

**UTILIZATION OF BY-PRODUCT FROM TOMATO PROCESSING  
INDUSTRY FOR THE DEVELOPMENT OF NEW PRODUCT**

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Thesis submitted in partial fulfillment of the requirements for the award of the degree  
of **MASTER OF TECHNOLOGY in FOOD SCIENCE AND TECHNOLOGY** to  
The **Indian Institute of Crop Processing Technology, Thanjavur**

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**2015**

## **CERTIFICATE**

This is to certify that the thesis entitled “**Utilization Of By-product From Tomato Processing Industry For The Development Of New Product**” submitted in partial fulfillment of the requirement of **the Degree of Master of Technology in Food Science and Technology** to the **Indian Institute of Crop Processing Technology, Thanjavur** is a record of bonafide research work carried out by **Er. B. KARTHIKA DEVI** under my supervision and guidance and that no part of the thesis has been submitted for the award of any other degree, diploma, fellowship or other similar titles or prizes and that the work has not been published in part or full in any scientific or popular journal or magazine. The research work is original and the research advisory committee approves the research work.

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## **ABSTRACT**

### **UTILIZATION OF BY-PRODUCT FROM TOMATO PROCESSING INDUSTRY FOR THE DEVELOPMENT OF NEW PRODUCT**

By

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Extrusion cooking is recognized as a smart technology for food processors. It is a low cost, high temperature, short-time process and starchy ingredients to create a puffed snack. The only drawback is that it contains multiple parameters that need to be rigorously controlled to develop an optimal process. This study investigated the blends of corn flour, rice flour and tomato pomace (peel and seed), processed in a co-rotating twin screw extruder. And examined the affect of incorporation of tomato by-product derivatives on final extruded product quality of the ready -to -eat expanded product. Furthermore the physico -chemical properties, post cooking quality were analysed for the extruded product. As tomato pomace, corn and rice flour are naturally gluten free, the extruded product would appeal to people who suffer from gluten intolerances, allergies and celiac disease. Dried and milled tomato peel and seed at levels of 0-30% and 0-5%, respectively were added to the formulation mix. A D-optimal mixture design was chosen, which generated 17 combinations; within these combinations, the control formulation existed. The formulations were processed in a twin-screw extruder with a combination of parameters including: solid feed rate kept constant, water feed adjusted to 14%, screw speed of 300–350 rpm and process temperatures 30–140 °C. It was found that addition of tomato pomace significantly increased the crude fibre content and level of protein content

in the final product. The expansion ratio, hardness, colour, and overall acceptability varied significantly with respect to tomato pomace addition. Sensory test panel indicated that tomato pomace extrudate could be incorporated into ready-to-eat expanded products up to the level of 0-30% and it was acceptable. Optimization using D-optimal mixture design suggested that the best formulation extruded product with high desirability was the one consisting of 40% corn flour, 30% rice flour, 25% tomato peel and 5% tomato seed.

The results suggest that tomato pomace can be extruded with corn and rice flour into an acceptable and highly nutritious fibre enriched snack food.

## TABLE OF CONTENTS

CHAPTER NO.	TITLE	PAGE NO.
I	INTRODUCTION	1
II	REVIEW OF LITERATURE	6
III	MATERIALS AND METHODS	22
IV	RESULTS AND DISCUSSION	33
V	SUMMARY AND CONCLUSION	55
	REFERENCES	58
	APPENDICES	76

## LIST OF TABLES

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<b>Table No.</b>	<b>Title</b>	<b>Page No.</b>
3.1	Experimental Design with 17 combinations	26
4.1	(A) Sensory Evaluation Scores for 15 Formulations	35
4.2	(B) Sensory Evaluation Scores for 15 formulations	36
4.3	Experimental Design and Results of Response Variable	37
4.4	Proximate composition of Rice and Corn flour (Average $\pm$ SD)	38
4.5	Proximate composition of Tomato Peel and Seed (Average $\pm$ SD)	38
4.6	Mean Values of Sensory Scores for OA	50
4.7	Solutions Obtained From D-Optimal Mixture Design	52
4.8	Desirability of Responses for the Optimized formulations	52

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## LIST OF FIGURES

Figure No.	Title	Page No.
1.1	Indian Production of Tomato (Source: National Horticulture Board (NHB))	2
1.2	Vegetable Productions in the State of Tamil Nadu	2
3.1	Sample Preparation Process Steps	24
4.1	Sensory Evaluation of 15 different formulated extruded products with different sensory response	33
4.2	3D contour plots of Crude Fibre (%)	40
4.3	3D contour plots of Protein (%)	42
4.4	3D contour plots of Fat (%)	44
4.5	3D contour plots of Expansion ratio (%)	46
4.6	3D contour plots of Hardness (N)	47
4.7	Contour plots of Colour ( <i>a</i> ) value	49
4.8	3D contour plots of Overall acceptability	51
4.9	Bulk density (g/cm <sup>3</sup> )	53
4.10	Water Absorption and Water Solubility Index	55

## LIST OF PLATES

<b>Plate No.</b>	<b>Title</b>	<b>Page No.</b>
3.1	Forced – Electric Tray drier	23
3.2	Tomato pomace	23
3.3	Dried and Separated Tomato Pomace	24
3.4	IR Moisture Balance	25
3.5	Co-Rotating Twin-Screw Extruder	27
	(A) Cross sectional view of Twin screw	
3.6	(B) Cross sectional view of Die head (4.5mm)	28
3.7	Hot Air Oven	28
3.8	Texture Analyzer	30
3.9	Hunter Colour Lab	31
3.10	Extruded samples for Sensory Evaluations	32

## LIST OF APPENDICES

<b>Appendix No.</b>	<b>Title</b>	<b>Page No.</b>
1	Analysis of variance (ANOVA) of the final regression equation for the response: Crude Fibre	76
2	Analysis of variance (ANOVA) of the final regression equation for the response: Protein	77
3	Analysis of variance (ANOVA) of the final regression equation for the response: Fat	78
4	Analysis of variance (ANOVA) of the final regression equation for the response: Expansion Ratio	79
5	Analysis of variance (ANOVA) of the final regression equation for the response: Hardness	80
6	Analysis of variance (ANOVA) of the final regression equation for the response: Colour	81
7	Analysis of variance (ANOVA) of the final regression equation for the response: Overall Acceptability	82
8	Sensory Score Card	83

## LIST OF SYMBOLS AND ABBREVIATIONS

TF	-	Total Fiber
TP		Tomato Pomace
TDF	-	Total Dietary Fiber
ANOVA	-	Analysis of variance
AO	-	Antioxidants
AOAC	-	American Association of Analytical Chemists
<i>a</i>	-	Redness value
mg	-	milli gram
min	-	minute (s)
ml	-	milliliter
mm	-	millimeter
MT	-	Metric tonne
NHB	-	National Horticulture Board
RTE	-	Ready-To-Eat
DPPH	-	2,2-diphenyl-1-picrylhydrazyl
EU	-	European Union
FAO	-	Food and Agriculture Organization
g	-	gram
GC	-	Gas chromatography
h	-	hour
HPLC	-	High performance liquid chromatography
L	-	Lightness
l	-	litre
IDF	-	Insoluble Dietary Fiber
g/Kg		gram per kilogram
SDF	-	soluble Dietary Fiber
ppm	-	parts per million
m	-	meter

WAI	-	Water absorption index
WSI	-	Water solubility index
CD	-	Celiac disease
μm	-	micrometer
%	-	percentage
°C	-	Degree Centigrade
w.b.	-	Wet basis
3D	-	Three Dimension
P	-	probability
R <sup>2</sup>	-	Coefficient of determination
<i>et.al</i>	-	and others
wt	-	weight
BD	-	Bulk density
NaOH	-	Sodium Hydroxide
PDPF	-	Partially defatted peanut flour

## CHAPTER I

### INTRODUCTION

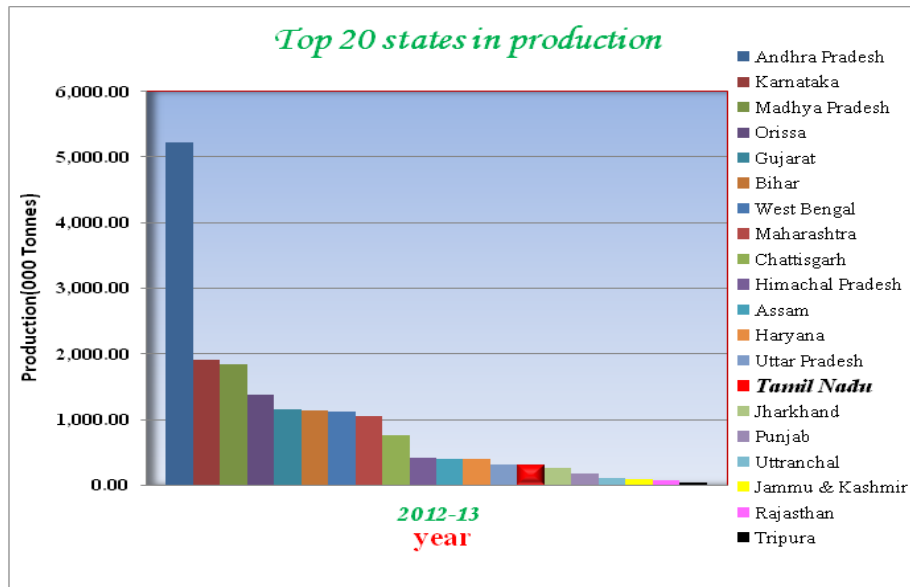
Effective utilization of food by-product/waste as secondary source for the new product development is an emerging area of research. Residues from food industry waste (solid as well as liquid) have some potential benefits on health aspects. So recent research has been focussing on this food waste for utilization as nutraceuticals and pharmaceuticals, and also for energy generation in the form of production of biogas, hydrogen and bio-ethanol etc (Mirabella et al., 2014; Van Dyk et al., 2013).

In food processing industry, food wastes require further processing before being used in food products. This transformation from food waste to value products implies high costs in research and development. Hence, it is essential to obtain important and high value-added products in order to justify the investment.

Tomato (*Lycopersicon esculentum* L.) is one of the world's major vegetable with a worldwide production of 126 million tons in 2005 (FAOSTAT, 2007). It is the second most important vegetable crop next to potato worldwide, with annual production at 100 million tons fresh fruit produced in 144 countries (Kalogeropoulos et al., 2012).

In India, Andhra Pradesh is the top most leading state with the production of 5,218.10 Tonnes of tomatoes in the year 2012-2013 where as Tamilnadu produced about 302.27 Tonnes in year 2012-2013 and ranked in 14 place (Indian Horticulture Database, 2013, NHB, MoA, GoI, India).

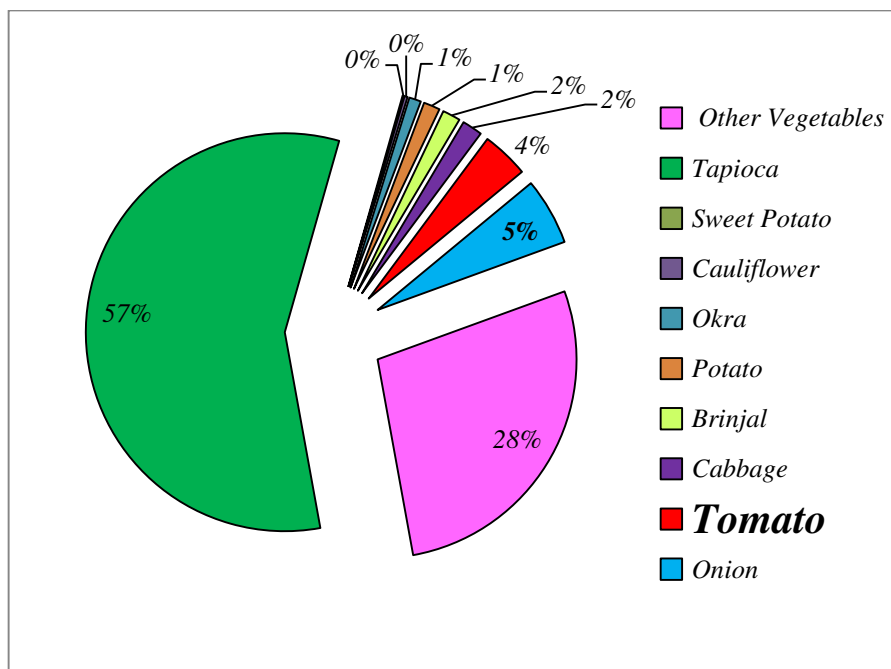
During industrial transformation of tomato on concentrate, the yield of production can range between 95% and 98%, which means that about 4% solid tomatoes by-product is generated. Tomato by-products, consisting of peel and seeds, are rich in nutrients and bioactive compounds such as sugars, organic acids, pigments, fibre, proteins, oils, antioxidants and vitamins (Del Valle et al., 2006)



**Fig: 1.1**

**Indian Production of Tomato (Source: National Horticulture Board (NHB))**

According to Otto & Sulc (2001) about 3-7% of raw material is wasted during tomato juice pressing. The seeds account for approximately 10% of the fruit and 60% of the total waste, respectively, and are a source of protein (35%) and fat (25%). Tomato seed oil has attracted interest since it is rich in unsaturated fatty acids, especially in linoleic acid about 56% (Askar & Treptow, 1998; Roy, Goto, & Hirose, 1997).



**Fig: 1.2 Vegetable Production in the State of Tamil Nadu  
(Total Production in 000'MT: 7897.93)**

A number of researchers have used fruits and vegetable by-products such as apple, pear, orange, peach, blackcurrant, cherry, artichoke, asparagus, onion, carrot pomace (Grigelmo-Miguel and Martin-Belloso, 1999; Ng et al., 1999; Nawirska and Kwasnievska, 2005; N. O'Shea et al., 2014) as sources of dietary fibre supplements in refined food. Dietary fibre concentrates from vegetables showed a high total dietary fibre content and better insoluble/soluble dietary fibre ratios than cereal brans (Grigelmo-Miguel and Martin-Belloso, 1999). The beneficial effects of TDF on human health and body function are well-documented; thus, a high consumption of TDF is associated with a reduced incidence of common disorders and diseases in developed societies such as chronic bowel disorders, obesity, diabetes, cardiovascular disease, and cancer (Bessesen, 2001; Johnson, 2004; Kris-Etherton et al., 2002). Consumption of fibre in daily diet has some physiological effects such as laxation and modulation of blood glucose have been related to the consumption of dietary fibre (Brennan, 2008).

Lycopene is the principal carotenoid causing the characteristic red hue of tomatoes. Most of the lycopene is associated with the water-insoluble fraction and the skin (Sharma & Maguer, 1996). Lycopene, a pigment from the carotenoid family, is a major antioxidant present in tomato with predominant nutritional value; it has been associated with various health benefit claims including immune system modulation, as a free radical scavenger and as having anti-carcinogen properties (Giovannucci, 1999; Omoni & Aluko, 2005). Also diet rich in lycopene is related to a decreased risk of certain cancers, particularly cancers of the digestive tract, prostate cancer and pancreatic cancer due to protective effect of lycopene against oxidative damage. Daily consumption of 6–15 mg lycopene is recommended for improved health (Kun, Lule, & Xiao-Lin, 2006). Amount of lycopene differs according within the paste, skin and tomato derivatives.

In recent years, there is an increasing demand for conversion of fruit and vegetable wastes into useful products. The primary motivation is to minimize environmental impact of these by-products from food industry to avoid environmental problems and to utilize valuable constituents that remain, such as lycopene and dietary fibre. One viable method for utilization of fruit and vegetable by-products into useful products is extrusion processing due to its versatility, high productivity, relative low cost, energy efficiency and lack of effluents.

Successful incorporation of tomato pomace into extruded products that deliver physiologically active components represents a major opportunity for food processors providing the consumer a healthy tomato pomace-based product to choose from which is currently lacking in the marketplace.

Extrusion cooking is an important and popular food processing technique classified as a high temperature/short time process to produce fibre-rich products (Gaosong & Vasanthan, 2000; Vasanthan, Gaosong, Yeung, & Li, 2002). Extrusion can be used to produce a wide variety of starchy foods including snacks, ready to eat (RTE) cereals, confectioneries and extruded crisp breads (Suknark, Philips, & Chinnan, 1997). Extruded foods have been proven to provide nutritious products and combine quality ingredients and nutrients to produce processed foods that contain precise levels of each required nutrient (Cheftel, 1986).

Extruded foods are composed mainly of cereals, starches, and/ or vegetable proteins. The major role of these ingredients is to give structure, texture, mouth feel, bulk, and many other characteristics desired for specific finished products (Launay & Lisch, 1983; Tahnoven et al., 1998). Consumer acceptance of extruded foods is mainly due to the convenience, value, attractive appearance and texture found to be particular for these foods, especially when it concerns snack products.

Extruders generally consist of a single or twin screw; the twin screws usually operate via co-rotating or counter-rotating manner within the extruder barrel (Brennan et al. 2013). Extensive work has been carried out using twin screw extruders to investigate the effects of tomato pomace, grape pomace, cauliflower by-products, brewers spent grain and red cabbage trimmings on the macro-structure and functional aspects of extruded puffed snacks (Altan et al. 2008, Stojceska et al. 2009).

