

4.4.7 Effect of Storage Conditions and Packaging Material on Browning Index of Different Potato Chips

The change in browning content with respect to storage period for aluminium lined polyethylene and polyethylene (HDPE), shown in Figure 4.30. It was observed that the browning content was increased initially with increasing the storage days in both aluminium lined polyethylene and polyethylene packs and later it was decreased. For baked chips the browning content has decreased from 0.43% to 0.63% in polyethylene packs and then it is decreased from 0.63% to0.57 %. Whereas in aluminium lined polyethylene it has decreased from 0.43% to 0.60 % during the storage from 0 to 45 days and then it was decreased from 0.60% to 0.57%. In the microwave fried chips the browning content had increased from 0.72% to 0.92% in polyethylene packs and then it was decreased to 0.86%. Where as in aluminum lined polyethylene it had increased from 0.72% to % 0.81during the storage from 0 to 45 days and decreased to 0.78%. Whereas for traditional fried chips the browning content for aluminum lined polyethylene was increased from 0.91% to 0.97% where as for polyethylene it was increased from 0.91% to 0.99% during the storage from 0 to 45 days.

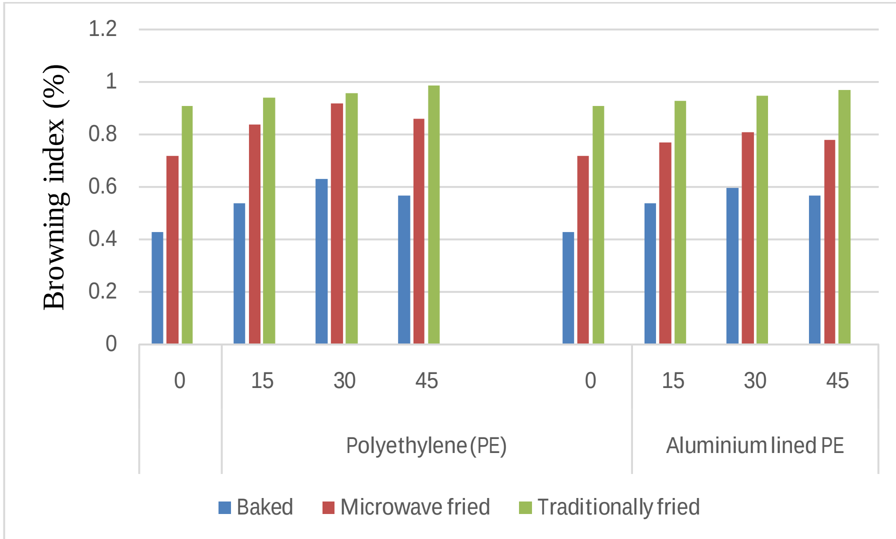

Figure 4.30: Variation of Browning index with storage period and pakaging material

From the storage study it was observed that the aluminium lined polyethylene has retained the quality parameters of baked potato chips when compared with polyethylene packs. The reason behide the best quality parameters in aluminium lined polyethylene may be due to the excellent gas barrier properties and odour, light resistant properties.

Chapter V

SUMMARY AND CONCLUSIONS

Potato chips were prepared by microwave baking process. The study involved the effect of three independent variables namely slice thickness (0.5, 1.0, 1.5, 2.0 and 2.5 mm), baking power level (300, 450, 600, 750 and 900 Watts) and baking time (4, 6, 8, 10 and 12 min). The effect of these operational parameters on the physico-chemical characteristics (Moisture, ash, proteins, fats, carbohydrates, browning index and hardness) of baked potato chips was studied. Optimization of the process parameters was done using Response Surface Methodology. Quadratic regression equations describing the effects of the process parameters on the physico-chemical attributes were developed. The baked potato chips were compared with the traditional and microwave deep fat fried chips. The best sample obtained by optimization was kept for storage studies in polyethylene and aluminium lined polyethylene packaging materials. The following conclusions are drawn from this investigation.

1. At the constant slice thickness and power level, the process parameters namely moisture, fat, protein and browning index decreased with increased baking time while ash, carbohydrate and hardness increased. At the constant power level and baking time, the process parameters namely ash and hardness content decreased with increased thickness while moisture, fat, carbohydrates, protein and browning index increased. At the constant slice thickness and baking time, the process parameters namely moisture, fat and protein content decreased with increased power levels while ash, carbohydrates and hardness increased.