Cereals such as corn are ideal for extrusion; they are gluten free, easily accessible and have a high starch content, which can give excellent expansion characteristics. The only disadvantage of using corn is that it is likely to be relatively low in nutrients such as dietary fibre and minerals (Pastor- Cavada et al. 2011). Rice flour has become an attractive ingredient in the extrusion industry due to its unique attributes such as bland

taste, attractive white colour, hypoallergenicity and ease of digestion (Kadan, Bryant, & Pepperman, 2003).

While corn starch provides all the features for production of highly acceptable extruded snack foods, its nutritional value is far from satisfying the needs of health-conscious consumers (Rampersad, Badrie, & Comissiong, 2003). What the literature is lacking is the investigation of the effects of tomato pomace using a twin screw extruder to explore its effects on the structural, functional and nutritional aspects of an extruded puffed corn and rice based snack foods.

Therefore, the objective of this research was to investigate process ability of mixing the tomato pomace into the rice and corn flour as a major ingredient to produce snack food in a twin-screw extruder. The effect of the variables such as tomato pomace (peel and seed) content, on the functional properties and physical properties of extrudates were evaluated by using Mixture design, D-optimal. Sensory properties were determined in terms of color, texture, taste, flavour and overall acceptability for selected extrudate samples.

#### OBJECTIVES:

- ✓ To remove bitter compounds from tomato peel
  
- ✓ To include tomato peel fibre and seeds as a value-added ingredients into an existing extruded formulation using twin screw extruder.
  
- ✓ To optimize the process parameters and the formulation to develop a snack food for the best product in terms of texture, colour and overall acceptability.

## **CHAPTER II**

### **REVIEW OF LITERATURE**

#### **2.1 Current status and management of food processing waste**

Food Waste is a concerned topic in which substantial amount of food that should have been eaten and ends up as waste along the food value chain. This in general not only representing the resource problem but also the environmental issue and also economically increasing. Food waste production is increasing with increasing population, in this era of the statement about 15% of population in developing countries are starving (FAO, 2012) all over developing countries all dealing with over-consumption of food, food related diseases and the increase in food waste. This concerned issue related to food waste has been brought since in 90's to the scientific community (Kroyer, 1995).

Food processing wastes are produced as solid and liquid wastes. The solid waste is the portion of the starting material that cannot be utilised in the production of the intended products, such as these kins, pips and fibres of fruit which are removed in the production of juice. Approximate Global production of Tomatoes in 2010 were expected to be about 145,751,507 MT (FAO 2012). The waste production in 2010 in the processing between 3% and 7% is lost as waste. Approximately 4,372,545 MT and 10,202,605 MT of waste were generated in 2010 (Schieber A et al., 2001).

According to Joshi VK et al., 2006 and Laufenberg.G et al., 2003, However, a different category of food processing wastes are left over and these are underutilized and occasionally incinerated, the energy input is costly due to the low calorific value and high water content and it may also results in air and environmental problems .So these wastes should be taken into consideration for the further usage in foods for its beneficiary compounds. Many factories simply dump the waste close to the plant. Since these wastes have high nutrient levels and water content and can support bacterial growth and fermentation, these may cause odours and other environmental problems. A further means of disposal of food waste is through its utilisation as animal feed, mostly for cattle feed. The waste may be dried and formed into pellets prior to sale as animal feed. Arvanitoyannis IS et al., (2006) told that food waste can also be utilised as a soil conditioner or fertiliser.

In developing countries about 15% of population is starving (FAO, 2012), this large amount of food waste implies an increasing great loss of valuable materials. It also raises management problem due to associated resource consumption and pollutant emission. It has been estimated that for each ton of food waste there is an emission of about 2 tons of CO<sub>2</sub> (European Commission, 2010).

Van Dyk et al., 2013, During the production season large quantities of tomato waste are generated, this may be from the insufficient processing of agricultural products. In recent years due to increase in population food production have increased and have led to over-consumption of processed food. However, this over production and consumption produce different category of tomato waste and these are generally remains largely underutilized, waste produced may be from households, losses occur in the food manufacturing industry, during food sector (ready- to- eat food, catering and restaurants), lost along distribution chain the waste consist of lot of nutrients and can be a promising sources for food supplementation therefore these should be investigated for further beneficiation for the industrial processing of food waste. He also reported that waste from food processing industry is produced in large quantities especially from juice industry and in some cases it is utilized as secondary raw material such as pectin, dietary fibre, phenolics, and other antioxidants in food production but also contain high amount of lignocelluloses based indigestible substances which is underutilized and discarded and this could serve as feedstock for bio ethanol production.

Nadia Mirabella et.al., (2014) states that food industry produce large amount of food manufacturing waste in which this valuable material also raises serious management problem both from environment and economic point of view and hence recycling can be done to produce new product for reducing burden on virgin raw material comes from food processing waste.

## 2.2 Tomato

Tomato (*Lycopersicon esculentum L.*) is one of the world's major vegetable with a worldwide production of 126 million tons in 2005 (FAOSTAT, 2007). Epidemiological studies have pointed out that consumption of fruits and vegetables imparts health benefits, e.g. reduced risk of coronary heart disease and stroke, as well as certain types of cancer. Tomatoes (*Lycopersicum esculentum*) are rich in bioactive and valuable compounds, such as carotenoids, mainly lycopene (80-90%),  $\beta$ -carotene, plus vitamin C, vitamin E and various phenolic compounds (Dumas et al., 2003) the consumption of tomatoes has been associated with the prevention of several diseases (Sharoni & Levi, 2006; Wilcox, Catignani, & Lazarus, 2003) mainly due to the content of antioxidants, including carotenes (lycopene as well as  $\beta$ -carotene), ascorbic acid, tocopherol, and phenolic compounds (Martínez- Valverde, Periago, Provan, & Chesson, 2002; Periago et al., 2009). Phenolic compounds exhibit a wide range of physiological properties, such as anti-allergenic, antiatherogenic, anti-inflammatory, anti-microbial, antioxidant, antithrombotic, cardioprotective, and vasodilator effects (Balasundram, Sundram, & Samman, 2006).

## 2.3 By-product utilization

However when tomatoes are processed into products like Ketchup, salsa, jam and sauces, 10–30% of their weight becomes waste or pomace (King and Zeidler, 2004). The new ingredients from several vegetable origins could be of great interest for the food and pharmaceutical industries. There is a rapidly growing body of literature covering the role of plant secondary metabolites in food and their potential effects on human health. Furthermore, consumers are increasingly aware of diet related health problems, therefore demanding natural ingredients which are expected to be safe and health-promoting.

By-products of plant food processing represent a major disposal problem for the industry concerned, but they are also promising sources of compounds which may be used because of their favourable technological or nutritional properties. Since synthetic additives are more and more rejected by consumers, functional ingredients should preferably originate from natural sources. This is particularly valid for phenolic

compounds which, in contrast to most carotenoids and vitamins, are not chemically synthesized and need to be extracted from plant material.

Several research has been done on exclusively research on utilization of by-product from food processing wastes Bhushan et.al (2008) most prominent usage of food waste can be as pectin which is highly present in peel of all fruits and vegetables and can be used as thickener and stabilizer in foods mostly extracted from citrus pomace, apple and sugar beet pulp. In addition, (Al-Wandawi et al.1985) tomato skin and seeds were reported to contain essential amino acids and the tomato seeds had higher amounts of minerals (Fe, Mn, Zn and Cu).

Baysal, Ersus, and Starman (2000) clearly stated that a large quantity of carotenoids is lost as waste in tomato processing. Supercritical CO<sub>2</sub> extraction of lycopene and  $\beta$ -carotene from tomato paste waste resulted in recoveries of up to 50% when ethanol was added (Baysal et al., 2000). Enzymatic treatment of tomato marc enhanced lycopene extractability (Tiemeni, & Otto, 2000). Recently, saccharification to obtain biomass from tomato pomace has also been reported (Avelino et al., 1997). Haddadin, Abu-Resh, Haddadin, and Robinson (2001) described the utilization of tomato pomace as a substrate for the production of vitamin B12.

Galanakis (2012) have been told that emerging methodology like nano-techniques is applicable for the recovery of valuable compounds from food waste and that can be accomplished by avoiding extreme processing conditions (i.e. non thermal technologies) and this concept will improve the overall efficiency of other methodology over extending shelf life of the product and will meet the consumer high quality standards and organoleptic characteristics near in future.

### **2.3.1 Tomato peel**

The important by-product from tomato is its peel, which is rich in fibre. Fibre is not a simple and well defined chemical compound, but a combination of chemical substances in composition and structure, such as cellulose, hemicelluloses, lignin, etc. being defined as “edible parts of plants or analogous carbohydrates that are resistant to digestion and absorption in the human small intestine with complete or partial

fermentation in the large intestine” (Mongeau, 2003). Fibre includes: insoluble fibre (lignin, cellulose and hemicelluloses) and soluble fibre (pectins,  $\beta$ -glucans, galactomanan gums, and a large range of non-digestible oligosaccharides including inulin).

(Bessesen, 2001; Johnson, 2004; Kris-Etherton et al., (2002) reported that tomato fibre considered to be high in by-product obtained from food industry, Studies suggest that it may concerned to be as a source of total dietary fibre in food products as a interesting ingredient since it is beneficial for the human consumption associated with reduced incidence of common disorders and disease which is developed among the societies such as chronic bowel disorders, obesity, diabetes, cardiovascular disease, and cancer.

Numerous studies have been conducted for the utilization of tomato by-product as a source of secondary functional ingredient in new product development García Herrera et al., (2010) conducted study on tomato fibre sample taken from two different season (2005 & 2006) found that protein content was varying between the range of 57.9 and 71.1  $\text{gkg}^{-1}$ . Hogarth, Hunter, Jacobs, Garleb, and Wolf 2000 reported that samples tested for sugars by using HPLC confirmed that tomato fibre consist of fructose and glucose and in less amount of frcto-oligosaccharides 0.32, 0.26 and 0.60  $\text{gkg}^{-1}$  of kestose, nystose and fructosylnystose, respectively. Since tomato fruit itself contains kestose, nystose and fructosylnystose in very low concentration.

Furthermore Studies (Femenia et al., 1998) have been reported on fibre content present in tomato peel samples are comparatively higher when compared to other vegetables by-product which represent about 80% being insoluble fiber content (726–798  $\text{gkg}^{-1}$ ) much higher than soluble fiber (44–85  $\text{gkg}^{-1}$ ), with no statistically significant differences in both samples. Some authors have been already reported in their study it can be observed that tomato peel shows higher average value of 827.0  $\text{gkg}^{-1}$  of total fibre while cauliflower by-product has about (23  $\text{gkg}^{-1}$  of total fiber in floret and 31  $\text{gkg}^{-1}$  in upper stem), artichoke by-product (32  $\text{gkg}^{-1}$  in receptacle and 36  $\text{gkg}^{-1}$  in stem) and chicory by-product (7  $\text{gkg}^{-1}$  in leaf bud and 48  $\text{gkg}^{-1}$  in root) However, the ratio between insoluble and soluble fiber in TF (near 10:1) is more similar to grains than to other fruit products (Grigelmo-Miguel & Martín-Belloso, 1999). Since there is a tremendous increase in the amount of fibre in tomato (García Herrera et al., 2010) suggest

that this fibre can be used as functional ingredient in product which is poor in fibre intake among population.

In other study TDF content of tomato peel fibre has been reported to be higher than those reported in other vegetables as discussed earlier IDF 71.82 g/100 g and SDF 14.33 g/100 g that is about 5:1 ratio in proportions (Inmaculada et al., 2011). It has been also reported by the same researchers that the main sugars of tomato peel fibre are mannose (38.56%), galactose (16.17%), xylose (15.38%), arabinose (15.16%), and glucose (14.64%), which indicates that hemicelluloses are the predominant polysaccharide of this fibre. In addition, dietary fibre obtained from plant foods is rich in phenolic compounds and has been considered as a dietary source of antioxidants (Saura-Calixto, 1998).

In most of the previous work conducted on tomato reveals that, antioxidants have been measured, mainly in, whole tomatoes or processed tomato products (Lavelli et al., 2000; Martinez- Valvercle et al., 2002; Raffo et al., 2002). In agreement with this, Stewart et al. (2000) reported that the majority of the flavonols in tomatoes are present in the skin. Similarly, Sharma and Le Maguer (1996) observed that most of the lycopene was associated with the skin and water insoluble fraction of the tomato pulp. Although Elbadrawy and Sello (2011) conducted study on antioxidant activity of tomato peel extracts in which the results shows that tomato peels are essential and it is good source of amino acids and fatty acids and are besides having high amount of flavonoids, phenolic acids, lycopene, ascorbic acid and minerals (Ca, Cu, Mn, Zn, and Se) it has been told that it also contain antioxidant in higher fractions and removal of this during processing will reduce the nutritional value of the final product in human diet .

Tomato skin contains more than 20 ppm lycopene, protected within the chromoplasts in the cells, while in tomato paste, lycopene is available at a much higher concentrations (>450 ppm) and is more accessible due to the prior processing and the generally weaker structure of the cells comprising the lycopene (Gartner, Stahl, & Sies, 1997). Also researches have conducted studies regarding tomato wastes for their evaluation as potential source of phenolic antioxidants and anticancer agents. It has also been reported that tomato pomace significantly reduced cholesterol level in liver and heart by 15% and 18%, respectively (Bobek, Ozdin, & Hromadova, 1998)

Lycopene and phenolic compounds are resistant to thermal processing, which is present high in tomato peel than pulp. (Rao & Agarwal, 1999). Lycopene exhibits strong antioxidant activity hence it modulates hormones, immune system and other metabolic pathways (Balasundram, Sundram, & Samman, 2006). Phenolic compounds exhibit a wide range of physiological properties, such as anti-allergenic, antiatherogenic, anti-inflammatory, anti-microbial, antioxidant, antithrombotic, cardio protective, and vasodilator effects (George, Kaur, Khurdiya, & Kapoor, 2004).

Kalogeropoulos et al., (2012) has been found that industrial by-product from tomato processing has some significant amount of several bioactive compounds like sterols, tocopherols, carotenes, terpenes and polyphenols when compared with unprocessed tomato and also has antioxidant properties therefore value adding ingredient can be isolated from the by-product by various methods that can be used as a functional source in food product or it can be serve as additives in food products to increase its shelf life.

Vinha et al., (2014) conducted study which shows that effect of removal of peel and seed will significantly reduces the beneficial compounds like total phenolic compounds and bioactive compounds present in peel and seed its already been stated that antioxidant capacity is reduced by the ability of tomato material to capture DPPH this states that peeling affects the functional compound greater which loses its antioxidant capacity than seed removal.

### **2.3.2 Tomato Seed**

Askar & Treptow, 1998; Roy, Goto, and Hirose, 1996) reported that tomato seed oil has been attracted since it is rich in unsaturated fatty acids, especially in linoleic acid. Product developed from tomato seed oil and sunflower oil showed that no significant difference (Sogi, Kiran, & Bawa, 1999). The preparation of dietary fiber from by-products has already been summarized (Larrauri, 1999), and residual sources of natural antioxidants were the subject of a recent review (Moure et al., 2001).

O' Kennedy et al., (2006). Tomato seed consist of unsaturated fatty acids and also rich in bioactive compounds and minerals they are discarded during processing has some loss, furthermore recent studies states that consumption of tomato seed can help to improve healthy blood circulation by preventing blood from clotting.

Fahimdanesh and Bahrami (2013) Tomato seed is the major by-product of the tomato paste manufacturing industry that produce is about 71%-72% from total waste production Tomato seeds by-product give a report nearly 10% of the fruit and 60% of the total tomato industry waste. This results reports that oil content of the tomato seeds tend to have nearly about 35% on a dry weight basis. The result showed that palmitic acid (12.26%) was the major saturated fatty acid, followed by stearic acid (5.15%) in tomato seed samples. Linoleic acid (56.12%) was the major unsaturated fatty acid followed by oleic acid (22.17%). Physico-chemical analysis showed that it contains highly mixture of saturated and unsaturated fatty acids which is essential for the human diet.

Lisichkov et. al., (2011) based on their study by isolating tomato seed oil by using Super Critical Fluid CO<sub>2</sub> Extraction, represents the potential raw material for the design of new bioactive compounds that can be formulated in food products According to the quantitative results obtained regarding the composition of the tomato seed oil, it is evident that the unsaturated fatty acid - linoleic acid (C<sub>18</sub>:2, C<sub>18</sub>H<sub>32</sub>O<sub>2</sub>, omega-6) constitutes the highest share of the tomato seed oil composition.

Kamazani et al., (2014) studied on tomato seed oil extracton by using Ultrasound technique in which the result indicates that the oil contains high quality of linoleic acid with the value of 47.6%. Other unsaturated fatty acids such as oleic acid (27.76%),  $\alpha$ -linolenic acid (1.81%) and others (1.21%) were present. Due to high proportion of unsaturated fatty acids ( $\approx$  78.38%) makes this oil a valuable oil. However total sterols content of tomato seed oil was (2911 mg/kg) lower than that of soyabean oil (1800-4500 mg/ kg) (Ghavami et al., 2008). Lazos et al., (1998) determined the total sterol content of tomato seed oil as 4550 mg/kg. Similar results has been reported by Eller et al. (2010) the total sterol content of tomato seed oil extracted using supercritical fluid, hexane and ethanol were 2100 mg/kg, 2200 mg/kg and 2400 mg/ kg respectively.

## 2.4 Dietary Fibre

(Grigelmo-Miguel and Martin-Belloso, 1999).reported that vegetable by-product are inexpensive, available in large quantities, characterised by a high dietary fibre content resulting with high water binding capacity and relatively low enzyme digestible organic matter contributes more amount of total dietary fibre especially insoluble and soluble fibre compared to cereal bran

Spiller, 1994 stated that dietary fibre could also promote beneficial physiological effects including laxation and blood cholesterol attenuation as well as blood glucose attenuation (Bijlani, 1985). It may also prevent cancer (McCann et al., 2001), diabetes (Wang et al., 2001), heart disease (Fernandez, 2001), and obesity (Iwata and Ishiwatari, 2001).

Prebiotic is a food ingredient which is not digested by human upper gastrointestinal tract, but it an enzyme which can improve the host heath beneficially by increasing the stimulation of the growth of gut microbes and or increasing the bacteria one or in limited numbers in the colon (Gibson and Roberfroid,1995). Crude fiber refers to be one type of dietary fiber, the type that remains as residue after food receives a standardized laboratory treatment with dilute acid and alkali. AOAC defines Crude fibre, as the residue of a feeding material after treatment with boiling sulphuric acid, sodium hydroxide, water, alcohol, and ether. It is a measure of the cellulose and lignin content mainly.

Marin FR et al., 2007 revealed that human consumption of dietary fibre is important for the prevention of constipation, haemorrhoids and other that also helps to reduce cholesterol and may reduce risks in colon cancer. .

Donatella peressini et.al., 2014 evaluated the potential use of inulin as a fibre in an extruded flour- based product significantly modified dough rheological properties and characteristics of extruded snacks and its effect on processing on products were also checked using rheological, physico -chemical and sensory analyses.

## **2.5 Methods to utilize tomato by-product**

### **2.5.1 Extrusion technology as a vehicle for snack production**

Consumer appeal for ready-to-eat (RTE) food for consumption without further heating or processing products is forecast to grow rapidly over the next 5 years as consumers demand convenient snacks with exciting sensory and textural properties. Extrusion technology has been used extensively in the production of cereal RTE snacks due to its ease of operation and ability to produce a variety of textures and shapes which appeal to consumers.

In general many of the existing RTE products are relatively high in sugar and salt, thus being regarded as energy dense but nutritionally poor foods. However, there exists a potential to manipulate the nutritional status of extruded RTEs by altering the digestion potentials of starch and protein, and by the incorporation of bioactive components such as dietary fibre, antioxidants etc. There are two forms of extrusion – cold (below 70°C) it can also called as ready to cook and hot (above 70°C) ready to eat. There are three major screw-types in hot extrusion: single-screw and intermeshing twin screw in either counter rotating or co-rotating styles (Miller & Mulvaney, 2000 , Stojceska and Ainsworth, et.al., (2009)

Bhattacharya & Prakash, 1994 explains that the extrusion cooking combines a number of unit operations *i.e.* mixing, cooking, shearing, puffing, final shaping and drying in one energy efficient rapid continuous process (Harper, 1989). This thermo mechanical action during extrusion process brings about gelatinization of starch, denaturation of protein and inactivation of enzymes, microbes and many anti-nutritional factors; all this occurs in a shear environment, resulting in a plasticized continuous mass.

In the extruder, the food mix is thermo-mechanically cooked to high temperature, pressure and shear stress which are generated in the screw-barrel assembly (Arhaliass, Bouvier, & Legrand, 2003). The cooked melt is then texturized and shaped in the die. The high temperature environment modifies moistened expansible starchy material *via* a

combination of driving force that help to build up high pressure and shear forces to produce a puffed end product. Final Product quality can vary considerably depending on the extruder type, screw configuration, feed moisture, and temperature profile in the barrel section, screw speed and feed rate. (Asare et al. 2004; Singh et al.2007; Yang et al. 2008). Many studies has been conducted using by-product pomace blends including orange peel, grape seed and tomato pomace in a single screw extruder on the physical and functional properties of a rice-grits based extruded snack (Yagci and Gogus 2008;Yagci and Gogus 2009).

Janssen, 1989 explains mechanisation of extrusion cooking as, in extruder at the end of the screw, the product is forced (at high pressure and temperature) through a restrictive orifice commonly called the die this is fixed based on the size needed for the acceptance of the consumer. Twin-screw extruders works in co-rotating or counter rotating motion have a variable residence time (time spent travelling along the barrel before leaving the extruder die) of the product along the barrel which is generally affected by the screw configuration. This in turn may have effects on the product as it travels along the barrel, potentially causing a positive displacement pumping mechanism effect.

Extrusion cooking is a popular food-processing technique, especially for the production of fibre-rich products, such as breakfast cereals, flat breads, dextrinized or cooked flour. Due to its high content of TDF and a high proportion of SDF. Food processors takes steps for an investigation into the use of tomato peel in a variety of extruded products is of importance from a nutritional point of view for the consumers.

Also researches explains the extrusion process is a continuous process being used for production of snack foods which is highly accepted by the consumers and so the food processing industries move to develop extruded product in which during extrusion chemical modifications and structural changes occur, such as starch gelatinization (Akdogan, 1999, Van Den Einde et al., 2005), protein denaturation (GUY, 2001; IWE et al., 2004), pigment and vitamin degradation, (Ilo And Berghofer, 1999), the loss of volatile compounds (Bhandari et al., 2001) and so food with various combination which meets the consumer requirements by retaining the final nutrition of the product several studies have been carried out for the acceptability with incorporation of functional ingredient as food processing waste. (Nabeshima and Grossmann, 2001) also says that

Extrusion cooking is a technology with high versatility and efficiency, low cost, high yield and short reaction time, with no waste generation.

(Gaosong & Vasanthan, et.al., (2000) Extrusion processing is widely applied technology for ready-to eat products in which food mix undergoes the thermo-mechanical actions at high temperature, pressure and shear stress will implies gelatinization of starch, denaturation of proteins and inactivation of enzymes microbes and other anti-nutritional factors of the food mix at high temperature/short time to produce fibre –rich products, and all these process occurs in shear environment to produce texturized and shaped products.

Food processor choose Extrusion cooking for wide range of application due to various reasons like its versatility, high productivity, relatively low cost, energy efficiency, and lack of effluents (Altan, McCarthy, & Maskan, 2008). During extrusion the starch itself gets depolymerised and which leads to increase in the amount of easily digestible carbohydrates which increases the glycemic index and due to these characteristics (Brennan, Derbyshire, Tiwari, & Brennan, 2013). (Yagci & Gogus., 2008) also evaluated the addition of food processing by-products in extruded foods as source of fibre and bioactive compounds .

(Ralet et al., 1991), used extrusion technology for solubilisation of pectic substances of by-product obtained from sugar –beet pulp and Ng et al. (1999) studied on the effect of extrusion cooking on onion waste to observe the characteristic changes in the physicochemical properties and microstructures changes in the cell wall of onion by-product. It is proved that extrusion cooking shows increased in solubility of pectic polymers and hemicelluloses present in the vegetable co-products by an increase in swelling of the cell-wall material.

### **2.5.2 Extruded products using tomato derivatives**

Aylin Altan et .al., (2008) have been used tomato processing by-product, for development of extruded product combined with barley which is high in dietary fibre. The study revealed that that varying levels of tomato pomace could be incorporated depending on texture of the final product and the system parameters and product

responses were found to be most dependent on temperature and pomace level. Extrudates with 2% and 10% at 160°C and 200 rpm showed higher preference levels of sensory acceptability.

Zeinab et.al, (2010) Incorporated of tomato lycopene at various temperatures in first 4 barrel section with feed rate of ingredients kept constant at 11.5 kg/h, screw speed was 350 rpm and water feed rate 0.51/h. Although the amount of lycopene retained after extrusion was very low, and shows increase in starch content. Furthermore, studies can be done to increase the amount of lycopene by incorporation of tomato peel to the snack products.

## **2.6 Post cooking quality and Physico -chemical properties of Extruded products**

Miriam Mabel Selani et al., (2014) found that addition of by-product which is rich in fibre relatively reduced the expansion ratio due to the reduction in the starch and protein which is responsible for puffiness of the extruded product and this is compared with other studies which has been told that addition of fibre may also influence the rupture of cell wall before the gas bubbles may expanded to their full potential (Lue et al., 1991). Although with reduction in expansion ratio there is increase in density was observed in extrudate with 21% of pineapple pomace, this may be due to sugar and fibre present in pineapple pomace has the capacity to absorb water which can lead to increase in density of product (Dehghan-shoar et al., 2010). Water absorption index was observed to have influence on temperature and moisture at low moisture of the extrudate causes more polymer damage and results in low WAI. However decrease in Water solubility index was observed in carrot pomace due to the fibre present in carrot (kumar et al.,2010).

Aylin Altan et al., (2008) evaluated snack foods from barley-tomato pomace blends by extrusion cooking, results shows that the changes in the colour parameters increases with the addition of tomato pomace increased in product, among the colour parameters *L*, *a* value shows the tremendous increase as expected due to the lycopene content of tomato pomace (Ilo and Berghofer 1999) reported that colour change in yellowness decreased in (*b value* ) may be due to increase in temperature and also reported that during extrusion cooking yellowness of maize flour will be induced by two

reaction namely: non-enzymatic browning and pigments destruction like carotenoids damage due to thermal treatment and so the colour loss is observed

Sibel Yagci and Fahrettin Gogus (2007) studied the effect of extrusion condition on incorporation of fruit waste which results in change in product textural properties and colour of the produced snacks, extruded snacks with increasing moisture content and decreasing temperature caused an increasing the expansion ratio for all product.

Qing-Bo Ding et al., (2006) investigated some significant changes in physical properties and functional properties of wheat based extruded snacks when changing the feed rate, feed moisture content, screw speed, barrel temperature. Results showed that increasing feed rate results in increasing viscosity of the mix in the extruder which results in giving a denser and harder extrudate. Hardness is also increased by increasing feed rate at low feed moisture levels and becoming less significant at higher feed moisture levels. Feed moisture level is directly proportional to the energy required to puncture the extrudates. Some significant changes are also observed when increasing feed moisture content that increases the hardness of the extrudate at low feed rate. In controversy Increasing screw speed leads to decrease in hardness at higher barrel temperature.

Feed moisture has been found to be the most dependent factor which affects the extrudate density and expansion. When increasing feed moisture leads to sharp decrease in expansion and increase in density of the extrudate. (Faubion & Hosney, 1982; Fletcher, Richmond, & Smith, 1985; Ilo, Liu, & Berghofer, 1999; Launay & Lisch, 1983), however increasing screw speed and barrel temperature also shows slight decrease in density of the extrudate. This effect has been already reported by (Fletcher et al., 1985) that increasing screw speed causes lower melt viscosity of the mix which directly increases the elasticity of dough which results in reduction in the density of the extrudate.

When considering the post cooking properties; the WAI and WSI are important quality factors for the extruded product, as WAI measures the amount of water absorbed by starch and can be used as an index of gelatinisation (Anderson et al., 1969) and WSI, often used as an indicator of degradation of molecular components (Kirby, Ollett, Parker, & Smith, 1988), increasing feed moisture and barrel temperature both decreases the WAI and significantly increase in WSI. Similar results has been reported

by Mercier and Feillet (1975) found that soluble starch increased with increasing extrusion temperature and decreasing feed moisture. They also found that as extrusion temperature increased at feed moisture of 18.2%, WSI increased; WAI achieved a maximum value at extrusion temperatures of 180–200 °C. Anderson et al. (1969), WAI of extruded maize flour increased progressively with increased barrel temperature and increased feed moisture.

Ilo et al. (1996) has also been reported that the degree of gelatinisation of extruded maize grits decreased with increasing feed moisture, and increased with increasing feed rate and product temperature.

## **2.7 Gluten free Snack products**

Grehn, Fridell, Lilliecreutz, & Hallert, (2001) Gluten free snack products are generally targeted for the people suffering from celiac disease which is the inflammatory condition of human gastrointestinal tract caused by permanent intolerance to gluten protein present in cereals such as wheat, barley, rye and effective treatment can be only to avoid gluten ingestion throughout life.(Meister, 1996) adults diagnosed with CD have lower intake of fibre when compared with control group and this increase various disease among people consuming gluten protein.

Food processor has been already developed gluten free snacks which can be a best substitute diet for those having CD and this gluten-free products made from refined or starch flour are not enriched or fortified and so this considered to be low in fibre.

## **2.8 Sensory Evaluation-Nine Point Hedonic Test**

Products developed under extrusion technology are widely estimated for the sensory evaluation based on the several criteria for the best product to be obtained. Generally researches adopted, Affective or Nine-point hedonic test for the product made in extrusion, Nine point Hedonic testing is used to quantify the degree of liking or preference of a product, by having panellist choose amongst the alternatives or rate their degree of liking on a scale. It identifies whether a taster likes or dislikes a particular

product. This related with the categories were rated from 1 (absent/extremely dislike) to 9 (very high/extremely like) in order to evaluate the snack characteristics, which are flavors (absent to very high), color (extremely dislike to extremely like), texture (extremely dislike to extremely like) and overall acceptability (dislike extremely to like extremely) and other attributes based on consumer perceptions. (Mendonça et al., 2000, Aylin Altan et al., 2008, Sibel Yagci et al., 2008).

## **2.9 Experimental design**

For the optimization of the combination with respect to responses generally many design are carried out for the better snack foods to be obtained. When there are constraints on the mixture components, and the number of mixture components and process variables increase, the D-optimal criterion is often used for generating a design (Myers and Montgomery 2002, Yagci,Gogcus 2007). It then allows an optimised product or process to be developed based on the factors impact on the responses for the best optimised formulation to be obtain. (McCarthy et al. 2005). It has been successfully used in extrusion studies previously (Singh et al. 2007; Yang et al. 2008).

To examine the full effects of tomato pomace in a corn and rice -puffed snack, extensive preliminary trials were carried out to produce a control with favourable expansion characteristics and known moisture content. This would allow the authors to make strong comparisons between combinations and see the effects of the tomato peel and seed addition on the final product quality of snacks. Also this research is basically focused for the utilization of the by-product from tomato processing industry in terms of new product development for the enrichment of valuable nutrients from tomato by-product; which is lacking in current snack foods in market.

## CHAPTER III

### MATERIAL AND METHODS

#### 3.1 Materials

Ingredients used for ready- to-eat snack preparation were: Maize flour and Rice flour. They were obtained from the local market, and were sieved to a particle size of 0.355  $\mu\text{m}$  (mesh 44). The flours were stored at 4°C until used. Tomato pomace (TP) a byproduct from the tomato processing industry was obtained from the Sakthi Fruits tomato paste processing plant located in Erode (Tamil Nadu district).

The pomace obtained from the tomato processing industry, had a moisture content of around 80% (w.b.). It was dried at 50°C for 72 h in a Forced – Electric Tray drier (Industrial & Laboratory Tools Corporation, Chennai) to a moisture content of 5 $\pm$ 1% (wb). The dried pomace was passed on different standard test sieve (Heico, Standard Test sieve, India) for the separation of seed and skin from the pomace; final particle size maintained for both peel and seed was 355  $\mu\text{m}$ . Following this the sieved tomato peel and seed were separately milled and finally stored in vacuum packed polythene bags at -20°C for further usage.

#### 3.2 Sample preparation:

Ingredient formulations are given in the (Table 3.1). The raw ingredients were weighed separately according to the formulation made by mixture design and blended in a mixer for 10 min. Moisture content of samples were determined by IR moisture meter (Kett, FD-240). These blends were chosen according to preliminary study and for the acceptable product's physical characteristics.

These samples were conditioned to 14% moisture (w.b.). Moisture content was chosen based on preliminary trials and earlier published work, to ensure least variations in hardness of the final product. Water addition was conducted by spraying calculated amount of water prior to extrusion and mixing continuously in a mixer, this preconditioning procedure was employed to ensure uniform mixing and hydration and to minimize variability of the feed material (Stojceska et al.,2009).