2. The three process variables namely thickness, microwave power levels and baking time significantly affected the physico-chemical attributes of the baked potato chips.

3. In the sensory evaluation test, potato chips of 1.5mm thickness baked at 600 Watts power level for 8 minutes scored highest values in terms of color, taste, texture, flavour and overall acceptability. Samples of 2.5mm thickness baked at 900 Watts power level for 12minutes scored the second highest.

4. The microwave baked potato chips had less moisture, fat, ash and browning index when compared with microwave fried chips and traditionally fried chips. The protein, hardness and carbohydrate content of the baked potato chips were more than the microwave fried chips and traditionally fried chips.

5. Findings indicated that the samples stored in aluminium lined polyethylene exhibited best shelf life than the samples stored in polyethylene.

6. It was possible to obtain baked potato chips in micro oven. The physico-chemical attributes of the microwave baked potato chips were on par with the potato chips produced by the traditional deep fat frying even at very low fat content. Microwave baked potato chips had lower fat content (0.44%) than microwave fried (28.32%) and conventionally fried (40.02%) potato chips.

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Note: The literature is cited as per the "Thesis Guidelines" prescribed by Acharya N.G. Ranga Agricultural University, Rajendranagar, Hyderabad-500 030.

APPENDICES

Appendix-A: Design of experiment for baked potato chips preparation with three independent variables in CCRD

Expt. No.	Thickness, mm (X_1)	Power level, watts (X_2)	Time, min (X_3)
1	0.5 (-1.682)	300 (-1.682)	4 (-1.682)
2	2.5 (+1.682)	300 (-1.682)	12 (+1.682)
3	1.5 (0)	600 (0)	8 (0)
4	1.5 (0)	600 (0)	8 (0)
5	2.5 (+1.682)	900 (+1.682)	4 (-1.682)
6	0.5 (-1.682)	900 (+1.682)	12 (+1.682)
7	0.5 (-1.682)	900 (+1.682)	4 (-1.682)
8	2.5 (-1.682)	900 (+1.682)	12 (+1.682)
9	2.5 (+1.682)	300 (-1.682)	4 (-1.682)
10	0.5 (-1.682)	300 (-1.682)	12 (+1.682)
11	1.5 (0)	600 (0)	8 (0)
12	1.5 (0)	600 (0)	8 (0)
13	1.5 (0)	600 (0)	8 (0)
14	1.5 (0)	600 (0)	8 (0)

Appendix-B: Quality parameters of microwave baked potato chips baked at different baking conditions