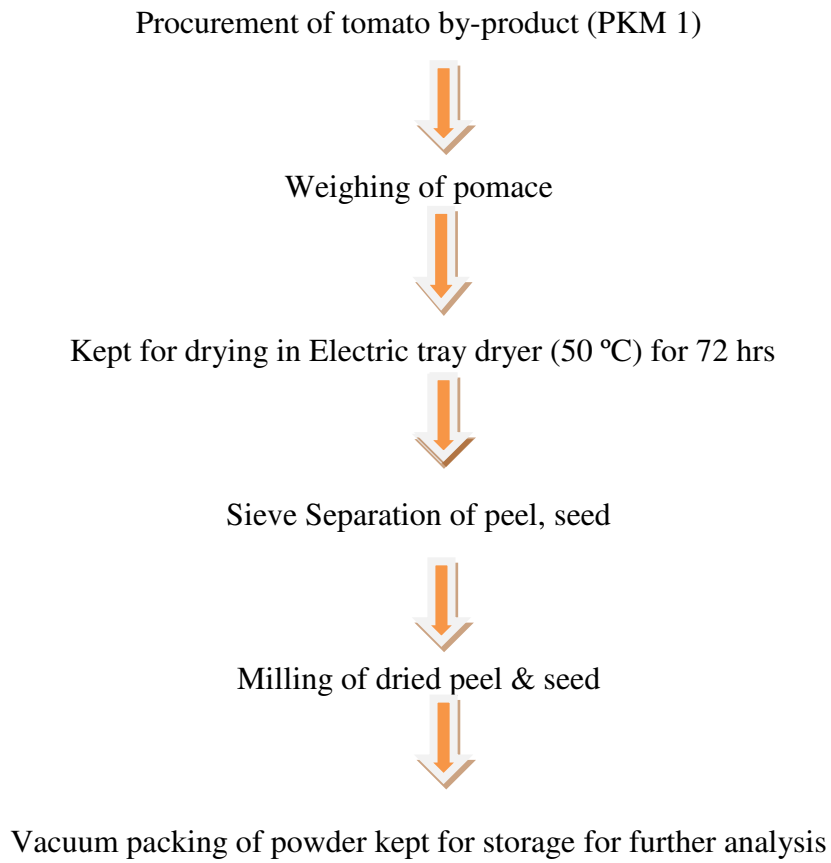
**Plate: 3.1 Forced – Electric Tray drier**



**Plate: 3.2 Tomato pomace**

**(A) Tomato pomace (80%) of Moisture content**

**(B) Tomato pomace (5%) of Moisture content**



**Fig: 3.1 Sample Preparation Process Steps**



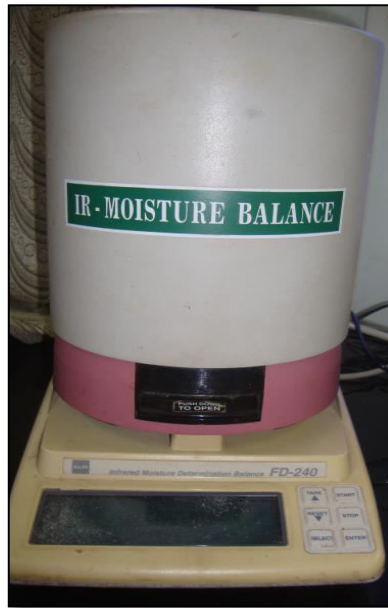
**(A)**



**(B)**

**Plate: 3.3 Dried and Separated Tomato Pomace**

**(A) -Dried peel (B) - Dried seed**



**Plate: 3.4 IR Moisture Balance**

### **3.3 Experimental Design and Statistical analysis:**

To optimize four component mixtures, combined design was chosen to identify the relationship between the mixture components (Altan et al., 2008; Yagci and Gogus, 2008; Ding et al., 2005; Montgomery, 2001). The main ingredients used were corn flour, rice flour, tomato peel, tomato seed as independent variables and the response variables studied were Physico-chemical properties, functional properties, texture, colour and overall acceptance. Based on preliminary study, these component mixture ranges were chosen for the design. This design combines independent variables, mixture components in one design, keeping the equipment process variables fixed (such as die size, temperature, feed rate, moisture content). The experimental design was created and analysed using Design Expert 9.1.6. (Stat-Ease Inc., Minneapolis, MN, USA).

A D-optimal mixture design was employed by fixing lowest and highest percentage of each independent variable for the design. These ranges were considered as the lower and upper bounds resulting in the constrained representing formulations (1-17) prepared for the experiment. In four mixture Corn flour (A), Rice flour (B), Peel (C), Seed (D) made upto total of 100% of the actual formulations. The lower and upper boundaries of ingredients were determined to be as corn flour ( 40-60%) , rice flour (30-40%), peel( 0-30%) and seed(0-5%) added to 100% of the mixture design. Constant variables were screw speed set at 300 rpm, die head temperature 130 °C. The tomato pomace level was restricted to 0-30% range, this was based on the previous studies

reported by Hsieh et al. ( 1989). Dependant variables (or responses) were selected based on descriptors that would best describe a high-quality puffed extruded snack on sensory quality. These were Hardness, Colour, Protein, Fat, Crude Fibre, Expansion Ratio (ER) and Overall acceptance. The generation of response surface plot and statistical analysis were performed using Design Expert software. The main advantage of design is, that it reduces the number of experimental runs needed to provide sufficient information for statistically acceptable results. ANOVA was adopted in the design of experimental combinations for the identification of significant difference in the formulations

**Table 3.1 Experimental design with 17 combinations (including replication)**

<b>Runs</b>	<b>Corn flour (%)</b>	<b>Rice flour (%)</b>	<b>Peel (%)</b>	<b>Seed (%)</b>
1*	60	30	5	5
2(control)*	60	40	0	0
3	55.3	36.2	5.8	2.6
4	60	30	10	0
5	60	30	10	0
6	50	35	15	0
7	40	40	15	5
8	60	37.5	0	2.5
9	60	30	5	5
10	40	35	25	0
11	40	35	20	5
12	40	30	30	0
13	40	40	20	0
14	50	30	17.5	2.5
15	47.5	40	7.5	5
16	40	30	25	5
17	55	40	0	5

(including replications)\*

A quadratic model with one centre point was selected, resulting in 17 combinations generated *via.* the Design Expert software. Within these 17 combinations, the control was created, and two combinations were repeated twice to assess error within the model. The model that best fitted the response was selected during analysis of measurements. Analysis of variance (ANOVA) was carried out on each response model to identify the coefficient ( $R^2$ ), and significant difference ( $p < 0.0001$ ).

### 3.4 Extrusion Cooking:

Extrusion cooking trials were performed using a laboratory-scale Co-rotating twin-screw extruder (model SYSLG-IV) the barrel consisted of three independent temperature zones, zone 1 (entering zone), zone 2 (kneading zone), and at the barrel end, indicated as zone 3. Screw diameter was 30 mm. The exit diameter of the circular die used was 4.5 mm. The extrusion was carried out with following conditions; 300-350 rpm screw speed and barrel temperature zone 30, 60, 100, 140°C respectively while feeder screw speed was set at 30 rpm throughout the experiment. The extrudates were dried in a hot air oven at 50°C. Final dried samples contained a maximum of 4-5% (w.b.) moisture. Dried samples were stored in polythene bags at room temperature and used for further analysis.



**Plate: 3.5 Co-Rotating Twin-Screw Extruder**



(A)



(B)

**Plate 3.6 (A) Cross sectional view of Twin screw**

**(B) Cross sectional view of Die head (4.5mm)**



**Plate : 3.7 Hot Air Oven**

### 3.5 Analysis of Extruded products

#### 3.5.1 Expansion ratio

The diameter of 20 pieces of extruded products was measured using a caliper (Mitutoyo, Tokyo, Japan), and the expansion ratio was calculated by dividing the average diameter of the products by the diameter of the die. (Alvarez-Martinez et al., 1988)

$$SEI = \frac{De^2}{Dd^2}$$

Where,  $De^2$  is the diameter of the extrudate and  $Dd^2$  is the diameter of the die.

#### 3.5.2 Bulk density

Bulk density (BD) ( $\text{g}/\text{cm}^3$ ) of 10 pieces of extrudates were calculated according to Alvarez-Martinez et al. (1988) method, where  $m$  is mass (g) of a length  $L$  (cm) of extrudate, with diameter  $d$  (cm).

$$BD = \frac{4m}{\pi d^2 L}$$

#### 3.5.3 Texture

The hardness of the sample was measured with a TA.XT plus, Texture Analyzer (Stable Micro System, Surrey, UK ) equipped with 5 kg load cell. Hardness in N was determined by measuring the maximum force required to break the extruded samples (50 mm long ) using three point bend test with a sharp-bladed probe (90mm wide, 32mm high, 9mm thick).The test speed was 1 mm/s and the distance between two supports was 22mm. A force –time curve was recorded and analysed by Texture Exponent 32 software programme (version 5.0). Ten measurements were performed on each sample and averaged



**Plate 3.8 Texture Analyser**

### **3.5.4 Colour**

Hunter Lab Color Flex XE (Hunter Associates Laboratory Inc., Reston, VA, USA) was used to determine colour values of the ground extruded in terms of  $L$ ,  $a$  and  $b$  as measures of lightness, redness and yellowness respectively. The colorimeter was calibrated against a standard white tile ( $L = 91.43$ ,  $a = -0.74$ ,  $b = -0.25$ ). The extrudates were ground in a mixer and passed through a 40 mesh sieve prior to colour analysis. For each sample three measurements were taken and averaged.



**Plate: 3.9 Hunter colour Lab**

### **3.5.5 Water absorption and solubility indices**

The water absorption index (WAI) is the weight of gel obtained per gram of dry ground sample. The WAI of extrudates was determined according to the AACC method 56–20 (AACC, 1995). The ground extrudate was suspended in water at room temperature. After standing for 10 min, gently stirred during this period, samples were centrifuged for 15 min at 1000g (REMI Centrifuge, REMI Elektrotechnik Ltd, Maharashtra, India). The supernatant was decanted into a tarred aluminum pan. The WAI was calculated as the weight of sediment obtained after removal of the supernatant per unit weight of original solids as dry basis.

The water solubility index (WSI) is the percentage of dry matter recovered after the supernatant is evaporated from the water absorption determination. The supernatant was dried in a vacuum oven at 84.4 °C and 20–24 mm Hg gauge pressure for 24 h and weighed. The WSI was the weight of dry solids in the supernatant expressed as a percentage of the original weight of sample on dry basis (Aylin Altan , 2008 and Jin, Hsieh, & Huff, 1995). WAI and WSI determinations were replicated.

### 3.5.6 Analytical methods

To characterize the chemical composition of the corn flour, rice flour, tomato peel and seed and the final extruded products, the protein content was measured using the Kjeldahl method (AOAC, 2005;), and fat content was determined using the Soxhlet method (AOAC, 2005;). Ash content was obtained by drying the samples in a muffle furnace at 550°C for two hours. Crude fiber was determined by the acid sequence method using 1.25% H<sub>2</sub>SO<sub>4</sub> and 1.25% NaOH for acid and alkaline hydrolysis, respectively. Carbohydrate content was calculated by the difference between the total and the contents of all other ingredients. Each analysis were carried in replicates.

### 3.5.7 Sensory evaluation

All formulations were given for sensory evaluation to the panel members. Nine point hedonic scales were adopted and the categories were rated from 1(absent/dislike extremely) to 9 (very high/like extremely) in order to evaluate the extrudate characteristics. The attributes examined were (Appearance, Colour, Flavour, Initial bite, Texture, Graininess, Tate, Umami, Tangy, Cohesivness, After taste). The panelists consisted of 10 semi-trained panellists (between 20–45 year old males and females) who are students and faculty members of the Department of Food Engineering IICPT, Thanjavur. Panelists were selected in preliminary sessions and experienced with the products and terminology.



**Plate: 3.10 Extruded samples for Sensory Evaluations**

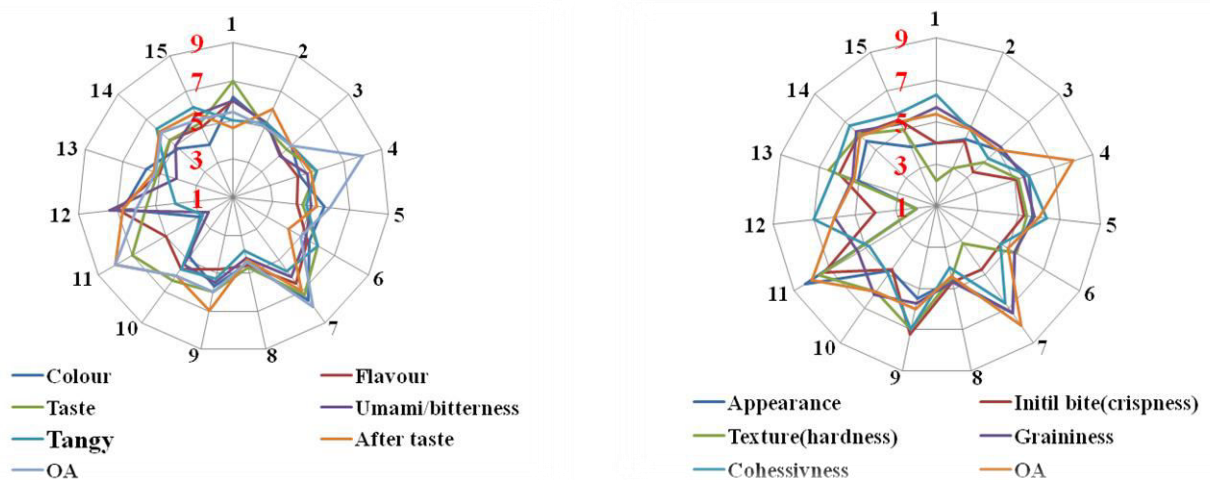
## CHAPTER IV

### RESULTS AND DISCUSSION

This chapter describes the results obtained from the experimental work and the inferences drawn from them. The effect of tomato pomace on the final quality of extruded snack product were studied, the quality of extruded product were analysed by various physical, textural and sensory properties. The optimization steps were performed in order to obtain best combination in terms of consumer acceptability of the snack food.

#### 4.1 Sensory evaluation

Sensory evaluation was conducted for all 15 combinations which were generated from mixture design, of the extruded products. The comparison was based on different sensory features and rated on the 9 point Hedonic scale. The mean values of sensory panel ratings of extrudates are presented in (Table 4.1 and 4.2). Significant differences were observed in the sensory scores for all formulations following addition of tomato peel and seed (fig: A & B).



(A)

(B)

**Figure: 4.1** Sensory Evaluation of 15 different formulated extruded products with different sensory response (A) Colour, Taste, Tangy, OA, Flavour, Umami , Aftertaste and (B) Appearance, Texture, Cohesiveness, Initial bite, Graininess and Overall acceptability

From (fig 4.1) Strong flavour was found in the sample containing higher amount of peel. However no bitterness was observed in any of the extruded product, instead umami flavour was observed in samples which contained higher percentage of tomato peel. The reason for no bitterness in the extruded product may be due to the fact that the bitterness imparting components which are generally the phenols such as naringenin, rutin, quercetin, rutin derivatives and chlorogenic acid derivatives (Inmaculada Navarro et al., 2011) may have got degraded at high temperature of extrusion cooking. Korus et al. (2007) investigated the effect of extrusion on polyphenol content and antioxidant activity of common bean they observed a significant decrease in polyphenol content and antioxidant activity. Yagci and Gogus (2010) also observed that extrusion cooking caused significant decrease in total phenolic content. Phenolic compounds during extrusion may undergo decarboxylation due to high barrel temperature and high moisture content and may promote polymerisation of phenols and tannins leading to reduced extractability and antioxidant activity (Repo-Carrasco-Valencia, de La Cruz et al., 2009, Repo-Carrasco-Valencia, Pena et al., 2009; Dlamini, Taylor, & Rooney, 2007). Similarly degradations of phenolic content has been reported in earlier studies for extruded bean, oat cereals and oat extrudates (Zadernowski et al., 1999 Viscidi et al., 2004; Korus et al., 2007; Aylin Altan et al., 2009). Alonso et al. (2000) stated that high temperature of extrusion may alter their molecular structure and either reduce their chemical reactivity or decrease their extractability due to a certain degree of polymerization.

Umami has been explained as savory, mouthfullness, or broth like taste which is found in various foods in the world and was first discovered by Dr. Ikeda, who in 1908 isolated glutamate as the source of taste in a broth used in Japan, prepared from sea-weed konbu, a substance with high levels of natural glutamate. Glutamate, a component of protein is the most abundant amino acid in nature. It is found in fish, meat, milk, and many vegetables. It is essential to human metabolism and is a dominant umami compound found in foods (Kumiko Ninomiya 2002). Natural Umami substance in tomato is Glutamic acid which has been reported to increase with increasing ripening of tomato. The glutamate content in tomato is around 246mg/g, it is also present in other vegetables like onion, cabbage, broccoli, spinach, sea weed, cheese etc. The majority of these compounds are lost during processing due to their sensitivity towards processing conditions such as temperature (Riaz et al., 2009). Critical extrusion process variables such as temperature, screw speed, and moisture content may induce desirable

modifications, thus improving palatability and technological properties of extruded products (Brennan, Monro, & Brennan, 2008).

Other sensory parameter such as appearance of extrudates was evaluated in terms of porosity by panelists, it is noted that increase in addition of tomato pomace (peel and seed) which is a fibrous material significantly affects the surface of the extrudates leading to lesser score. Sensory scores for colour increased as tomato pomace level in the formulation increased (20%- 30% peel) which may be attributed to increase in the lycopene content present in the peel of tomato. Moreover lycopene has been reported to be relatively stable compared to polyphenols or ascorbic acid, at higher temperatures of extrusion cooking. Texture in terms of hardness of the extrudates were observed to be high for the combination with (>20% peel) and in combination with seed, this may be due to the effect of fibre and protein present in peel and seed.

From sensory graph the mean values for the overall acceptability of tomato pomace extruded product ranged low in accordance with the variability of texture, colour, umami and flavour, the extrudates shows higher preference for the formulations with 25:5% and 15:0% (peel and seed) with respect to control (no peel or seed).

**Table 4.1 (A) Sensory Evaluation Scores for 15 Formulations**

Run	Colour	Flavour	Taste	Umami/bitterness	Tangy	After taste	OA
1	6.2	6	7	6	5	4.6	5.4
2	5.1	5.2	5	5.2	5.2	6	5
3	5	4.3	4.7	4.2	5	5	5
4	4.6	4.5	5.5	5	5.5	5.2	8
5	5.7	4.3	4.6	5	4.8	5.3	6
6	5.5	5.4	6	5.3	6	4.3	5
7	7.6	6.5	7.2	6.1	5.7	7	8
8	4.5	4.6	4.7	4.2	3.8	4.3	4.4
9	5.7	4.8	6	5.5	5.3	7	6
10	4.8	5.6	6.3	5.3	5.6	6	6
11	3	5	7	2.5	2.8	8	8
12	6.7	7	5.5	7.4	4	6.7	6
13	5.7	5	5.1	4.1	4.6	5.3	5.2
14	4.8	5.4	5.4	5	6.3	6.1	6
15	4	5	5.2	5.7	6.1	5.8	5.4

**Table: 4.2 (B) Sensory Evaluation Scores for 15 Formulations**

Run	Appearance	Initial bite (crispness)	Texture (hardness)	Graininess	Cohesivness	OA
1	4	4	2.2	5.7	6.3	5.4
2	4.5	4.4	3	5.1	5	5
3	5	3.4	4.1	5.2	4.4	5
4	5.7	5.1	5.2	5.5	5.7	8
5	5.7	5.3	5.4	5.8	6.4	6
6	5.4	4.6	5.5	5.4	4.6	5
7	7.3	4.7	3.2	7.3	6.7	8
8	4.6	4.7	4.5	4.7	4	4.4
9	5.5	7.2	7	5.7	7	6
10	4.8	4.7	6	6.2	5	6
11	8.4	7.3	7.6	5.4	4.8	8
12	2	4	2	6	7	6
13	5	6	6.5	5.3	6.3	5.2
14	5.6	6.1	6.1	6.3	6.7	6
15	4.1	5.5	5	5.3	5.8	5.4

**Table 4.3 Experimental Design and Results of Response Variable (Including replication)**

<b>Run</b>	<b>Corn flour (%)</b>	<b>Rice flour (%)</b>	<b>Peel (%)</b>	<b>Seed (%)</b>	<b>Crude Fibre (%)</b>	<b>Protein (%)</b>	<b>Fat (%)</b>	<b>ER (%)</b>	<b>Hardness(N)</b>	<b>Colour(a)</b>	<b>OA</b>
1	60	30	5	5	1.18	11.82	2.85	4.00	4.54	10.68	6
2	60	40	0	0	0.24	9.41	1.27	4.78	5.29	4.33	8
3	55.27	36.25	5.83	2.63	1.20	12.04	2.2	3.89	2.48	10.47	6
4	60	30	10	0	1.70	11.83	2.04	4.11	2.38	13.38	6
5	60	30	10	0	1.70	11.83	2.04	4.11	2.38	13.38	6
6	50	35	15	0	1.82	10.75	3.1	3.81	3.00	15.79	8
7	40	40	15	5	1.58	10.03	2.62	3.58	3.97	18.39	5
8	60	37.5	0	2.5	1.60	11.60	2.05	3.39	4.96	12.55	5
9	60	30	5	5	1.18	11.82	2.85	4.00	4.54	10.68	6
10	40	35	25	0	2.05	11.54	2.1	3.79	3.69	16.58	5.4
11	40	35	20	5	1.93	11.60	2.56	3.41	3.39	15.38	5
12	40	30	30	0	3.20	11.83	1.41	3.80	4.72	20.91	6
13	40	40	20	0	2.90	11.16	2.37	3.41	2.79	16.10	4.4
14	50	30	17.5	2.5	2.93	12.76	2.17	3.38	2.73	16.23	5.4
15	47.5	40	7.5	5	0.73	9.60	1.72	3.59	1.84	7.03	5.2
16	40	30	25	5	4.75	11.60	2.5	3.67	2.40	18.27	8
17	55	40	0	5	0.43	10.28	2.2	3.61	4.39	6.37	6

## 4.2 Proximate Analysis of extrudates

Chemical analysis was carried out for the raw material to know their composition (Corn flour, Rice flour, Peel and Seed) as given in (Table 4.4 and 4.5). It was observed that Crude fibre content was highest in tomato peel (29%) followed by seed (13 %) then corn flour (0.72%) and rice flour (0.5%). Interestingly it was observed that tomato seed contained highest fat content (25%) followed by peel (6.5%) then corn flour (4.4%) and rice flour (0.8%). Similarly protein content was found to be highest in seed (26.4%) followed by peel (16.2%) corn (10%) and lastly rice flour (6%) carbohydrate responsible for expansion was highest in rice flour(82%) followed by corn flour(77.3%) were in peel it was highest about (40%) and lastly seed (27.3%). As illustrated, variation in the initial formulation will affect the properties of the final extruded product depending on changes in fat, protein, crude fibre, and carbohydrate.

**Table 4.4 Proximate composition of Rice and Corn flour (Average± SD)**

<i>Components</i>	<i>Corn Flour (w.b.)</i>	<i>Rice Flour (w.b)</i>
Protein(%) <sup>a</sup>	10.03±0.04	5.81±0.12
Fat (%)	4.37±0.60	0.79±0.23
Ash (%)	0.50±0.00	0.50±0.00
Crude fiber (%)	0.72±0.24	0.45±0.42
Carbohydrate(%) <sup>b</sup>	77.26	82.95

<sup>a</sup> Protein =  $N \times 5.95$ . for rice

<sup>b</sup> Carbohydrate by difference.

**Table 4.5 Proximate composition of Tomato Peel and Seed (Average± SD)**

<i>Components</i>	<i>Tomato peel (w.b)</i>	<i>Tomato seed (w.b)</i>
Protein(%) <sup>a</sup>	16.19±0.00	26.39±1.42
Fat (%)	6.50±0.70	25.03±1.45
Ash (%)	2.50±0.00	3.5±0.00
Crude fiber (%)	29.35±5.79	13.37±1.87
Carbohydrate(%) <sup>b</sup>	40.06	27.31

<sup>a</sup> Protein =  $N \times 6.25$

<sup>b</sup> Carbohydrate by difference.

### 4.3 Effect of Crude fibre on the extruded products

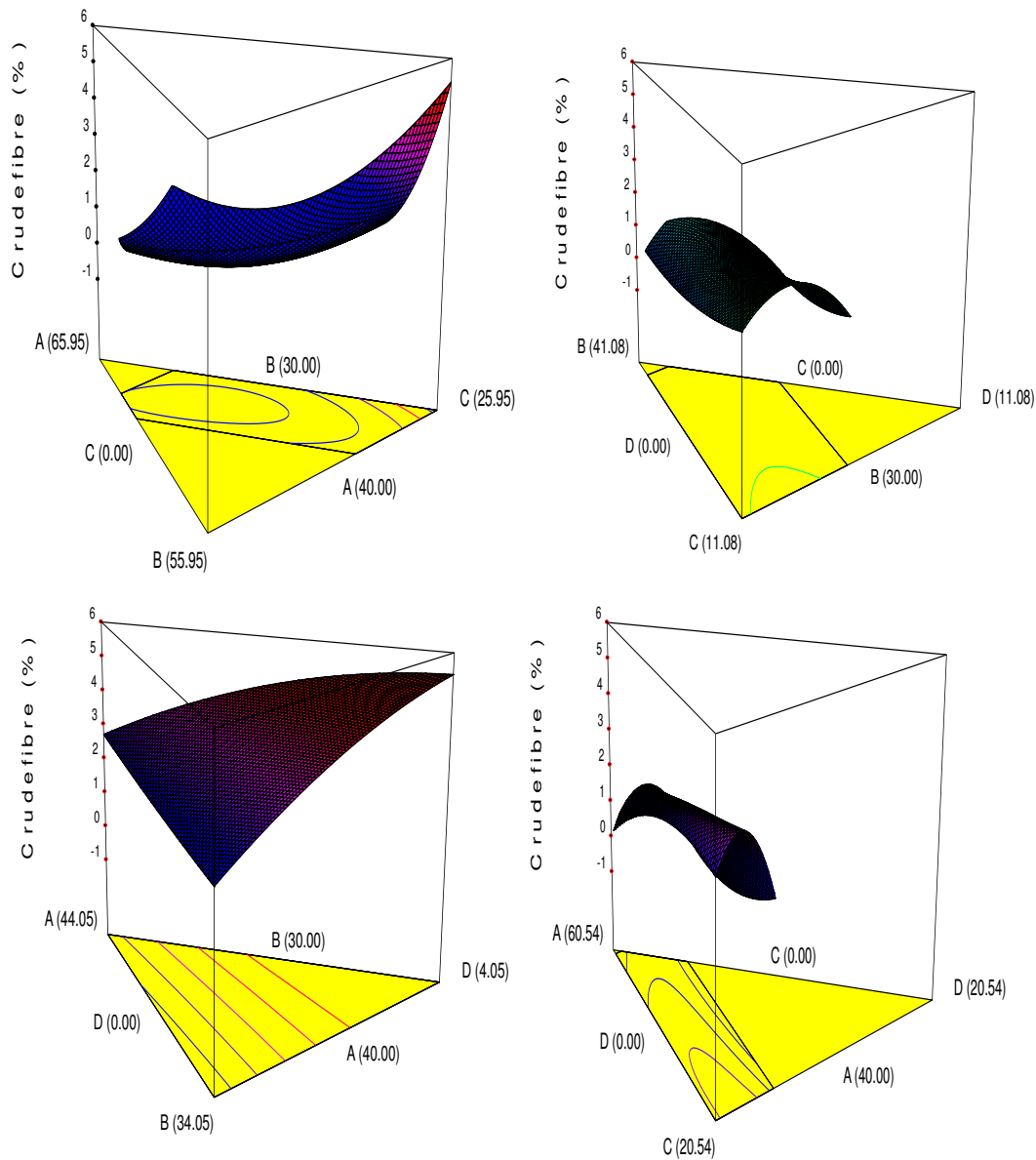
Consumption of Dietary fibre has been linked with various health promoting effects and thus has been recommended to be added in the food consumed. In the present study it was observed that crude fibre content was much higher in tomato pomace especially in tomato peel followed by tomato seed (Table 4.5). Hence it was observed that total crude fibre increased following addition of peel and seed in the extruded product formulation. The statistical analysis confirmed significant effect of the independent variable used in the formulation for extruded product.

The ANOVA showed significant effect ( $p < 0.05$ ) for the mixtures combinations of AD, BC, CD, ABC, ACD (A-corn flour, B-rice flour, C-peel, D-seed) leading to increase in the crude fibre content as tomato peel and seed were added to the product, this effect is not only due to present of tomato pomace but also due to some fibre content from the corn and rice flours (Table 4.4).

From Figure 4.2, it can be seen that the crude fibre content increased significantly following the increase in percentage of peel. To enhance the amount of fibre in food products it is obvious to add higher percentage of peel in the formulations as a source of fibre. Crude fibre, as defined by the association of Official Analytical Chemists is the residue of a feeding material after treatment with boiling sulphuric acid, sodium hydroxide, water, alcohol, and ether. It is a measure of the cellulose and lignin content mainly. The addition of fibre rich components like tomato peel affects the texture of the product such as hardness, moreover this effect is further intensified following thermal treatment during extrusion cooking if the components (corn flour, rice flour, tomato peel, seed) contains high amount of protein. This may also be due to the fact that at higher temperatures protein present in the components may get degraded and become insoluble. Similar results has been reported by several authors, while increasing fibre in the extruded product ultimately increases the hardness of extruded products (Mendonca et al., 2000; Yanniotis et al., 2007; Ainsworth et al., 2007) as a result of its effect on cell thickness.

Cereal fibres are added to the extruded product due to the fact that the fibre rich foods produces many beneficial effects on the digestive tract, such as the regulation of the intestinal function, improvement of the tolerance to glucose in diabetics, or prevention of chronic diseases as colon cancer. Codex Alimentarius recommends that any product claiming to be a “source” of fiber should contain 3 g of fiber per 100 g of serving or 1.5 g of fiber per 100 kcal of serving or 10% of daily reference value per serving. To claim that

a food is “high” in fiber, the product must contain at least 6 g of fiber per 100 g of serving or 3 g of fiber per 100 kcal of serving or 20% of daily reference value per serving (Codex, 2009). The extruded product with high fibre is preferable in such a way that it should possess consumer acceptability in terms of hardness. Due to the nature of crude fibre having both insoluble and soluble properties, it can be included in food products with consumer preferences.



**Fig: 4.2 3D contour plots of crude fibre (%)**

**(A-corn flour %, B-rice flour %, C-peel %, D-seed %)**

$$\text{Crude fibre (\%)} = 0.59467A + 1.82039B + 1.86752C - 24.15462D - 0.045090AB - 0.036075AC + 0.29058AD - 0.083106BC + 0.26484BD + 0.49100CD + 1.13793E - 0.33ABC - 1.62748E - 0.33ABD - 3.75759E - 0.03ACD - 3.15528E - 0.33BCD$$

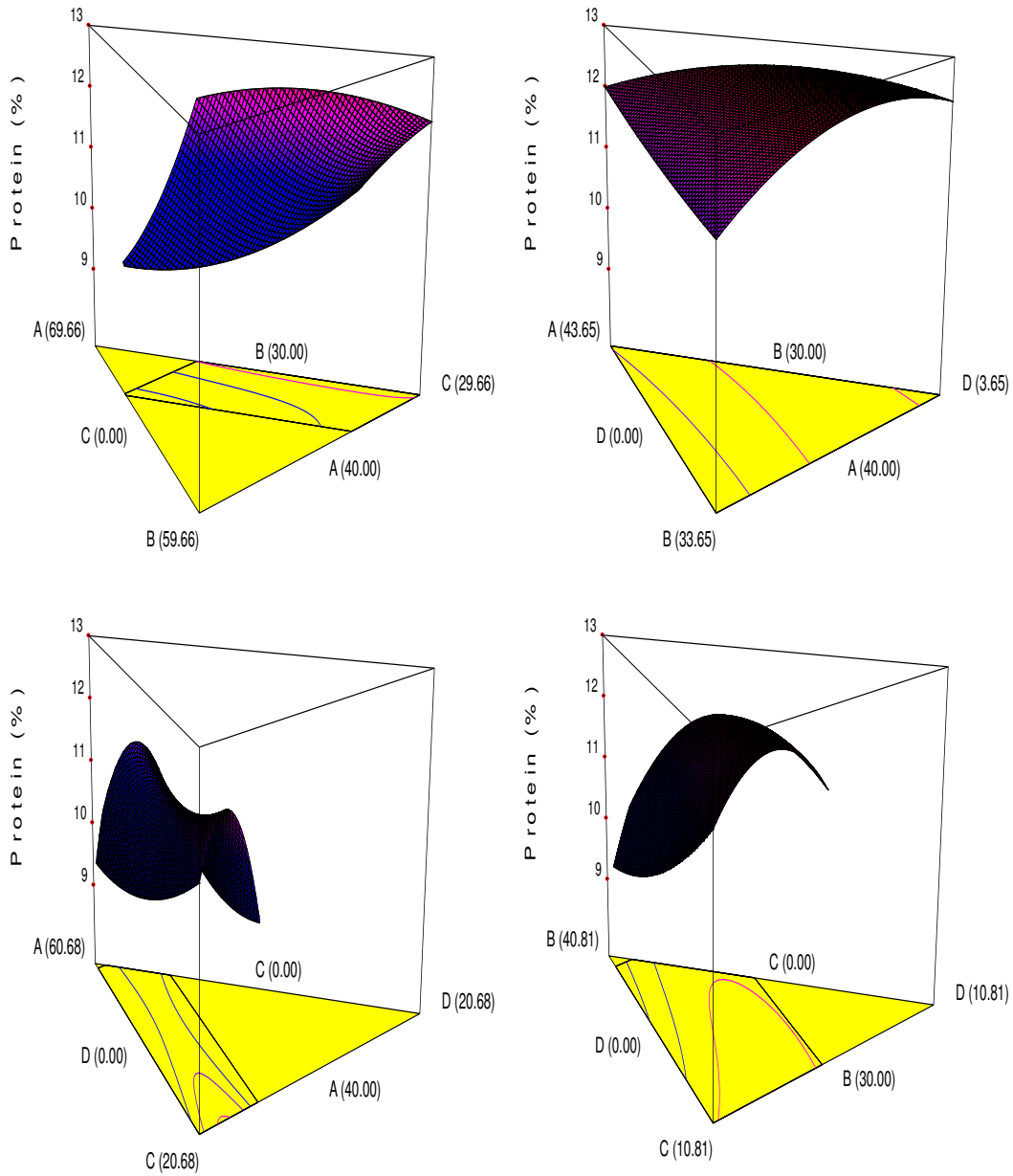
#### 4.4 Effect of Protein on Extrudate

The effect of Protein content of the extruded product is studied and all data are significantly different with addition of tomato pomace into the product. The protein content in our study, found to be in range of 9.405 -12.76% (wb) for all 17 combinations including replication. The raw material protein content also had a significant impact on product qualities in terms of hardness.