S.No.	T	PL	Ti	M (%)	A (%)	H (%)	F (%)	P (%)	C (g/100g)	BI (%)
1	0.5	300	4	6.92	3.72	3.4	0.94	4.57	82.1	0.65
2	0.5	300	6	6.57	3.94	3.8	0.92	4.12	81.8	0.63
3	0.5	300	8	6.14	4.15	4.3	0.88	3.89	81	0.58
4	0.5	300	10	5.59	4.48	4.9	0.84	3.56	79.9	0.52
5	0.5	300	12	5.37	4.79	5.4	0.79	2.87	79.5	0.45
6	0.5	450	4	6.78	3.82	3.6	0.86	4.32	82	0.6
7	0.5	450	6	6.23	4.14	4	0.82	3.89	81.1	0.57
8	0.5	450	8	5.89	4.37	4.6	0.76	3.12	80.6	0.5
9	0.5	450	10	5.27	4.64	5.2	0.68	2.64	79.8	0.46
10	0.5	450	12	4.93	4.82	5.6	0.62	2.12	79.1	0.41
11	0.5	600	4	6.33	3.94	4.2	0.81	4.04	81.9	0.54
12	0.5	600	6	5.94	4.32	4.5	0.76	3.44	81	0.46
13	0.5	600	8	5.12	4.45	4.9	0.69	2.98	80.1	0.42
14	0.5	600	10	4.88	4.89	5.3	0.62	2.22	79.4	0.37
15	0.5	600	12	4.49	4.92	5.8	0.55	1.89	78.1	0.3
16	0.5	750	4	5.82	4.17	4.9	0.75	3.78	81.6	0.55
17	0.5	750	6	5.41	4.48	5.5	0.68	3.12	80.5	0.48
18	0.5	750	8	5.07	4.69	5.9	0.61	2.48	79.6	0.44
19	0.5	750	10	4.72	4.94	6.6	0.54	1.98	79.2	0.39
20	0.5	750	12	4.29	5.02	7.2	0.46	1.52	77.7	0.32
21	0.5	900	4	5.67	4.32	5.4	0.69	3.56	81.2	0.6
22	0.5	900	6	5.14	4.69	5.9	0.58	2.89	80.3	0.57
23	0.5	900	8	4.79	4.72	6.7	0.48	2.26	79.4	0.51
24	0.5	900	10	3.92	5.14	7.4	0.37	1.78	78.1	0.47
25	0.5	900	12	3.59	5.39	7.9	0.29	1.45	77.5	0.43
26	1	300	4	7.12	3.52	3.2	0.96	4.37	82.6	0.67
27	1	300	6	6.89	3.79	3.6	0.94	3.98	81.9	0.65
28	1	300	8	6.37	4.02	4.2	0.89	3.56	81.3	0.6
29	1	300	10	5.89	4.27	4.5	0.85	3.19	80.4	0.54
30	1	300	12	5.54	4.48	5.2	0.8	2.66	79.9	0.48
31	1	450	4	6.97	3.69	3.4	0.88	4.12	82.3	0.61
32	1	450	6	6.52	3.98	3.9	0.84	3.59	81.4	0.59
33	1	450	8	6.17	4.22	4.4	0.78	2.97	80.9	0.53
34	1	450	10	5.79	4.48	4.8	0.69	2.48	80.1	0.49
35	1	450	12	5.24	4.79	5.4	0.64	1.89	79.9	0.43
36	1	600	4	6.59	3.88	3.9	0.83	3.88	82.1	0.55
37	1	600	6	6.02	4.12	4.3	0.78	3.24	81.2	0.47
38	1	600	8	5.64	4.39	4.7	0.7	2.76	80.5	0.43
39	1	600	10	5.17	5.56	4.9	0.64	2.07	79.9	0.38
40	1	600	12	4.72	4.87	5.5	0.57	1.68	79.1	0.32
41	1	750	4	6.23	4.02	4.5	0.77	3.47	81.9	0.54