Indeed, it is known that proteins are essential for human life as they are involved in every biological process at all organisational levels within the body. For example, proteins are essential components of body structure, muscle, skin, cell membranes, blood, hormones, antibodies, enzymes, and genetic material

From proximate analysis of raw ingredients it was observed that protein content of corn, rice, peel ,seed was observed to be (10.03 %, 5.81 % ,16.19% 26.39 %) and Statistical analysis ANOVA showed that there is significance ( $p \leq 0.01$ ) between the combinations AD, CD, ABC, ABD, BCD (A-corn flour, B-rice flour, C-peel, D-seed) when compared to control formulations. In treatment without pomace, there was no significant difference ( $p >0.05$ ) in the protein content between the extrudates. This hardness may be due to the extruders, with their shearing screws operating at high speeds, imparts significant structural changes to food components including proteins (Harper, 1981). However due to high protein content in (seed > peel > corn > rice) the product obtained also have the effect by the structural changes during extrusion which will increase the hardness and leads to lower expansion.

There are many reports suggested that as higher protein added to starch based-extruded snack, density and hardness are expressed to increases. Adding proteins to extruded starch-based snacks increases the number of sites for crosslinking, but reduces the starch matrix, resulting in tough, non expanded crusts. (Stojceska et al., 2008 Martinez-Serna and Villota, 1992 Onwulata et al., 2001 Veronica et al., 2006). On the other hand protein is essential for health and it can be suggested that 0-5% seed is appropriate amount to be included in the extruded product for the consumer acceptance in terms of hardness, expansion and density.



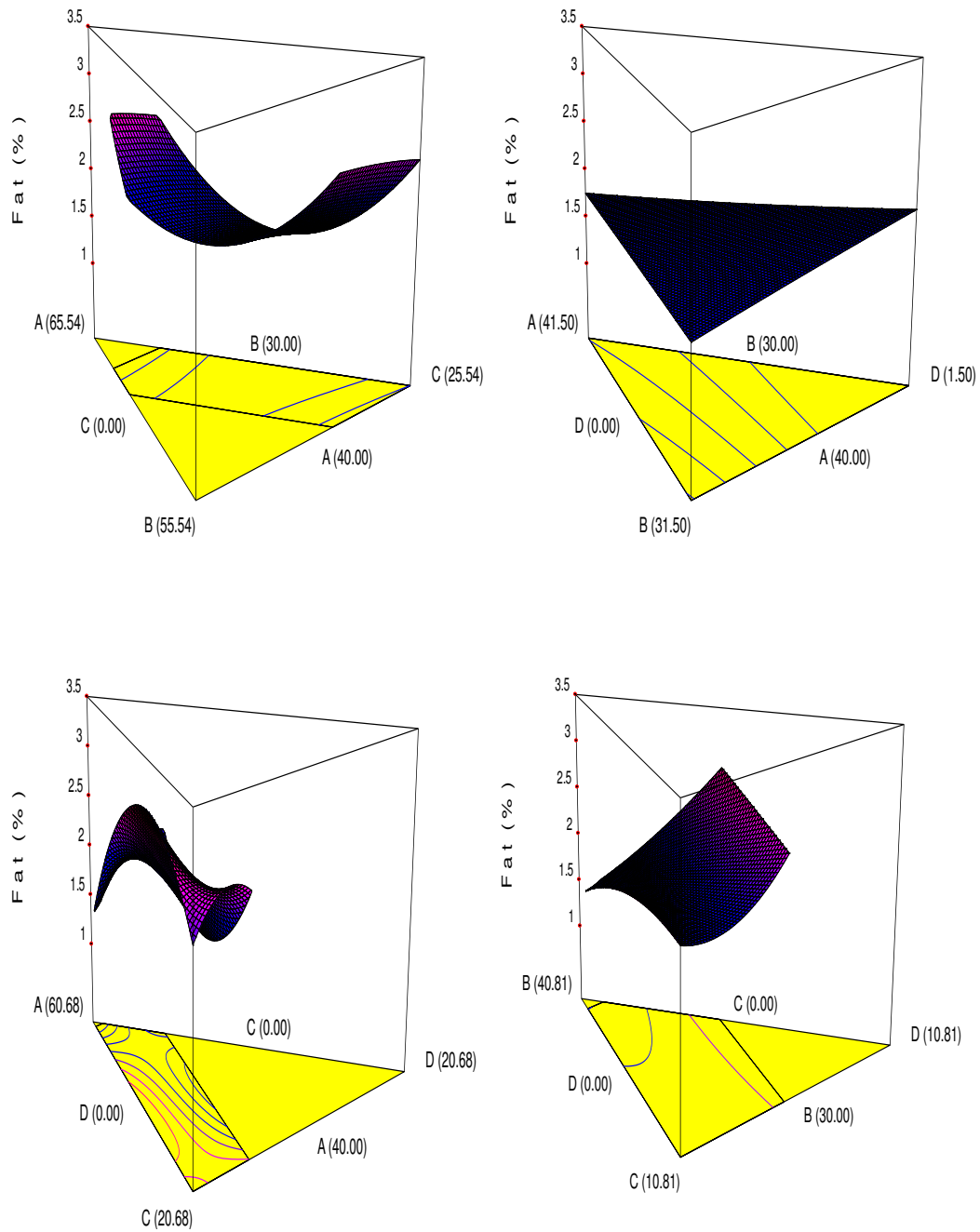
**Fig: 4.3 3D contour plots of protein (%)**  
**(A-corn flour %, B-rice flour %, C-peel %, D-seed %)**

$$\text{Protein (\%)} = 0.21711A + 0.23511B - 0.98028C - 0.31890D - 5.43930 \cdot 10^{-3}AB + 0.026526AC - 0.0092231AD - 0.040680 \cdot 10^{-3}BD - 5.48839E \cdot 10^{-4}ACD + 6.71313E \cdot 10^{-3}BCD$$

#### 4.5 Effect of Fat on extrudates

Tomato seed is the important component in the extruded product which also affects the extrudates in a complex manner. The high amount of fat content was observed in seed of tomato as shown in (Table 4.3). Generally for extruded snack foods, it is desirable to have low levels of fat content (Yagci Gogus 2007). In the present study it was observed that fat content in all extrudates did not exceed more than 3% and hence the product developed could be a low fat and high calorie snack food. However the fat content of extruded product enhances the taste of the product, which is directly proportional to the seed added in the extruded product formulation.

The fat content in the final extruded product varied significantly ( $p < 0.001$ ) and was directly propositional to the percentage of seed present in the initial formulation. Similarly in the case of formulations which included only corn, rice and/or peel flour, no significant difference was observed in terms of fat content. This observation may be explained by the fact that less amount of fat were present in those formulations where tomato seed was absent as is evident by (table no 4.3 and figure 4.3). Fahimdanesh et al . (2013) <sup>found</sup> that tomato seed consisted of essential fatty acids which are useful for the substitution in new product as a source from by-product. They further stated that palmitic acid (12.26%) was the major saturated fatty acid, followed by stearic acid (5.15%) whereas Linoleic acid (56.12%) was the major unsaturated fatty acid followed by oleic acid (22.17%) in those tomato seeds. Substitution of fat in extrudates more than 10% leads to an increase in hardness of the final product (citation), considering these factors, in present study it was restricted to 5% (seed) as a substitute for producing low fat snack foods. Hence increasing the amount of seed to 5% which in turn increased the fat% to 3% did not significantly affect the expansion of the extrudate.



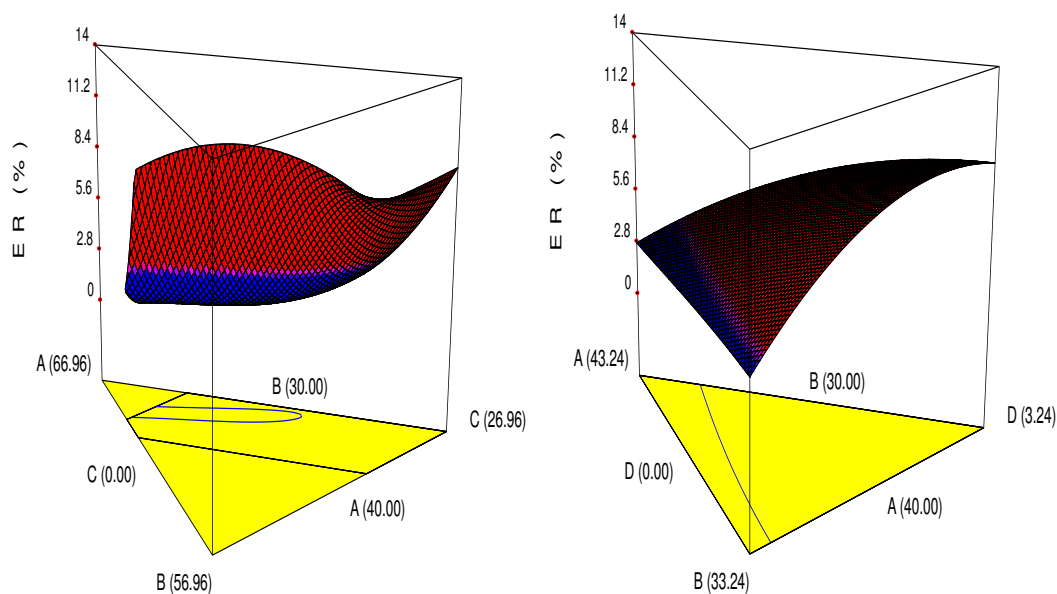
**Fig: 4.4 3D contour plots of fat (%)**  
**(A-corn flour %, B-rice flour %, C-peel %, D-seed %)**

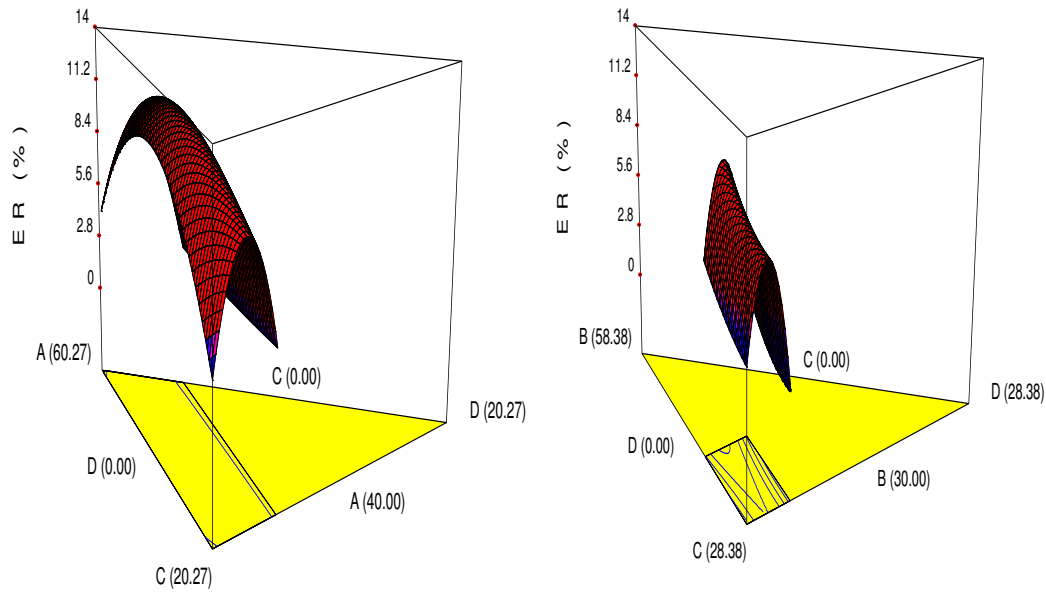
$$\text{Fat (\%)} = -0.20642A - 0.30476B - 0.47895C - 11.34714D + 0.010768AB + 0.010642AC + 0.21119AD + 7.69345E-003BC + 0.23817BD + 0.28765CD + 1.55966E-005ABC - 4.26613E-003ABD - 4.67595E-003ACD - 1.63695E-003BCD$$

#### 4.6 Effect of Expansion ratio on Extruded product

The expansion ratio of the extrudates seeks to describe the degree of puffing undergone by the dough as it exits the extruder. The stored energy was released in the expansion process, increasing the expansion ratio (Thymi *et al.* 2005). The extrusion of all combinations of corn flour, rice flour, peel and seed produced expanded snack at most conditions; however blends having higher peel % usually had lower expansion ratio. The expansion ratio measured for all the extruded samples ranged between (3.806-4.779 %). The expansion ratios of the extruded snacks were similar to the published values of rice-based extrudates (Ilo *et al.* 1999; Asare *et al.* 2004; Ding *et al.* 2005). The response surface plot for the expansion ratio as a function of components is shown in (Fig.4.4)

The analytical results indicated that expansion indices were linearly affected ( $p \leq 0.0001$ ) by the tomato pomace. As expected incorporation of tomato derivative reduced the expansion values when compared to the control (without by-product) similar finding were observed by Shoar *et al.* (2010). Tomato pomace which is rich in fibres, in the formulation tend to rupture the cell walls before the gas bubbles may expand to their full potential (Lue *et al.*, 1991) during the process of extrusion cooking. Decrease in the expansion ratio by the addition of products rich in fibre was also observed in studies done by Altan *et al.* (2008) and Dehghan-Shoar *et al.* (2010). The decrease in expansion ratio may further be aided by the relative reductions in the amount of starch and protein, mainly responsible for the puffiness of the final product.



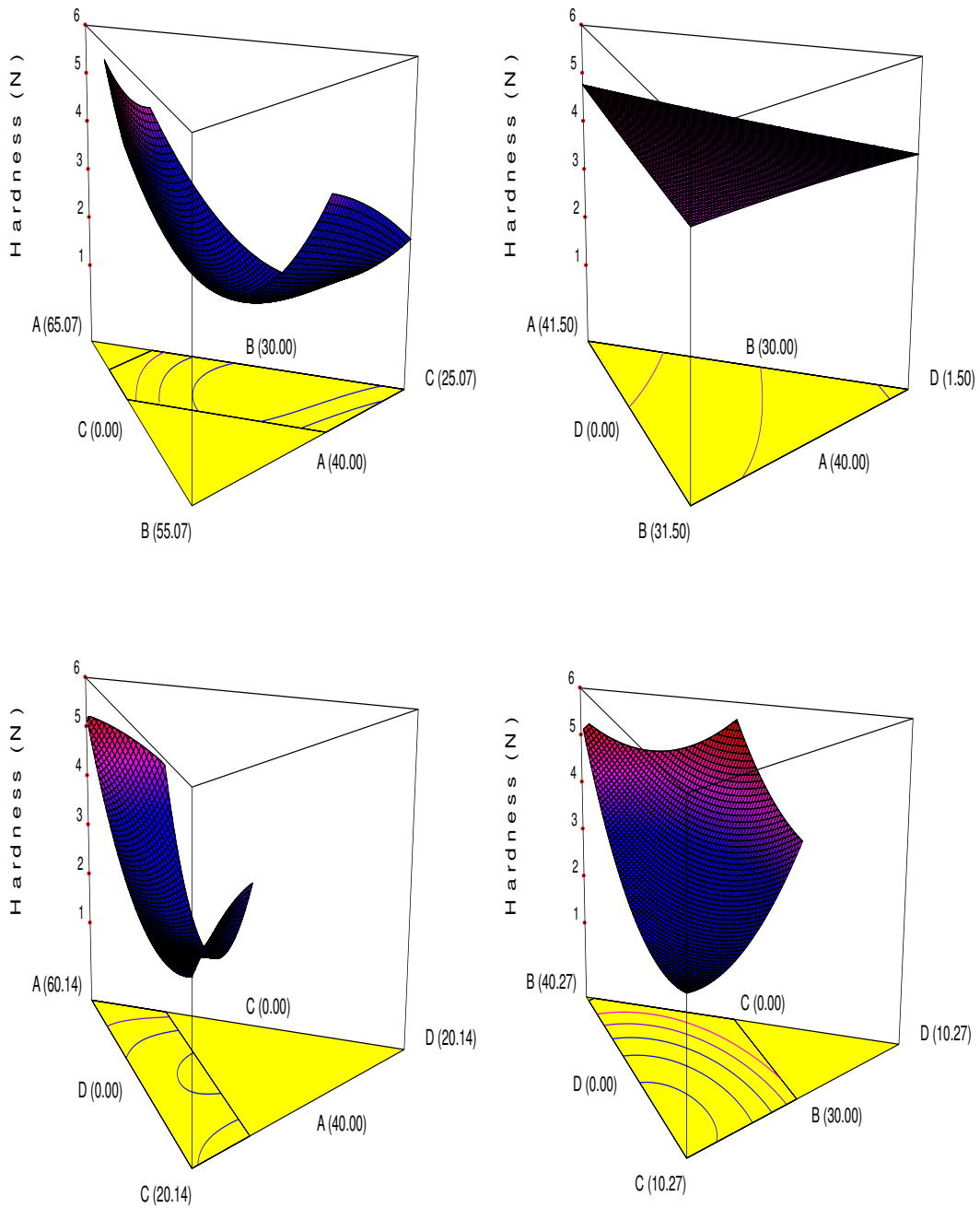


**Fig:4.5 3D contour plots of Expansion ratio (%)**  
**(A-corn flour %, B-rice flour %, C-peel %, D-seed %)**

$$ER \% = 9.925819A - 1.769B + 3.796C - 724.282D + 94.22852AB - 16.9765AC + 923.446AD + 6.606BC + 927.748BD + 872.758CD - 46.3771ABC - 573.483ABD - 404.853ACD - 85.968BCD - 299.541AB(A-B)$$

#### 4.7 Hardness

The formulation of the extruded snack had a direct effect on the textural properties of the final product especially the hardness of the extrudate which is an important factor affecting the acceptability of the extruded snack. The addition of tomato pomace linearly affected the hardness of the extrudate. (Fig: 4.6). In line with our result many studies have suggested that hardness of the extrudates can reduce following as increase in the level of corn starch in the formulation of the extruded snack. Moreover inclusion of pomace (>20%) can affect the dough viscosity, elastic swell effect and bubble growth effect which contribute to the structure change of the extrusion mix and highly imparts changes in product properties as hardness (Stojceska et al., 2008). It was observed that hardness is not only affected by fibre content but also by the presence of protein content in composition. Similar results have been reported by (Ding et al. 2006 , Shiraniet al., 2009).



**Fig: 4.6 3D contour plots of Hardness (N)**  
**(A-corn flour %, B-rice flour %, C-peel %, D-seed %)**

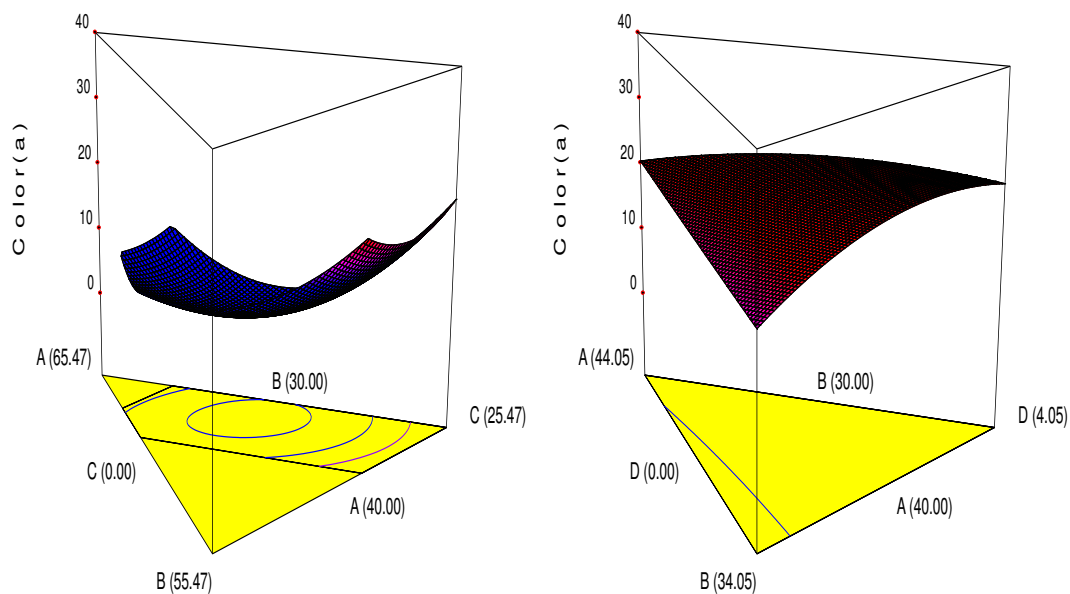
$$\text{Hardness(N)} = -0.61043A - 0.89269B - 2.55293C - 17.01502D + 0.032354AB + 0.079030AC + 0.36667AD + 0.091673BC + 0.21136CD - 2.32396E-003ABC - 8.77783E-003ABD - .96507E-003ACD + 1.56051E-003BCD$$

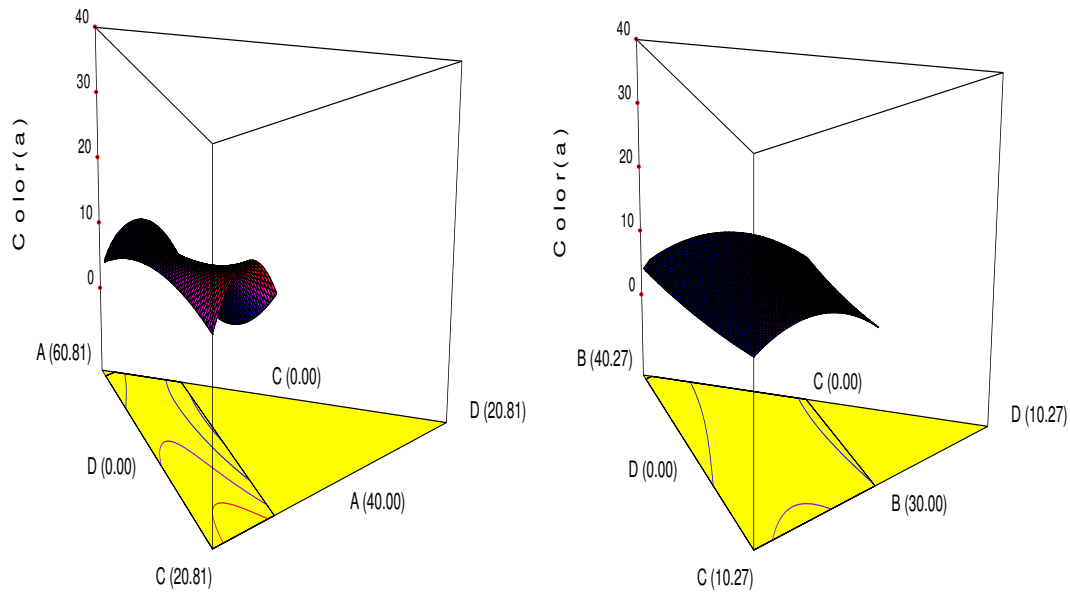
## 4.8 Colour

Colour is an important quality factor directly related to the acceptability of food products, and is an important physical property to report for extruded products. Results of colour recorded for the extrudates containing different concentrations of tomato pomace obtained using different mixture designs are presented in (Fig:4.7). Among the colour parameters, the redness  $a$  values showed marked changes due to addition of tomato pomace only.

An increase in tomato peel level in product, increased the  $a$  value of samples as expected due to the lycopene pigment in the tomato peel. Similar result were reported by Ilo and Berghofer (19990, Altan et al. (2008), Shoar et al. (2010). Results of ANOVA showed significant difference among the linear mixtures by the addition of pomace in the extrudates ( $p < 0.05$ ).

There were however, some formulations like ABC and BCD which did not show significant difference among them with regards to colour. This phenomenon may be due to the yellowness colour which was not significant in most of the formulations and which are due to the carotenoid content in seed and corn flour may have some effect on the  $a$  value of the extrudate samples ( Altan et al., 2008).





**Fig: 4.7 3D contour plots of colour (a) value**

**(A -corn flour %; B rice flour % ; C peel% ; D seed %)**

$$\text{Colour (a)} = 0.818377A + 2.984478B + 2.87473C - 168.15113D - 0.068337AB - 0.036134AC + 2.36710AD - 0.14561BC + 2.74845BD + 2.75589CD + 1.91089E - 0.33ABC - 0.033385ABD - 0.012147BCD$$

#### 4.9 Overall Acceptability

A 9 point hedonic scale was used for the sensory evaluation of the extruded products. The rating was given for overall acceptability based on the parameters given in (Table 4.6) The mean scores of overall acceptability showed that all products with tomato pomace were within the acceptable range. Statistical analysis showed that the model was ( $P < 0.05$ ) significant with addition of pomace.

It was observed that tomato pomace had significant effect on final product quality in terms of appearance, colour, flavour and taste. Overall acceptability of the products ranged from (4.4-8), Extrudates with different levels of tomato pomace had higher scores with respect to control sample, combinations which had the Overall acceptability was the one with peel and seed ratio, 15:0% and 25:5% respectively.

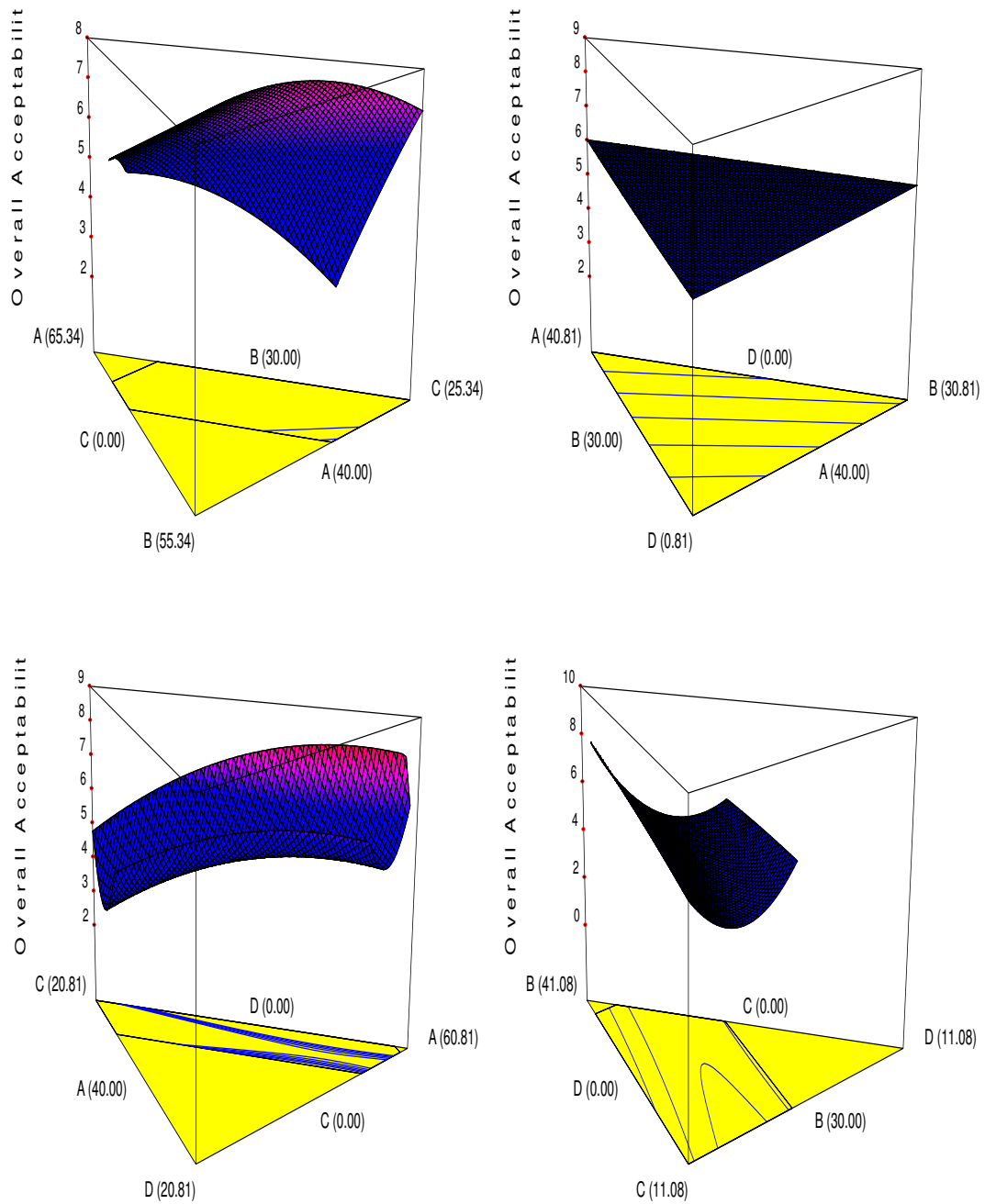
Furthermore it could be explained that combination with seed also ranged high due to the fact that seed contained fat content which increases the taste of the sample over consumption. Although due to increase in peel and seed percentage some variation of textural properties were observed in all combinations, especially hardness may increase due to increase in fibre and protein content as discussed earlier this certainly affects the

crispness of the product. Some product showed Umami flavour after taste which increased when addition of pomace (>20%) was done. Higher the peel percentage eventually increased the colour of the product.

Above all results indicated that extrusion of tomato pomace, in combination with rice and corn flour can produce acceptable extrudate snack food. Moreover the tomato pomace content was the most important parameter affecting the sensory properties of extruded product.

**Table 4.6 Mean Values of Sensory Scores for OA**

Run	Corn flour (%)	Rice flour (%)	Peel (%)	Seed (%)	OA
1	60	30	5	5	6
2	60	40	0	0	8
3	55.27	36.25	5.83	2.63	6
4	60	30	10	0	6
5	60	30	10	0	6
6	50	35	15	0	8
7	40	40	15	5	5
8	60	37.5	0	2.5	5
9	60	30	5	5	6
10	40	35	25	0	5.4
11	40	35	20	5	5
12	40	30	30	0	6
13	40	40	20	0	4.4
14	50	30	17.5	2.5	5.4
15	47.5	40	7.5	5	5.2
16	40	30	25	5	8
17	55	40	0	5	6



**Fig:4.8 3D contour plots of Overall acceptability  
(A-corn flour %, B-rice flour %, C-peel %, D-seed %)**

$$\text{Overall acceptability} = -0.50999A - 0.95199B - 0.043458C + 27.45048D + 0.031987AB + 0.011021AC - 0.27136AD + 5.06584E - 003BC - 0.30404BD - 0.26368CD$$

#### 4.10 Optimization of Formulation based on Desirability by using Mixture (D-Optimal) Design

The optimization tool from the design expert software was utilized to derive the optimal formulations based on response results evaluated. This was implemented by choosing the criteria of maximum limits for both the favourable factors and desirable responses, i.e. tomato peel and seed (factor), corn flour and rice flour were kept in range and response with maximum limits are expansion ratio, protein, fat, crude fibre, colour (a) and Overall acceptability. Undesirable responses (e.g. hardness) were minimized to produce formulations with a more crispy texture but less hardness. 17 formulations with predicted quality response values were generated based on these entered parameters. Depending on the best desirability ratings, 1 formulation was chosen. The details of these formulations can be seen in (Table) the combinations were F1, F2, F3, F4 (desirability 0.845 i.e. 84.5%) tomato pomace, corn flour and rice flour, die head temperature of 130 °C and screw speed of 300 rpm.

**Table: 4.7 Solutions Obtained From D-Optimal Mixture Design**

<i>Solutions</i>					
<i>Number</i>	<i>Corn flour</i>	<i>Rice flour</i>	<i>Peel</i>	<i>Seed</i>	<i>Desirability</i>
<b>1</b>	<b>40</b>	<b>30</b>	<b>25.24</b>	<b>4.76</b>	<b>0.84</b>
2	54.82	30	13.42	1.75	0.58
3	46.78	40	12.04	1.18	0.55
4	60	30	5.72	4.28	0.48

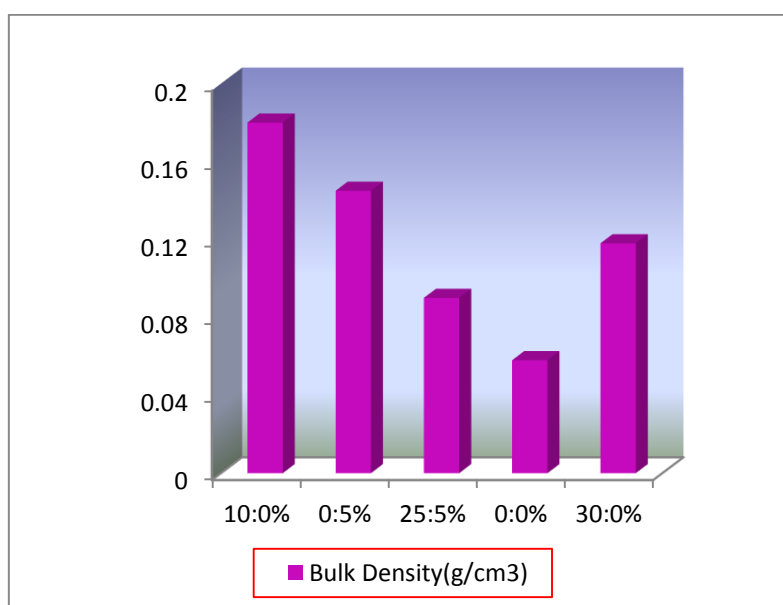
**Table: 4.8 Desirability of Responses for the Optimized formulations**

<i>Responses for the Optimized Formulation</i>								
<i>Number</i>	<i>Crude fibre</i>	<i>Protein</i>	<i>Fat</i>	<i>ER</i>	<i>Hardness</i>	<i>Colour (a)</i>	<i>Overall Acceptability</i>	<i>Desirability</i>
<b>1</b>	<b>4.98</b>	<b>11.76</b>	<b>2.51</b>	<b>4.78</b>	<b>2.54</b>	<b>19.82</b>	<b>7.19</b>	<b>0.84</b>
2	2.53	12.72	2.31	4.78	2.86	16.31	5.50	0.58
3	3.17	10.96	2.73	12.71	2.22	17.63	5.36	0.55
4	1.78	12.21	2.61	6.07	3.93	12.91	5.13	0.48

#### 4.11 Bulk density

From figure it was observed that there is significant increase in combinations with the addition of pomace, when compared to control formulations (corn flour and rice flour). It was observed that following increase in level of tomato pomace in the formulation leads to increase the bulk density of the extrudates. Effect of component variables on the bulk density of important combinations of the extrudates is presented (Fig: 4.8). This phenomena may be due to the fact that the addition of increasing amounts of fibre and protein to the blend may affect the extent of starch gelatinization and thus the rheological properties of the melted material in the extruder. The non-starch polysaccharides in fibre may bind water more tightly during extrusion compared to protein and starch. This binding may inhibit water loss at the die and thus reduce expansion thus leading to an increase in density (Camire & King, 1991). Similar effects were reported during extrusion with orange peel, grape peel, and tomato pomace (Yagci & Gogus, 2008). An increased bulk density with addition of tomato pomace agrees with the results of fiber-added corn extrudates (Hsieh, Mulvaney, Huff, Lue, & Brent, 1989) and extrusion of partially defatted peanut flour (PDPF) with starch (Suknark et al., 1997).