42	1	750	6	5.79	4.24	5.3	0.69	2.89	80.8	0.47
43	1	750	8	5.28	4.59	5.7	0.63	2.24	7908	0.42
44	1	750	10	4.89	4.82	6.4	0.55	1.85	79.4	0.37
45	1	750	12	4.44	4.98	7	0.48	1.36	78.4	0.31
46	1	900	4	5.93	4.22	5.1	0.7	3.34	81.7	0.59
47	1	900	6	5.42	4.35	5.6	0.59	2.76	80.4	0.56
48	1	900	8	4.94	4.67	6.4	0.49	2.19	79.6	0.5
49	1	900	10	4.32	5.09	7.2	0.39	1.58	78.3	0.45
50	1	900	12	3.88	5.24	7.6	0.31	1.24	77.9	0.42
51	1.5	300	4	7.3	3.39	3	0.97	4.28	82.9	0.69
52	1.5	300	6	6.94	3.56	3.4	0.96	3.66	82.3	0.66
53	1.5	300	8	6.57	3.87	3.9	0.9	3.32	81.7	0.62
54	1.5	300	10	6.12	4.01	4.2	0.86	2.98	80.6	0.58
55	1.5	300	12	5.89	4.24	4.8	0.81	2.45	80.1	0.5
56	1.5	450	4	7.12	3.57	3.2	0.89	3.98	82.7	0.63
57	1.5	450	6	6.76	3.78	3.7	0.86	3.44	81.6	0.6
58	1.5	450	8	6.42	3.99	4.2	0.79	2.78	81.2	0.55
59	1.5	450	10	5.98	4.12	4.5	0.71	2.24	80.4	0.51
60	1.5	450	12	5.42	4.34	5	0.65	1.79	80	0.47
61	1.5	600	4	6.82	3.78	3.4	0.85	3.66	82.5	0.56
62	1.5	600	6	6.47	3.92	4	0.79	3.14	81.4	0.49
63	1.5	600	8	6.12	4.12	4.4	0.71	2.53	80.9	0.45
64	1.5	600	10	5.59	4.22	4.5	0.65	1.98	80.2	0.39
65	1.5	600	12	5.14	4.64	5.3	0.58	1.57	79.4	0.33
66	1.5	750	4	6.42	3.98	4.3	0.79	3.25	82.2	0.53
67	1.5	750	6	5.94	4.05	5.1	0.71	2.67	81.2	0.45
68	1.5	750	8	5.54	4.37	5.4	0.65	2.18	80.2	0.41
69	1.5	750	10	5.12	4.64	6.1	0.56	1.69	80.1	0.35
70	1.5	750	12	4.78	4.48	6.8	0.49	1.17	79.2	0.3
71	1.5	900	4	6.32	4.07	5	0.71	3.12	82.1	0.57
72	1.5	900	6	5.69	4.17	5.4	0.6	2.58	81.1	0.55
73	1.5	900	8	5.24	4.48	6.2	0.51	1.92	80.1	0.49
74	1.5	900	10	4.89	4.89	7	0.43	1.36	79.6	0.43
75	1.5	900	12	4.45	5.15	7.4	0.35	1.17	78.3	0.41
76	2	300	4	7.68	3.12	2.9	0.99	4.08	83.2	0.7
77	2	300	6	7.14	3.34	3.2	0.98	3.47	82.5	0.67
78	2	300	8	6.89	3.69	3.5	0.92	3.12	81.9	0.63
79	2	300	10	6.42	3.99	3.9	0.87	2.66	80.9	0.59
80	2	300	12	6.14	4.05	4.6	0.83	2.24	80.4	0.53
81	2	450	4	7.39	3.36	3	0.91	3.69	82.9	0.64
82	2	450	6	7.05	3.57	3.4	0.89	3.24	81.9	0.63
83	2	450	8	6.74	3.79	3.7	0.81	2.58	81.4	0.56
84	2	450	10	6.29	3.88	4.2	0.74	2.16	80.6	0.53
85	2	450	12	5.74	4.12	4.8	0.69	1.59	80.2	0.48
86	2	600	4	7.14	3.57	3.2	0.87	3.46	82.7	0.57
87	2	600	6	6.79	3.77	3.8	0.81	2.98	81.7	0.5

88	2	600	8	6.42	3.98	4.2	0.74	2.47	81.2	0.47
89	2	600	10	6.02	4.17	4.3	0.69	1.89	80.4	0.41
90	2	600	12	5.49	4.48	5.2	0.61	1.37	79.9	0.34
91	2	750	4	6.78	3.79	4.1	0.81	3.12	82.5	0.52
92	2	750	6	6.37	3.88	4.9	0.75	2.48	81.4	0.44
93	2	750	8	5.94	4.01	5.2	0.69	1.92	81	0.39
94	2	750	10	5.45	4.39	6	0.59	1.4	80.2	0.32
95	2	750	12	4.92	4.66	6.6	0.54	1.06	79.4	0.28
96	2	900	4	6.59	3.98	4.9	0.74	3.07	82.4	0.54
97	2	900	6	6.12	4.05	5.2	0.64	2.48	81.2	0.52
98	2	900	8	5.74	4.29	6	0.59	1.78	80.9	0.47
99	2	900	10	5.22	4.57	6.9	0.48	1.21	79.8	0.42
100	2	900	12	4.94	4.89	7.2	0.39	1.07	78.6	0.38
101	2.5	300	4	7.89	2.98	2.7	1.1	3.92	83.6	0.72
102	2.5	300	6	7.42	3.15	3	0.99	3.22	82.8	0.68
103	2.5	300	8	7.14	3.42	3.3	0.94	3.07	82.2	0.64
104	2.5	300	10	6.79	3.66	3.5	0.89	2.48	81.7	0.6
105	2.5	300	12	6.32	3.98	4.4	0.85	2.17	80.9	0.55
106	2.5	450	4	7.55	3.07	2.9	0.94	3.47	83.2	0.65
107	2.5	450	6	7.27	3.36	3.2	0.91	3.12	82.2	0.64
108	2.5	450	8	6.92	3.54	3.5	0.83	2.48	81.9	0.58
109	2.5	450	10	6.59	3.78	4	0.79	2.07	81.4	0.55
110	2.5	450	12	6.07	4.06	4.6	0.72	1.36	80.5	0.49
111	2.5	600	4	7.44	3.22	3.1	0.89	3.22	83	0.58
112	2.5	600	6	6.95	3.58	3.4	0.84	2.78	82.1	0.51
113	2.5	600	8	6.72	3.89	4	0.76	2.34	81.5	0.48
114	2.5	600	10	6.22	3.92	4.5	0.72	1.78	81.2	0.43
115	2.5	600	12	5.89	4.28	4.8	0.64	1.19	80.1	0.35
116	2.5	750	4	7.24	3.57	3.8	0.83	2.99	82.9	0.51
117	2.5	750	6	6.78	3.78	4.4	0.79	2.24	81.9	0.43
118	2.5	750	8	6.42	3.98	4.9	0.71	1.78	81.3	0.37
119	2.5	750	10	5.88	4.12	5.8	0.62	1.22	81	0.3
120	2.5	750	12	5.24	4.44	64	0.56	0.98	79.6	0.26
121	2.5	900	4	6.94	3.72	4.7	0.79	2.88	82.7	0.53
122	2.5	900	6	6.52	3.98	5	0.68	2.24	81.7	0.5
123	2.5	900	8	6.19	4.12	5.8	0.61	1.69	81.2	0.44
124	2.5	900	10	5.66	4.3	6.5	0.54	1.12	80.3	0.4
125	2.5	900	12	5.12	4.57	7	0.48	0.89	78.9	0.35

where **T**=Thickness (mm), **PL**= Power levels (Watts), **Ti**=Time (min), **M**=Moisture content (%), **A**=Ash content (%), **H**=Hardness (%), **F**=Fat content (%), **P** =Protein content (%), **C**=Carbohydrates (g/100g), **B.I**= Browning index (%).

Appendix-C: The central composite rotatable experimental design (in un-coded levels of three variables and five levels) employed for development of microwave baked potato chips

Independent variables				Dependent variables values						
Run	**(X1)**	**(X2)**	**(X3)**	**M**	**A**	**H**	**F**	**P**	**C**	**B.I**
1	0.5	300	4	6.92	3.72	3.4	0.49	4.57	82.1	0.38
2	2.5	300	12	6.32	3.98	4.4	0.49	2.17	82.3	0.4
3	1.5	600	8	6.12	4.12	4.4	0.44	2.53	82.5	0.43
4	1.5	600	8	6.12	4.12	4.4	0.44	2.53	82.5	0.45
5	2.5	900	4	6.94	3.72	4.7	0.51	2.88	82.4	0.47
6	0.5	900	12	3.59	5.39	7.9	0.36	1.45	84.2	0.58
7	0.5	900	4	5.67	4.32	5.4	0.42	3.56	83.1	0.51
8	2.5	900	12	5.12	4.57	7	0.42	0.89	83.1	0.52
9	2.5	300	4	7.89	2.98	2.7	0.58	3.92	81.4	0.31
10	0.5	300	12	5.37	4.79	5.4	0.42	2.87	83.1	0.46
11	1.5	600	8	6.12	4.12	4.4	0.44	2.53	82.5	0.43
12	1.5	600	8	6.12	4.12	4.4	0.44	2.53	82.5	0.43
13	1.5	600	8	6.12	4.12	4.4	0.44	2.53	82.5	0.43
14	1.5	600	8	6.12	4.12	4.4	0.44	2.53	82.5	0.43

where **X1**=Thickness (mm), **X2**= Power levels (Watts), **X3**=Time (min), **M**=Moisture content (%), **A**=Ash content (%), **H**=Hardness (%), **F**=Fat content (%), **P** =Protein content (%), **C**=Carbohydrates (g/100g), **B.I**= Browning index (%).

Appendix-D: Regression coefficient of the second order polynomial model for moisture, ash, hardness, fat, protein, carbohydrate content and browning index (coded values)

Variables	**Estimated coefficient**						
	M	**A**	**H**	**F**	**P**	**C**	**B.I**
Intercept	7.99	4.12	4.40	0.44	2.53	82.50	0.45
X_1	0.74	-0.37	-0.41	0.039	-0.32	-0.41	2.50
X_2	-2.05	0.32	1.14	-0.034	-0.59	0.49	-0.058
X_3	-0.18	0.50	1.06	-0.039	-0.94	0.46	-0.090
X_1X_2	3.66	0.01	0.01	-1.250	0.014	-0.037	-0.040
X_1X_3	7.50	-0.036	-0.062	-6.250	8.75	-0.062	2.50
X_2X_3	-8.12	-0.019	0.14	1.250	-0.081	-0.012	2.50
X_1^2	-0.14	0.064	0.71	0.021	0.26	0.21	0.08
X_2^2	0.00	0.00	0.00	0.00	0.00	0.00	0.00
X_3^2	0.00	0.00	0.00	0.00	0.00	0.00	0.00
R^2	0.9997	0.9998	1.000	0.9999	0.9999	0.9993	0.9995
CV	0.47	0.37	0.21	0.23	0.65	0.037	0.82
APR	177.071	185.296	603.807	256.014	251.923	107.236	107.236

Where **M**=Moisture content (%), **A**=Ash content (%), **H**=Hardness (%), **F**=Fat content (%), **P** =Protein content (%), **C**=Carbohydrates (g/100g), **B.I**= Browning index (%).

Appendix-E: Analysis of variance showing the effect of thickness, power level and time on moisture content

Source	Sum of squares	Degrees of freedom	Mean squares	F value	p-value prob>F
Model	12.53	7	1.79	2192.38	< 0.0001***
X_1	0.12	1	0.12	148.00	0.0003***
X_2	0.42	1	0.42	515.21	< 0.0001***
X_3	0.58	1	0.58	715.11	< 0.0001***
X_1X_2	0.097	1	0.097	118.53	0.0004***
X_1X_3	7.200	1	7.200	8.82	0.0412*
X_2X_3	0.076	1	0.076	93.12	0.0006***
X_1^2	0.054	1	0.054	66.31	0.0012**
X_2^2	0.000	0			
X_3^2	0.000	0			
Residual	3.267	4	8.167		
Lack of Fit	3.267	1	3.267		

*** P<0.001; ** P<0.01; * P<0.05; ^{ns} Non-significant

Appendix-F: Analysis of variance showing the effect of thickness, power level, time on ash content

Source	Sum of squares	Degrees of freedom	Mean squares	F value	p-value prob>F
Model	3.92	7	0.56	2388.73	< 0.0001***
X_1	1.10	1	1.10	4704.48	< 0.0001***
X_2	0.80	1	0.80	3413.81	< 0.0001***
X_3	1.99	1	1.99	8490.72	< 0.0001***
X_1X_2	2.112	1	2.11	9.01	0.0399*
X_1X_3	0.011	1	0.011	44.85	0.0026**
X_2X_3	2.812	1	2.812	12.00	0.0257*
X_1^2	0.011	1	0.011	46.24	0.0024**
X_2^2	0.000	0			
X_3^2	0.000	0			
Residual	9.375	4	2.344		
Lack of Fit	9.375	1	9.375		

*** P<0.001; ** P<0.01; * P<0.05; ns Non-significant

Appendix-G: Analysis of variance showing the effect of thickness, power level, time on hardness

Source	Sum of squares	Degrees of freedom	Mean squares	F value	p-value prob>F
Model	22.28	7	0.19	30557.14	< 0.0001***
X_1	1.36	1	3.18	13068.00	< 0.0001***
X_2	10.35	1	1.36	99372.00	< 0.0001***
X_3	9.03	1	10.35	86700.00	< 0.0001***
X_1X_2	1.250	1	9.03	12.00	0.0257*
X_1X_3	0.031	1	1.25	300.00	< 0.0001***
X_2X_3	0.15	1	0.031	1452.00	< 0.0001***
X_1^2	1.35	1	0.15	12996.00	< 0.0001***
X_2^2	0.000	0			
X_3^2	0.000	0			
Residual	4.167	4	1.042		
Lack of Fit	4.167	1	4.167		

*** P<0.001; ** P<0.01; * P<0.05; ns Non-significant

Appendix-H: Analysis of variance showing the effect of thickness, power level, time on fat content

Source	Sum of squares	Degrees of freedom	Mean squares	F value	p-value prob>F
Model	0.035	7	4.954	4756.00	< 0.0001***
X_1	0.012	1	0.012	11532.00	< 0.0001***
X_2	9.112	1	9.112	8748.00	< 0.0001***
X_3	0.012	1	0.012	11532.00	< 0.0001***
X_1X_2	1.250	1	1.250	12.00	0.0257*
X_1X_3	3.125	1	3.125	300.00	< 0.0001***
X_2X_3	1.250	1	1.250	12.00	0.0257*
X_1^2	1.204	1	1.204	1156.00	< 0.0001***
X_2^2	0.00	0			
X_3^2	0.00	0			
Residual	4.167	4	1.042		
Lack of Fit	4.167	1	4.167		

*** P<0.001; ** P<0.01; * P<0.05; ^{ns} Non-significant

Appendix-I: Analysis of variance showing the effect of thickness, power level, time on protein content

Source	Sum of squares	Degrees of freedom	Mean squares	F value	p-value prob>F
Model	11.02	7	1.57	5228.33	< 0.0001***
X_1	0.84	1	0.84	2785.37	< 0.0001***
X_2	2.82	1	2.82	9368.51	< 0.0001***
X_3	7.13	1	7.13	23668.86	< 0.0001***
X_1X_2	1.513	1	1.513	5.02	0.0885^{ns}
X_1X_3	6.125	1	6.125	2.03	0.2269^{ns}
X_2X_3	0.053	1	0.053	175.43	0.0002***
X_1^2	0.18	1	0.18	593.07	< 0.0001***
X_2^2	0.000	0			
X_3^2	0.000	0			
Residual	1.204	4	3.010		
Lack of Fit	1.204	1	1.204		

*** P<0.001; ** P<0.01; * P<0.05; ^{ns} Non-significant

Appendix-J: Analysis of variance showing the effect of thickness, power level, time on carbohydrate content

Source	Sum of squares	Degrees of freedom	Mean squares	F value	p-value prob>F
Model	5.14	7	0.73	782.92	< 0.0001***
X_1	1.36	1	1.36	1452.00	< 0.0001***
X_2	1.90	1	1.90	2028.00	< 0.0001***
X_3	1.71	1	1.71	1825.33	< 0.0001***
X_1X_2	0.011	1	0.011	12.00	0.0257*
X_1X_3	0.031	1	0.031	33.33	0.0045**
X_2X_3	1.250	1	1.250	1.33	0.3125^{ns}
X_1^2	0.12	1	0.12	128.44	0.0003***
X_2^2	0.000	0			
X_3^2	0.000	0			
Residual	3.750	4	9.375		
Lack of Fit	3.750	1	3.750		

*** P<0.001; ** P<0.01; * P<0.05; ^{ns} Non-significant

Appendix-K: Analysis of variance showing the effect of thickness, power level, time on browning index

Source	Sum of squares	Degrees of freedom	Mean squares	F value	p-value prob>F
Model	0.054	7	7.740	825.59	< 0.0001***
X_1	6.613	1	6.613	705.33	< 0.0001***
X_2	0.035	1	0.035	3745.33	< 0.0001***
X_3	0.011	1	0.011	1121.33	< 0.0001***
X_1X_2	1.125	1	1.125	12.00	0.0257*
X_1X_3	1.250	1	1.25	1.33	0.3125ns
X_2X_3	3.125	1	3.125	33.33	0.0045ns
X_1^2	1.504	1	1.504	160.44	0.0002***
X_2^2	0.00	0			
X_3^2	0.00	0			
Residual	3.7	4			
Lack of Fit	3.75	1			

*** P<0.001; ** P<0.01; * P<0.05; [ns] Non-significant

Appendix-L **HEDONIC RATING TEST (Proforma)**

Name: **Date:**

Taste the samples and check how you like or dislike each one. Use the appropriate scale to show your attitude by checking the points that best describes your feeling about the sample (Ranganna, 1994).

S.NO	Colour	Taste	Texture	Flavour	4. Overall acceptability
S_1					
S_2					
S_3					
S_4					
S_5					
S_6					
S_7					
S_8					
S_9					

Signature

Hedonic Scale:

9. Like extremely

8. Like very much

7. Like moderately

6. Like slightly

5. Neither like nor dislike

4. Dislike slightly

3. Dislike moderately

2. Dislike very much

1. Dislike extremely