Bulk density is directly affected by expansion ratio and it is an quality indicator as well. Hence increase in bulk density means decreases the acceptability of the product.

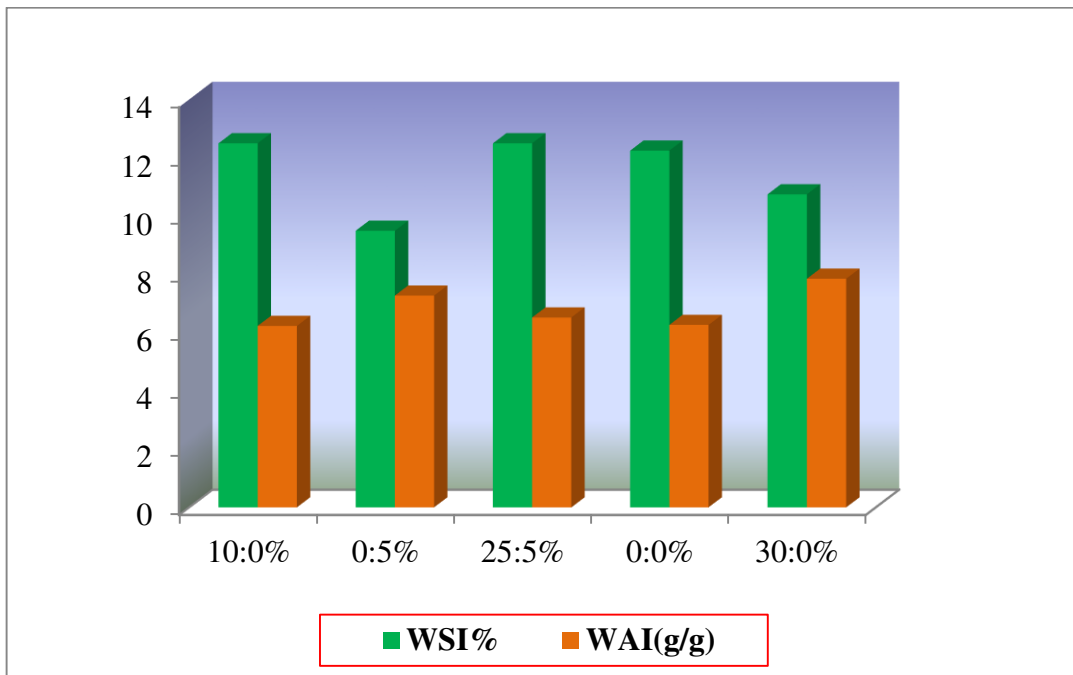


**Fig: 4.9 Bulk Density (gcm<sup>3</sup>)**

#### **4.12 Water Absorption & Water Solubility Index:**

The WAI measures the volume occupied by the granule or starch polymer after swelling in excess water. While the WSI determines the amount of free polysaccharide or polysaccharide released from the granule after addition of excess water (Sriburi & Hill, 2000). The water absorption ranged from 6.04 -7.85 g/g for the extrudates. Water absorption index can be used as an index of starch gelatinization (Anderson et al., 1969). WAI and WSI represent the post cooking quality of the extrudates. And as well it is a quality indicator in which higher the WAI lower the expansion ratio additionally increases the bulk density which is not acceptable for the final quality. In extrusion amylose and amylopectin molecules contribute to the gel formation and viscosity to the cooked paste, respectively. The result obtained was WAI increased as the percentage of tomato pomace increased, this may be due to the addition of pomace and competition of absorption of water between pomace and available starch (Fig: 4.9). Earlier studies state that fiber in pomace also has the capacity to hold water. Similar results have been reported by (Miriam Mabel Selani et al., 2014). However control formulation corn flour and rice flour (60:40) had a lower WAI which may be due to the gelatinization of starch or probably with increase in temperature leads to decomposition/degradation of starch molecules (Pelembe et al., 2002). Ding et al. (2006) also stated that the WAI decreases with increasing temperature if dextrinization or starch melting prevails over the gelatinization phenomenon. The formulation with seed shows significant increase in WAI, this increase may be due to some proteins are degraded and converted into fibre due to higher temperature. WSI ranged from 8.16-15.75% for the extrudates. It is often used as an indicator of starch degradation (dextrinization) leads to the generation of smaller and more water soluble molecules. (Ding, Ainsworth, Plunkett, Tucker, & Marson, 2006). The increase in WSI was observed and this may be due to several factors in consistent with other studies. The formulation with addition of lower pomace levels shows higher WSI in the extrudates (Fig: 4.9), this increase may be of screw speed induced by a sharp increase of specific mechanical energy, the high mechanical shear degraded macromolecules, and so the molecular weight of starch granules decreased and hence increased WSI. The increase in WSI with increasing screw speed was reliable with the other studies reported by (Jin et al., 1995; Mezreb, Goullieux, Ralainirina, & Queneudec, 2003; Aylin Altan et al., 2008).

In the combinations with higher fibre content shows decrease in WSI, this is along with the fact that these treatments have less amount of starch in their compositions, which during extrusion leads to a release of more soluble compounds. This decrease may also be besides changes in starch, influenced by structural changes of other components during extrusion, such as proteins, which undergo denaturation, affecting its solubility, and fibres. A decrease in WSI with an increase in fibre was also observed by Kumar et al. (2010), who used carrot pomace. However, reduction in WSI was observed in products with higher fibre content at moisture (14%).



**Fig: 4.10 Water Absorption and Water Solubility Index**

## CHAPTER V

### SUMMARY AND CONCLUSIONS

Using D-optimal mixture design as a tool, the effects of four factors on the physico-chemical characteristics, texture, post cooking quality (WAI & WSI) and chemical properties of extruded snack are highlighted in this study. The design demonstrated the ability of tomato pomace (TP) to affect all the responses. In all formulation, it was observed to be significant variation with the addition of TP on to the extruded product. Tomato pomace affected the expansion ratio, texture and hardness. This is attributed to the high fibre content present in TP and protein content in seed.

As discussed, fibre is well documented as having hydrophilic properties; beyond a certain limit, it can have a negative impact on the responses due to its ability to absorb excess water and damage aerated bubble structures. Optimisation of these four factors was crucial for the development of a high-quality puffed snack. The optimal extrusion conditions and TP inclusion to produce a high quality snack were calculated with the aid of the optimisation tool to be; corn flour, corn flour and tomato pomace within the range and TP addition with desirability of 0.84 %.

The study successfully demonstrates how tomato pomace could be utilised in an extruded puffed snack. Among experimental conditions used in this study, it was well explained about how for the extudate was affected by addition of TP. It also highlighted how an under-utilized by-product may be substituted for corn, rice flour and incorporated into an expanded puffed snack. Sensory acceptability of the product was showed to be most dependent with the pomace content.

However high level of tomato pomace was included into the extruded snack without compromising the expansion characteristics of the snack while potentially improving its nutritive properties with high fibre and protein enriched snack product. These kinds of products could help in utilizing the by-product as a source of fibre for the production of valuable products in the future. However, the nutritional aspects of the produced products still need to be analysed.

### **5.1 Recommendations for Future Research:**

- ❖ Further more storage study need to be conducted to know about the stability and changes in the final product.
- ❖ Developed high fibre Tomato pomace extruded product could be analysed for individual dietary fibre, antioxidant and lycopene in the extrudates.
- ❖ Prebiotic and probiotic formulations can be included to make a symbiotic product.
- ❖ Preclinical and Clinical trials can be conducted to study various health promoting properties of the extruded product such as anti-diabetic, anti-atherosclerosis, GI response, Bio-availability of fibre in human body.
- ❖ Extrudate can be mixed with seasoning (spices/sweet) for improving further taste of the final product.
- ❖ Inclusion of other food by-product, or underutilised food products may be considered for improvement in the health promoting properties of the extruded products.

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## APPENDICES

### Appendix : 1

**Analysis of variance (ANOVA) of the final regression equation for the response:  
Crude Fibre**

Source	Sum of Squares	df	Mean Square	F Value	p-value Prob >F	
Model	19.76	13	1.52	24.29	0.01	<b>significant</b>
Linear	14.26	3	4.75	75.99	0.00	
Mixture						
AB	0.96	1	0.96	15.28	0.03	
AC	0.01	1	0.01	0.21	0.68	
AD	1.64	1	1.64	26.20	0.01	
BC	0.60	1	0.60	9.53	0.05	
BD	0.31	1	0.31	4.97	0.11	
CD	1.85	1	1.85	29.62	0.01	
ABC	0.35	1	0.35	5.62	0.10	
ABD	0.02	1	0.02	0.25	0.65	
ACD	0.56	1	0.56	8.98	0.06	
BCD	0.05	1	0.05	0.87	0.42	
Residual	0.19	3	0.06			
Lack of Fit	0.19	1	0.19			
Pure Error	0.00	2	0.00			

## Appendix : 2

### Analysis of variance (ANOVA) of the final regression equation for the response: Protein

Source	Sum of Squares	df	Mean Square	F Value	p-value Prob >F	
Model	13.73	13.00	1.06	44.50	0.00	<b>significant</b>
Linear	8.46	3.00	2.82	118.78	0.00	
Mixture						
AB	0.01	1.00	0.01	0.59	0.50	
AC	0.04	1.00	0.04	1.57	0.30	
AD	0.61	1.00	0.61	25.60	0.01	
BC	0.00	1.00	0.00	0.00	0.98	
BD	0.00	1.00	0.00	0.12	0.75	
CD	0.59	1.00	0.59	24.84	0.02	
ABC	0.16	1.00	0.16	6.87	0.08	
ABD	0.37	1.00	0.37	15.79	0.03	
ACD	0.01	1.00	0.01	0.51	0.53	
BCD	0.25	1.00	0.25	10.34	0.05	
Residual	0.07	3.00	0.02			
Lack of Fit	0.07	1.00	0.07			
Pure Error	0.00	2.00	0.00			

### Appendix: 3

**Analysis of variance (ANOVA) of the final regression equation for the response:  
Fat**

Source	Sum of Squares	df	Mean Square	F Value	p-value Prob >F	
Model	3.86	13.00	0.30	4032.39	0.00	<b>significant</b>
Linear	0.84	3.00	0.28	3794.57	0.00	
Mixture						
AB	0.05	1.00	0.05	741.05	0.00	
AC	0.43	1.00	0.43	5818.18	0.00	
AD	0.19	1.00	0.19	2638.80	0.00	
BC	0.03	1.00	0.03	396.68	0.00	
BD	0.04	1.00	0.04	482.49	0.00	
CD	0.08	1.00	0.08	1103.59	0.00	
ABC	0.00	1.00	0.00	0.90	0.41	
ABD	0.11	1.00	0.11	1455.04	0.00	
ACD	0.87	1.00	0.87	11820.53	0.00	
BCD	0.01	1.00	0.01	198.26	0.00	
Residual	0.00	3.00	0.00			
Lack of Fit	0.00	1.00	0.00			
Pure Error	0.00	2.00	0.00			

#### Appendix: 4

#### Analysis of variance (ANOVA) of the final regression equation for the response: Expansion Ratio

Source	Sum of Squares	DF	Mean Square	F Value	Prob > F	
Model	2.034	14.000	0.145	63660000.00	< 0.0001	<b>significant</b>
Linear						
Mixture	-0.025	3.000	-0.008	63660000.00	< 0.0001	
AB	0.247	1.000	0.247	63660000.00	< 0.0001	
AC	0.295	1.000	0.295	63660000.00	< 0.0001	
AD	0.199	1.000	0.199	63660000.00	< 0.0001	
BC	0.022	1.000	0.022	63660000.00	< 0.0001	
BD	0.212	1.000	0.212	63660000.00	< 0.0001	
CD	0.201	1.000	0.201	63660000.00	< 0.0001	
ABC	0.145	1.000	0.145	63660000.00	< 0.0001	
ABD	0.258	1.000	0.258	63660000.00	< 0.0001	
ACD	0.193	1.000	0.193	63660000.00	< 0.0001	
BCD	0.053	1.000	0.053	63660000.00	< 0.0001	
AB(A-B)	0.233	1.000	0.233	63660000.00	< 0.0001	
AC(A-C)	0	0				
AD(A-D)	0	0				
BC(B-C)	0	0				
BD(B-D)	0	0				
CD(C-D)	0	0				
Pure Error	0	2	0			

## Appendix: 5

**Analysis of variance (ANOVA) of the final regression equation for the response: Hardness**

Source	Sum of Squares	df	Mean Square	F Value	p-value Prob>F	
Model	18.87	13.00	1.45	97.78	0.00	<b>significant</b>
Linear						
Mixture	1.57	3.00	0.52	35.34	0.01	
AB	0.49	1.00	0.49	33.16	0.01	
AC	0.30	1.00	0.30	20.26	0.02	
AD	0.30	1.00	0.30	20.17	0.02	
BC	0.00	1.00	0.00	0.05	0.84	
BD	0.03	1.00	0.03	2.26	0.23	
CD	0.01	1.00	0.01	0.79	0.44	
ABC	1.47	1.00	1.47	98.86	0.00	
ABD	0.45	1.00	0.45	30.54	0.01	
ACD	1.42	1.00	1.42	95.36	0.00	
BCD	0.01	1.00	0.01	0.89	0.41	
Residual	0.04	3.00	0.01			
Lack of Fit	0.04	1.00	0.04			
Pure Error	0	2	0			

## Appendix: 6

### Analysis of variance (ANOVA) of the final regression equation for the response: Colour

Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F	
Model	334.27	13.00	25.71	41.90	0.01	<b>significant</b>
Linear						
Mixture	259.76	3.00	86.59	141.09	0.00	
AB	2.20	1.00	2.20	3.58	0.15	
AC	1.56	1.00	1.56	2.54	0.21	
AD	52.31	1.00	52.31	85.24	0.00	
BC	2.02	1.00	2.02	3.29	0.17	
BD	15.55	1.00	15.55	25.34	0.02	
CD	43.86	1.00	43.86	71.46	0.00	
ABC	0.99	1.00	0.99	1.62	0.29	
ABD	6.56	1.00	6.56	10.69	0.05	
ACD	35.50	1.00	35.50	57.85	0.00	
BCD	0.80	1.00	0.80	1.31	0.34	
Residual	1.84	3.00	0.61			
Lack of Fit	1.84	1.00	1.84			
Pure Error	0	2	0			

## Appendix: 7

### Analysis of variance (ANOVA) of the final regression equation for the response: Overall Acceptability

Source	Sum of Squares	df	Mean Square	F Value	p-value Prob>F	
Model	15.78	9.00	1.75	3.94	0.04	<b>significant</b>
Linear						
Mixture	1.93	3.00	0.64	1.45	0.31	
AB	1.48	1.00	1.48	3.33	0.11	
AC	2.46	1.00	2.46	5.53	0.05	
AD	5.04	1.00	5.04	11.33	0.01	
BC	0.04	1.00	0.04	0.09	0.77	
BD	6.20	1.00	6.20	13.93	0.01	
CD	4.64	1.00	4.64	10.42	0.01	
Residual	3.12	7.00	0.45			
Lack of Fit	3.12	5.00	0.62			
Pure Error	0	2	0			



**INDIAN INSTITUTE OF CROP PROCESSING TECHNOLOGY**

**Thanjavur**

(Affiliated with Tamil Nadu Agricultural University)

Sensory Analysis Form: 9 point hedonic test

Name:

Date

<b>SENSORY CHARACTERISTICS</b>																			
<b>Appearance</b>																			
<b>Colour</b>																			
<b>Flavour</b>																			
<b>Initial bite</b>																			
<b>Texture</b>																			
<b>Graininess</b>																			
<b>Taste</b>																			
<b>Umami</b>																			
<b>Tangy</b>																			
<b>Cohesiveness</b>																			
<b>After taste</b>																			
<b>Overall acceptability</b>																			

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

Comments if any:

Signature: