DEVELOPMENT OF READY-TO-EAT EXTRUDED FISH BASED NOODLES IN SEMI-RIGID CONTAINERS

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Dedicated

To my

Parents

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Date: 20.07.2015

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*This is to certify that this thesis entitled "Development of ready-to-eat extruded fish based noodles in semi-rigid containers" embodies the original work done by **Mr. Kamalakanth C.K., Reg No: 3116**, under my guidance and supervision in the Fish Processing Division of Central Institute of Fisheries Technology, Cochin. I further certify that no part of this thesis has previously been formed the basis of award of any degree, diploma, associateship, fellowship or any other similar titles of this or in any other University or Institution.*

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Declaration

*I, **Kamalakanth C.K.**, do hereby declare that the thesis entitled "Development of ready-to-eat extruded fish based noodles in semi-rigid containers" is a genuine record of bonafide research carried out by me under the supervision of **Dr. T. K. Srinivasa Gopal**, Former Director (CIFT), Emeritus Scientist(KSCSTE), Central Institute of Fisheries Technology, Cochin and has not previously formed the basis of award of any degree, diploma, associateship, fellowship or any other similar titles of this or any other University or Institution.*

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Kamalakanth C.K.

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List of Abbreviations

µl	microlitre
µm	micrometer
AD	Anno Domini
Al	Aluminium
ALA	Alanine
ANOVA	Analysis of variance
AOAC	Association of Official Analytical Chemists
AOCS	American Oil Chemists' Society
APHA	American public health association
ARG	Arginine
ASP	Aspartic acid
ASTM	American society for testing and materials
atm	Atmosphere
BC	Before Christ
BD	Bulk Density
BIS	Bureau of Indian Standards
BPF	British Plastic Federation
CIE	Commission Internationale d' Eclirage
CL	Cooking loss
CMD	Cassava mosaic disease
CO_2	Carbon dioxide
CPP	Cast polypropylene
CRT	Constant Retort Temperature
CT	Cooking time
CT	Core temperature
CYS	Cysteine
dm	decimeter
EMC	Equilibrium moisture content
EVOH	Ethylene/vinyl alcohol
FDA	Food and drug administration

FFA	Free fatty acid
g	gram
GLU	Glutamic acid
GLY	Glycine
HCl	Hydrochloric acid
HDPE	High density polyethylene
HIPP	High impact polypropylene
HIPS	High impact polystyrene
HIS	Histidine
hrs	hours
HSD	Honest significant difference
HTST	High temperature short time
IS	Bureau of Indian standards
ISO	Isoleucine
K_2CO_3	Potassium carbonate
L/d Ratio	Length to diameter ratio
LEU	Leucine
LYS	Lysine
m	meter
MET	Methionine
mg	Milligram
ml	milliliter
mm	millimeter
Na_2CO_3	Sodium carbonate
NaCl	Sodium chloride
NCA	National canners association
nm	Nanometer
O_2	Oxygen
OTR	Oxygen transmission rate
PE	Polyethylene
PEST	Polyester

PHE	Phenylalanine
PLC	Programmable logic controller
PP	Propylene
ppm	Parts per million
PRO	Proline
PS	Polystyrene
psig	Pounds per square inch
PT	Product Temperature
PVC	Poly vinyl chloride
PVDC	Polyvinylidene chloride
RH	Relative humidity
RPM	Revolution per minute
RSM	Response surface methodology
RT	Retort temperature
SAS	Statistical analysis software
SER	Serine
SS	Shear strength
TBA	Thiobarbituric acid
TBHQ	Tertiary butylhydroquinone
TCA	Trichloro-acetic acid
TDT	Thermal death time
TFS	Tin free steel
THR	Threonine
TM	Trade mark
TMA-N	Tri-methyl amine-nitrogen
TPA	Texture profile analysis
TPT	Total process time
TRY	Tryptophan
TTI	Time-temperature integrators
TVB-N	Total volatile base nitrogen
TYR	Tyrosine

UHT	Ultra high temperature
UK	United Kingdom
US	United States
USA	United States of America
VAL	Valine
VRT	Variable retort temperature
WAI	Water absorption index
WVTR	Water vapour transmission rate

Chapter 1

INTRODUCTION

Contents

1.1 Introduction

Fish and fishery products are having a unique place in global food market due to its unique taste and flavour; moreover, the presence of easily digestible proteins, lipids, vitamins and minerals make it a highly demanded food commodity. Consumers usually prefer fish and fishery product because of their low energy (Holland, 1986) and highly nutritious content which are essential for the growth and better health. Fishery products constitute a major portion of international trade, which is a valuable source of foreign exchange to many developing countries. During the financial year 2013-14, exports of marine products reached an all-time high of US $ 5007 million. As far as India is concerned export of value added product is considered as one of the important sector to attract several foreign markets and foreign exchange. Several new technologies are emerging to produce various value added products from food; "extrusion technology" is one among them. Food extruder is a better choice for producing a wide variety of high value products at low volume because of its versatility. Extruded products are shelf-stable at ambient temperature. Extrusion cooking is used in the manufacture of food products such as ready-to-eat breakfast cereals, expanded snacks, pasta, fat-bread, soup and drink bases. The raw material in the form of powder at ambient temperature is fed into extruder at a known feeding rate. The material first gets compacted and then softens and gelatinizes and/or melts to form a plasticized material, which flows downstream into extruder channel and the final quality of the end products depends on the characteristics of starch in the cereals and protein ingredient as affected by extrusion process. The advantages of extrusion process are the process is thermodynamically most efficient, high temperature short time enables destruction of bacteria and anti-nutritional factors, one step cooking process thereby minimizing wastage and destruction of fat hydrolyzing enzymes during extrusion process and enzymes associated with rancidity.

Extruded products like noodles, wafers, flakes, etc. from vegetable sources are well established in the consumer market. Fish based extruded products have got very good marketing potential but are yet to gain popularity. Formulation of appropriate types of products using different fish mince, starches etc, attractive packaging for the developed products, market studies, etc. are needed for the popularization of such products.

Fish products are comparable to meat and dairy products in nutritional quality, depending on the methods used in preservation and preparation. The protein content of most fish averages 15 to 20 percent (Balachandran, 2001). Fish also contains significant amounts of all essential amino acids, particularly lysine, which are relatively poor in cereals (Davidson et al. 1979, Huss, 1983). Fish protein can be used therefore to complement the amino acid pattern and improve the overall protein quality of a mixed diet. Moreover, sensory properties of an otherwise bland diet can be enhanced through fish incorporated products, thus facilitating and contributing to greater consumption. Japanese threadfin bream (*Nemipterus japonicus*) is one of the major demersal fishery resources, contributing 15.34% of the total demersal landings in India (Swatipriyanka et al. 2014). A major portion of this fish is utilized for reduction purpose. Because of abundance, low cost and white meat of threadfin bream; it was widely used for the manufacture of surimi (Ravendra and Amjad, 2005). This fish was used for the production of value added products commercially (Shabeena and Nazeer, 2013).

Noodles are being consumed for thousands of years and remain an important part in the diet of many Asians. There is a wide variety of noodles in Asia with many local variations as result of differences in culture, climate region and a host of other factors. The demand for convenience foods with desirable sensory and nutritional attributes is growing rapidly. The modification of formulation and processing of noodles was necessary due to regional eating habits, taste preference, and advances in technology (Fu, 2008). Noodles can be made from different flour like wheat, rice, buckwheat, starches derived from potato, and from pulses. At present noodles are prepared from wheat flour, water and salt (Bin, 2008). The inadequacy of cereal proteins particularly that of wheat protein in meeting nutritional need for humans is well established. Therefore there is a need of addition of fish protein which will increase the protein content and thereby improving nutritional value. Egg is usually used as fortifying agents in noodles. Other fortifying agents used are soya flour, peanut flour, green peas flour and some solvent extracted powder are also used. The conventional production of noodles include mixing ingredients, the dough is usually compressed by a pole or rod, or by passing through rollers, rested, and then sheeted several times before cutting into strips (Miskelly, 1993; Corke and Bhattacharya, 1999; Hong-Zhuo et al.

2009). Noodles are sold fresh, boiled, steamed and dried, or steamed and fried (instant type). These noodles are further prepared for consumption by cooking with water, vegetables and other ingredients. This is time consuming and laborious. Hence, there is a need for developing ready to eat noodles incorporating all the above in a packaging material and which can be stored at ambient conditions for longer periods without refrigeration. Also it would be beneficial to industry if a process, such as extrusion, combining the above processes into one unit operation is developed (Sy-Yu and An-I, 2001).

Thermal processing is one of the effective means of preserving food. Numerous articles on the benefits of using pouches in food processing were published (Lampi, 1980; Mermelstein, 1978). Thermal process evaluation done for cans is generally found satisfactory for pouches also. The markets of ready to eat food products have witnessed tremendous growth in the past few decades. Retorting is the most convincing solution for the production of ready to eat food products. Different types of ready to eat thermal processed products from fish, meat and vegetables are available in the market. Semi rigid plastic containers are thermoformed containers that are economical and offer convenience to the user. These containers are thin in profile and three dimensional in shape with a filling volume. High impact polypropylene containers can withstand high processing temperatures without losing their shape and properties and has higher heat penetration rate due to reduced thickness of the material.

By this processing method, it is possible to develop several products to be available on the market shelves in a ready to eat form. Various fish and shrimp products have been standardized for thermal processing in both metal containers and retortable pouches (Hu et al. 1955; Gopal et al. 2001;

Ravishankar et al. 2002; Bindu et al. 2014). However, there is no report on thermal processing of ready to serve noodles in thermoformed containers. With this background the present work was undertaken to incorporate fish mince for the production of fish noodles by extrusion technology and to develop the standardized fish noodles in a ready to eat form in thermoformed container.

1.2 Objectives of the study:

- To develop fish mince incorporated extruded noodles with cereal flour using single screw extruder.
- To study the physical and chemical properties of extruded noodles.
- To study the feasibility of high impact polypropylene containers for packaging and serving ready to eat fish noodles.
- To standardize different process parameters for ready to eat fish noodles by thermal processing.
- To analyze the shelf life of the ready to eat fish noodles at ambient temperature (28±1°C).

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Chapter 2

REVIEW OF LITERATURE

Contents

2.1 Extrusion technology

Extrusion technologies are novel and versatile manufacturing technique in food industry for conveying and shaping fluid forms of processed raw materials like doughs and pastes (Guy, 2001). In 1797, Joseph Bramah from England used extrusion principle to develop hand operated piston press to extrude seamless lead pipe (Raiz 2000). Extrusion is a process of shaping by forcing softened and plasticised materials through dies or holes by pressure (Riha et al. 1996). Food ingredients of various types may be processed by extrusion and are referred to as extrudates (Paul and Dennis, 2009). Earlier extrusion methods were simple conveying devices and became sophisticated in the last decade. Presently, processing steps include conveying, mixing, shearing, separation, heating or cooling, shaping, co-extrusion, venting volatiles and moisture, flavour generation, encapsulation and sterilisation. Extrusion application of food industry includes ready to eat breakfast cereals, baby foods, pet foods and confectionary products (Hulya, 1999). It was found that the extrusion process is continuous in nature. In order to obtain the desired output, the process variables should be standardised.

2.1.1 Food extruder

Food extruder is equipment used for the shaping and restructuring process for food ingredients. Extrusion processing equipment has become popular in many food industries throughout the world (Riaz et al. 1996). The screw is the heart of the extrusion process and its design and speed of rotation greatly influence the extrusion operation. The screw has got three functions: conveying, shearing, heating and mixing. The feeder section accepts moistened granular feed materials and conveys them down the length of the screw to the exit. As the feed materials move along the screw, they encounter great friction, restriction or compression, causing them to completely fill the channel or the space existing between the screw flights. The energy necessary to make the viscous materials flow is supplied by a large drive motor turning the screw. Dies are provided at the exit to attain desired shape of the material and is cut into desired length using a cutter attachment fitted at the end of the discharge.

2.1.1.1 Classification of extruders.

There are mainly two types of extruders. they are single screw extruder and twin screw extruder. Both single-screw and twin-screw extruders are used for commercial production of a wide variety of food products, ranging from snack half-products, textured vegetable protein, animal feed (including pet foods), expanded ready-to-eat cereals, and flat breads (Paul and Dennis, 2009). In all extruders, the premixed ingredients are conveyed through the barrel by a conveying screw.

2.1.1.1.1 Single screw extruder

In a single screw extruder, conveying action results from friction between screw and the product. Similarly friction between barrel and the product (Sahay and Singh, 1994). In a single-screw extruder, barrel can be divided into three processing zones: feeding zone, kneading zone and the final cooking zone (Berset, 1989). The feeding zone generally has deep channels which receive the feed. The preconditioned or dry material entering this zone is conveyed to the kneading zone. As the material is conveyed into the kneading zone, its density increases. At the end of this zone, the feed material is a viscoamorphic mass at or above 100ºC (Faubion et al. 1982). Temperature and pressure are maximum in this region because of the extruder screw configuration. Shear is highest in this zone, and product temperature reaches its maximum and is held for less than five seconds before the product is forced through the die (Harper, 1978). The desired product can be obtained by placing different die. The product expands as a result of moisture vaporization as it exits through the die into a region of lower pressure and takes the shape of the die. The extruded material can be cut into desired lengths by the knife attachment (Riaz, 2001). In single screw extrusion, there are two types of extruders. They are wet extruder and dry extruder. In wet extrusion, steam and water can be injected into the barrel during processing. Barrels of these machines are provided with heating and cooling jackets. The products produced range from fully cooked, light density corn snacks, to dense, partially cooked and formed dry pasta (Rokey, 2000). In dry extrusion, the extruder does not have provision for external source of heat or steam for injection or jacket heating, In this extrusion, heating is accomplished by mechanical friction (Said, 2000). This type of extruder was developed initially for processing whole soybeans on the farm.

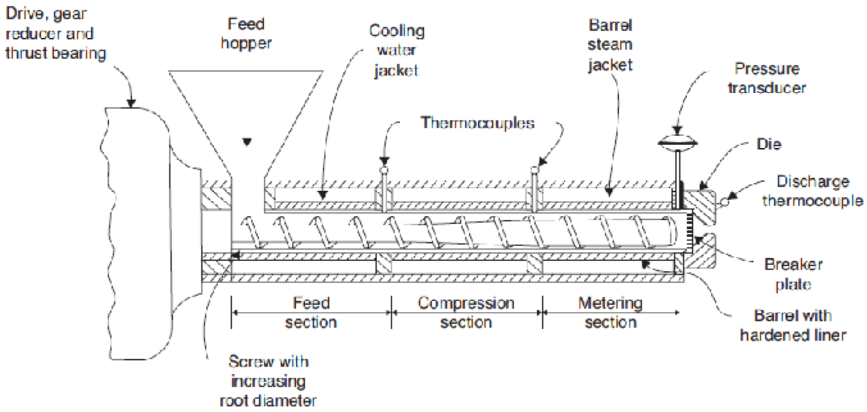


Figure-1. Schematic diagram of single screw extruder (Harper, 1981)

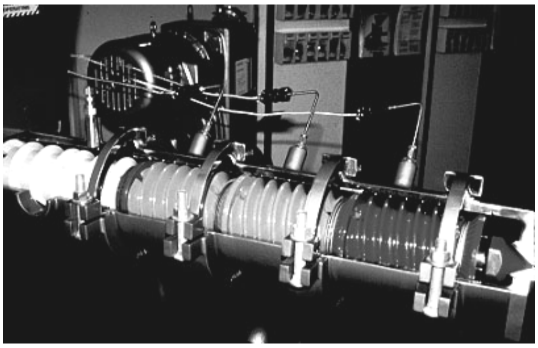


Plate-1. Dry extruder (Raiz, 2001)

2.1.1.1.2 Twin screw extruder

The term ‘twin-screw’ applies to extruders with two screws of equal length placed inside the same barrel. Twin-screw extruders are more complicated than single screw extruders. They provide much more flexibility and better control. Twin screw extruders are generally categorized according to the direction of screw rotation inside the barrel viz. counter-rotating twin-screw extruders and co-rotating twin-screw extruders. In the counter-rotating position, the extruder screw rotates in the opposite direction, whereas in the co-rotating position, the screw rotates in the same direction. These two categories can be further subdivided on the basis of position of the screw in relation to one another viz. intermeshing and non-intermeshing (Miller, 1990). The non-intermeshing twin-screw extruder is like two single-screw extruders sitting side by side with only a small portion of the barrels in common (Clark, 1978). These types of extruders attain temperature as described in single screw extruders. In non-intermeshed extruders, neither pumping nor mixing is positive. Their design does not provide a positive displacement action for pumping the product forward.

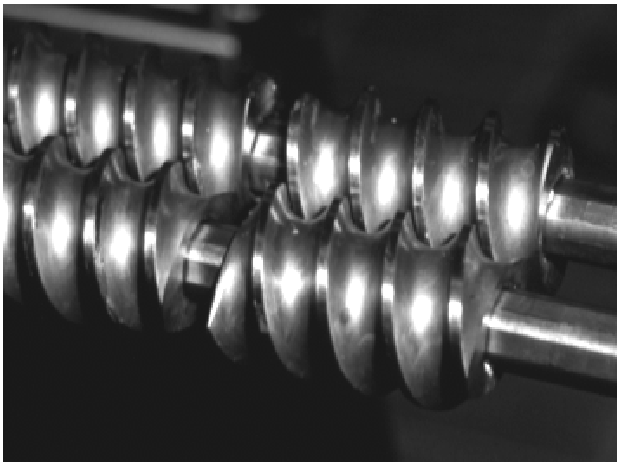


Plate-2. Twin screw of extruder (Raiz, 2001)

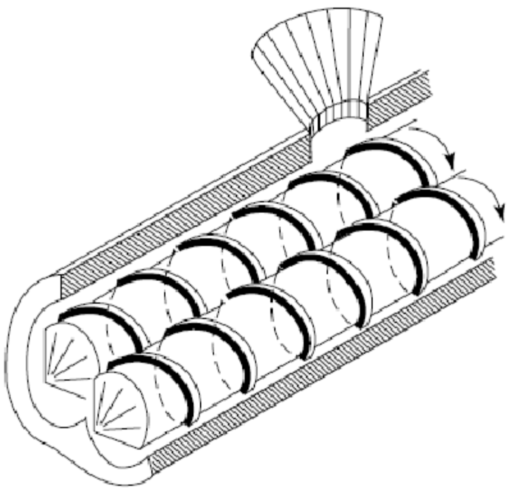


Figure-2. Schematic diagram of a co rotating twin screw extruder

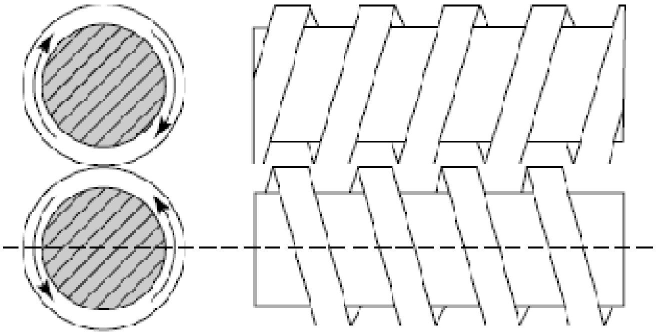


Figure-3. Schematic diagram of a counter rotating twin screw extruder

2.1.1.1.3 Comparison of single and twin screw extruders

The main difference between single and twin screw extruder is the conveying mechanism (Sahay and Singh,1994). In a single screw extruder, the conveying action is the result of the friction effects; the friction between screw and the product and the friction between barrel and product. The single screw extruder needs the barrel wall for the good conveying action. The product may co-rotate along with the screw. Whereas, in a twin screw extruder, the product is enclosed between the intermeshing screws and barrel and is conveyed positively towards the die. Due to such positive displacement action, the product is prevented from co-rotating with the screw. In twin screw extruder the friction at the barrel is of less importance. A single-screw extruder is the simplest food manufacturing device and is very economic to operate. Jianshe and Andrew (2009) suggested that single-screw extruders are only suitable for manufacturing of foods that contain less than 4% fat, 10% sugar and 30% water. The presence of high contents of fat, sugar and moisture will significantly reduce the friction between food material and the inner barrel surface and, therefore, impair the mixing and flow of food. Twin-screw extruders consist of two intermeshing screws either co-rotating or counter-rotating against each other. They have much higher mixing capability than single-screw extruders. One significant advantage of twin-screw extruders is the much extended product range. Food that contain 20% fat, 40% sugar and 65% moisture and can be handled by a twin-screw extruder (Jianshe and Andrew, 2009).

2.1.1.2 Advantages of extrusion cooking

A wide range of products, many of which cannot be produced easily by any other process, is possible by changing the ingredients, extruder operating conditions and dies. Lower processing cost of extrusion and higher productivity than other cooking and forming processes. Extruder can operate continuously with high throughput product quality: Extrusion cooking involves high temperatures applied for a short time, retaining many heat sensitive components of a food. The whole process is environmental friendly, as low-moisture process, extrusion cooking does not produce significant process effluents, reducing water treatment costs and levels of environmental pollution (Smith,1971; Riaz, 2000).

2.1.1.3 Disadvantages of extrusion cooking

Single-screw extruders have relatively poor mixing ability, they are usually supplied with premixed material which often has been preconditioned with added steam and water. Since the single-screw extruder has only one shaft, it will not self-clean as completely at the end of the operation. 'Wet extruders' have higher capital investment than 'dry extruders'.

2.1.1.4 Extrusion cooking of cereals with fish

Research on extrusion of fish muscle started in the 1980's (Choudhury and Gogoi, 1995; Ratankumar et al. 2014). A number of studies have reported successful incorporation of fish flesh or fish powder into starch-based materials by extrusion processes to produce nutritious extruded products that were acceptable by consumers (Binoy et al. 1996; Suknark et al. 2001). Choudhury et al. (1998) undertaken several studies to develop dry expanded snack food products from fish mince and starchy ingredients using single and twin-screw extruders and they found that incorporation of fish hydrolysates along with cereals improve the nutritional quality of extrudates. Rice flour and varying amounts (10–35%) of deboned minced carp were coextruded resulting in a precooked blend which had a shelf life of six months stored at room temperature (Joseph and Reddy, 1985). Rhee et al. (2004) successfully developed a snack food by extrusion of minced catfish with corn and defatted soya flour. Gry (1981) standardised conditions for best extrusion using cod mince, wheat flour and potato flour. Murray et al. (1980) reported that texture of the extruded product was improved by the addition of fish which also reduced the temperature required for optimal texturization during extrusion. During twin-screw extrusion of rice flour and pink salmon blends, the influence of location and spacing of reverse screw and kneading elements on specific mechanical energy input and product attributes were studied by Binoy et al. (1996). Thermal and physicochemical properties of rice flour fish mince based extruded products were studied by Dileep et al. (2010). The advantages of developing fish-based extruded products will help in supplying nutritious and balanced diets to undernourished people in developing countries (Venugopal and Shahidi, 1995). Clayton and Das (1982) suggested that fish with cereal flours offers shelf stable foods with better nutritional quality.

2.1.1.5 Extrusion of noodles

Extrusion processing is currently being used to produce fabricated foods. It has been widely used to produce ready to- eat foods and snacks that depend on the expansion at the die to produce the desired texture and size (Parsons et al. 1996). Extrusion is also used in the production of pasta, macaroni, spaghetti and other noodle products. Sefa-Dedeh and Saalia (1997) modified a laboratory screw oil expeller and adapted it as an inexpensive extruder for the extrusion of maize cowpea blends. The effects of alkaline salt (kansui) and lactic acid on the rheological properties of wheat flour dough and characteristics of extruded noodles were studied by Shiau and Yeh, 2001. Titus and Glory (2011) demonstrated production on extruded noodles from eight cassava mosaic disease (CMD) resistant varieties.

2.1.1.5.1 History of noodles

The first written account of noodles dates from the Chinese East Han Dynasty (Lajia archaeological site) between 206BC and 220AD (Bin, 2008; Hatcher, 2000; Hou and Kruk, 1998). However Chinese, Arabs, and Italians have all claimed to have been the first to create noodles. Later, noodles were transferred to Japan by the Japanese invasion on China. It is then transferred to other Asian countries. The word “noodle” was derived from the German “Nudel” (Harper, 2009). Noodle technology was transferred to Europe by Marco Polo in 13th century where noodles were evolved into the current pasta products (Hou, 2001). Noodles are very important in Chinese culture especially, symbolizing longevity. By eating the noodles, it was believed that a long life would be achieved. Noodles are made of unleavened dough which is rolled flat and cut into one of a variety of shapes. While long thin strips may be the most common, many varieties of noodles are cut into waves, helices, tubes, strings, shells, folded over, or cut into other shapes.

2.1.1.5.2 Classification of noodles

There are different types of noodles available in this world. These varieties come arise for different culture, climate, region and many other different factors. The modification of formulation and processing is necessary due to regional eating habits, taste preference, and advances in technology (Hatcher, 2000). The local uniqueness of formulation and processing has created many country-specific systems for noodle classification. There exist wide differences in the nomenclature for noodles among countries. The major classification of noodles was made by type of raw material, salt used, size of the product and processing method used.

2.1.1.5.2.1 Based on raw materials

The main ingredient for the manufacturing of noodles is wheat flour. The combination of wheat flour made from hard wheat with buck wheat flour (ie, wheat flour containing less than 40% buck wheat flour is called soba). This is mainly consumed in Japan and in Korea. The characteristics of this noodle are light brown or gray with a unique taste and flavour. Noodle made from hard wheat flours is termed as “Chinese type” which is characterized by a bright creamy white or bright yellow colour and a firm texture; whereas, “Japanese noodles” prepared from wheat flour of medium protein and it is characterized by a creamy white colour and a soft and elastic texture (Hou, 2001).

2.1.1.5.2.2 Wheat

Wheat grain belongs to the monocotyledonous family, Grammeae or grass family. The other principal cereal crops are rice, maize, sorghum, millet, barley, oats and rye. Among these rice and wheat are chief cereals of human consumption. Wheat is powdered in the form of flour for the production of different products like bread and other bakery products. "Chapatti" is a common food that is consumed mostly in India is made of wheat. Wheat is classified according to the texture of the endosperm and the protein content. Wheat types are classified as hard or soft and as strong or weak. Internationally wheat is arranged according to the degree of hardness as extra hard, hard, medium and soft. Hardness is due to the adhesion between starch and protein present in the endosperm. Usually the flour used in the noodle production is wheat. Wheat milled and having a particle size of 130µm or less is usually used for noodle preparation. Other than wheat flour, flours used are rice flour, multi grain flours, buckwheat flour, and starches derived from potato, sweet potato, and pulses. General protein content in the flour ranges from 10.5–13.5% (Hatcher, 2000). Different type of noodles has different protein content according to the flour used. Starch content also plays an important role in noodle texture. The starch pasting property was studied by Moss (1980). Starch and protein quality requirements of Japanese alkaline noodles was studied by Crosbie et al. (1999). Hou (2001) suggested that there is an optimum starch quality range for noodle eating quality. Low ash content in the range of 1.4% or lower is used for noodle preparation. The ash content is mainly got from the wheat used for preparation of noodles. Kruger (1996) reported that ash content is also having an effect on the colour of the noodles.

2.1.1.5.2.3 Based on salt used

Noodles can be classified as white/regular salted and yellow alkaline noodles. White salted noodles contain common salt. Yellow alkaline salt contains alkaline salt (mainly Na_2CO_3 and/or K_2CO_3) (Hou, 2001; Bin, 2008).

2.1.1.5.2.4 Based on size

Japanese noodles are classified into four types based on the width of noodle strand. They are So-men (0.7–1.2mm wide), Hiya-mugi (1.3–1.7 mm), Udon (1.9–3.8 mm wide), Hira-men (5–6mm wide) (Hou, 2001).

2.1.1.5.2.5 Based on processing method

In this classification, noodles are manufactured either by handmade or by machinery. The processing operations include mixing raw materials, dough sheeting, compounding, sheeting/ rolling and slitting. This noodle strand is further processed to produce different varieties. Among the manufacturing processing there are fresh, dried, boiled steamed, and steamed and fried noodles.

Fresh noodles are made by the noodles coming out of the slitting rolls and are cut and packed without any processing. Dried noodles are prepared by drying either in sun light or in a drying chamber. Boiled noodles are prepared either parboiling or by fully cooking. Steamed noodles are prepared by steaming in a steamer and softened with water through rinsing or steeping noodle strands. Instant noodles are prepared by waving and steaming fresh noodles and deep frying in hot oil (Hou and Kruk, 1998).

2.1.1.5.3 Different types of noodles available in the market

2.1.1.5.3.1 Cellophane noodles

It is also known as thread vermicelli or glass noodles. Thin, opaque threads are made from mixture of mung bean and tapioca starch having glutinous texture. These noodles absorb flavours well very ideal for soups and braised dishes.

2.1.1.5.3.2 Dried rice noodle sticks

It is translucent, flat noodles which are broader and thicker than rice vermicelli. These noodles need to be soaked in warm water for 15-20 min before use cooked so as to be still firm when consumed.

2.1.1.5.3.3 Dried rice vermicelli

It is one of Asia's most popular and versatile noodles made from rice flour paste, These noodles need to be soaked in boiling water for 6-7 min before use in stir-fries or soups when deep-fried, will expand to approximately four times its original size often used as garnish.

2.1.1.5.3.4 Hokkien noodles

They are thick, fresh egg noodles which have been cooked and lightly oiled before packaging. This is most often vacuum packed and need only one minute boiling before being used in stir-fries, soup, or salads.

2.1.1.5.3.5 Egg noodles

It is made from wheat flour and eggs, the most wide spread in Asia sold in variety of widths which can be stored in refrigerator for up to 1 week. These noodles need 1 minute for boiling in water while dried noodles need 3-4 min cooking.

2.1.1.5.3.6 Fresh chinese egg noodles - bamee

Chinese egg noodles is basically eggs and flour, just like pasta. These egg noodles are not normal American wide egg noodles (with the see through egg on the package). They are freshly made and keep well in freezer for a long time. It is the size of angel hair pasta. In the old days it was made by pulling the dough until getting the desire thickness instead of by extrusion or cutting. Making the noodles by pulling the dough is a real skill.

2.1.1.5.3.7 Fresh rice sheet noodles

White, flat noodles made from rice flour steamed and lightly oiled before being packaged. In boiling water they get loosened and separate and used after draining. It shouldn't be stored in refrigerator. They will go hard and commonly used in soups and stir-fries.

2.1.1.5.3.8 Ramen noodles

Japanese wheat flour noodles usually with broth or sachet. Popular snack all over Japan and are sold in instant form, available also in fresh or dried, need to be cooked in boiling water for 2-5 min.

2.1.1.5.3.9 Shanghai noodles

They are thick, round egg noodles very similar to Hokkien noodles, but have not been cooked or oiled, sold package loosely and dusted with flour.

2.1.1.5.3.10 Soba noodles

They are made from buckwheat or wheat flour and sometimes flavoured with green tea powder. This is usually consumed by adding in soups or served cold with dipping sauces. These noodles are available either fresh or dried and need to be cooked in boiling water for about 5 min for consumption.

2.1.1.5.3.11 Somen noodles

Fine, white Japanese noodles made from wheat flour most are commonly eaten cold or sometimes with a little broth need to be cooked in boiling water for 2 min before consumption.

2.1.1.5.3.12 Udon noodles

White Japanese noodles made from wheat flour made in a variety of widths, both fresh and dried should be boiled for 1-2 minutes before use most often eaten in soups, but can also be served cold or braised dishes.

2.1.1.5.3.13 Wheat noodles

Available fresh and dried egg-free noodles are extremely versatile. These noodles need to be cooked for 2–4 min in boiling water and rinsed in cold water. Fresh noodles can be kept in refrigerated storage for up to 1 week.

2.1.1.5.3.14 Couscous

A convenient, versatile staple of North African diets. The tiny nuggets of durum-wheat semolina cook up light and fluffy. Complementing flavours from sweet to savoury, this couscous is incredibly versatile and ready to serve in 5 min.

2.1.1.5.3.15 Capellini

Thicker than angel hair pasta, this long, narrow pasta pairs well with thin tomato sauces and light vegetable ragouts. This is served with zesty sauce zingara, flavored with mushrooms, garlic, ham, and tarragon, finished with Madeira wine and chopped truffles.

2.1.1.5.3.16 Instant noodles

Momofuku Ando invented "Chicken Ramen TM," the world's first instant noodle product manufactured by Nissin Foods, Japan, in 1958 (Neelam et al. 2014). Another achievement was the introduction of cup noodles by Nissin in 1971. Instant noodles are made from wheat flour, starch, water, salt or kansui (an alkaline salt mixture of sodium carbonate, potassium carbonate, and sodium phosphate), and other ingredients that improve the texture and flavour of noodles, partially cooked by steaming and further cooked and dehydrated by a deep frying process (Kim, 1996a; Neelam et al. 2014).

2.1.1.5.3.16.1 Types of instant noodles

Instant noodles are classified into two types on the basis of methods used for the removal of moisture, i.e., instant dried noodles and instant fried noodles. Instant dried noodles are produced in a fully automatic production. The noodle after steaming is fed into a continuous drying chamber using hot air as the drying medium. In fried noodles after steaming it is then deep fried in oil. Frying the noodles in oil decreases the moisture content to 2–5%, whereas, in hot air dried noodles, it is about 8–12%. Both frying and drying facilitates rehydration process by cooking the noodles.

2.1.1.5.4 Quality parameters of noodles

Quality factors important for instant noodles are colour, flavor, texture, cooking quality, rehydration rates during final preparation, and absence of rancid taste after extended storage. Sensory evaluation of noodles is carried out to judge the quality and acceptability of the final product (Neelam et al. 2014)

2.1.1.5.4.1 Colour

A bright and light yellow color is desirable for instant noodles (Kim, 1996a; Kubomura, 1998). Hutchings (1977) described its major role in the total human perception of food. Due to problems with subjectivity and an overall lack of reproducibility, Instrumental colour measurements for quality grading are most often carried out in the food industry (Hunter, 1975). Colour is usually measured by spectrocolourimeter. Instrumental methods like HunterLab colorimeter in terms of L* (brightness or lightness), a* (redness), and b* (yellowness) color scale are also used for quality evaluation. Protein quality parameters also exhibit a significant relationship with b* value of instant noodles (Park and Baik, 2004b).

2.1.1.5.4.2 Texture

The texture of instant noodles should be rubbery, firm, or smooth (Kubomura, 1998). Sensory and instrumental methods are used for the evaluation of noodle texture (Oh et al.1983; Lee et al.1987; Hou et al. 1997). Textural parameters are smoothness, softness, hardness/firmness, stickiness, cohesiveness, elasticity, chewiness and gumminess (Konik et al. 1993; Byung-Kee et al. 1994; Yun et al. 1997). Instrumental measurement of cooked noodle texture is reliable, convenient and alternative to the sensory evaluation (Oh et al. 1983; Lee et al. 1987; Hou et al. 1997; Kovacs et al. 2004). The basic methods used are compression, including simple compression and texture profile analysis (TPA) and tensile tests. TPA provides a number of textural characteristics like chewiness, hardness or firmness, gumminess and cohesiveness in a single test and is similar to the chewing in mouth.

2.1.1.5.4.3 Cooking quality

Cooked instant noodles should have a relatively strong bite with a firm, smooth surface, and good mouth feel according to Hou (2001). Cooking quality of instant noodles is influenced by several factors, such as protein content (Matsuo et al. 1986), ash content (Okada, 1971), damaged starch, starch quality (Mestres et al. 1988), thickness of noodle strands, and frying conditions. Rehydration rate, cooking time, and cooking loss are the measure of cooking quality and ease of preparation. Protein content and amylase content correlate positively and negative, respectively, with the optimum cooking time of noodles (Park and Baik, 2004a).

2.1.1.5.5 Commercially available noodles in India

In India, noodles have come a long way since its introduction in 1983. It was manufactured by Nestle India Limited's Maggi noodles, which has been dominating the instant noodles market in India for nearly three decades. Due to ease of cooking, Maggi today is the predominant brand consumed in the Indian market. A number of new entrants such as Hindustan Unilever's (HUL) Knorr Soupy noodles, GlaxoSmithKline's Horlicks Foodles, Top Ramen and Big Bazaar's Tasty Treat, Sunfesat yippee are among the other predominant brands. Apart from this, local made Chinese noodles are also available in the market. Instant noodles brands constantly enhance their product offerings by adding new flavours including Indo-Chinese, Chinese, tomato, etc. have been launched.

2.2 Thermal processing

Thermal processing is a method of preserving food by heating in hermetically sealed containers to eliminate the microbial pathogen at a given temperature and specific time. The first recorded work reported on canning was by Nicholas Appert, where he packed food into wide mouth glass bottles, corked and heated and preserved them. However, it was in 1860, Louis Pasteur explained that the heating process killed (or inactivated) the microorganisms which extended the shelf-life of food.

2.2.1 Principles of thermal processing

Since the art of thermal processing was invented in 1809, it continued to be the most common sterilization method for microbial destruction in food preservation. The effect of heat on microorganisms and enzymes was investigated and explained by Louis Pasteur in1860. He found that both microorganisms and enzymes could be inactivated by heat in order to prolong the shelf life of food. His discoveries form the basis of pasteurization, which is still applicable in many areas such as the dairy and citrus industry.

Depending on the severity of the heat treatment and the purpose of the process, different thermal process regimes such as pasteurization and sterilization can be described (Lund, 1975). Pasteurization involves application of mild heat treatment with the purpose of inactivating enzymes and destroying spoilage vegetative microorganisms (bacteria, yeast, and molds) present in low-acid foods (pH<4.6). Alternatively, if the pH of the foods were high (pH>4.6) the main concern would be the destruction of pathogenic microorganisms of public health risk. Such process is referred to as commercial sterilization. It is carried out in combination with other external factors such as controlling the storage temperature and packaging environment for ensuring long-term safety.

2.2.2 Thermal processing and destruction kinetics

Inactivation of microbes by heat has been found to follow a logarithmic order. Using a kinetic approach the equation describing the logarithmic destruction has been derived. From the standpoint of food sterilization, bacteria may be considered dead if they have lost their ability to divide. The most possible explanation for this observation has been accepted as the one given by Rahn (1945), who stated that the loss of reproductive power of bacteria subjected to heat is due to the denaturation of one gene essential for reproduction. Acceptance of death of bacteria to be of logarithmic nature allows its mathematical description in the same way as a unimoleuclar or first order bimolecular chemical reaction. Unimolecular reaction involves only one substance, and its rate of decomposition is directly proportional to its concentration.

Traditionally, heat inactivation curves of both enzymes and microorganisms are found to follow first order decay kinetics. The common basic equation for studying reaction kinetic for inactivation or degradation of biological materials is generally given as:

$$-dC/dt = k_n c^n \qquad (1.00)$$

where C is the concentration of a reacting species at any time t, k_n, is the specific reaction rate, with units $[\text{concentration}]^{1-n}$ $[\text{time}]^{-1}$, and n is the order of the reaction. Many authors reported that heat inactivation of microorganisms, enzymes or quality factors can be satisfactorily described by the zero order (Equation 1.01), first order (Equation 1.02) or second order reaction models (Equation 1.03):

$$C = C_o - kt \qquad (1.01)$$

$$C = C_o \exp(-kt) \qquad (1.02)$$

$$1/C = 1/C_o + kt \qquad (1.03)$$

where C is the measured concentration of microorganisms, enzymes, or quality attributes, C_o the initial concentration, t the heating time and k the reaction rate constant (min^{-1}). If N_o stands for the initial number of cells like C_o and N represents number of surviving cells after treatment time t, then:

$$t = \frac{2.303}{k} \log \frac{N_o}{N} \qquad (1.04)$$

The time required to kill 90% of the initial cell population is the time required for the curve to pass one log cycle. Therefore if this time is taken as D, then the slope of the survivor curve can be represented as:

$$\frac{\log N_o - \log N}{D} = \frac{1}{D} \qquad (1.05)$$

Substituting in the general equation of a straight line gives,

$$\log N_o - \log N = \frac{1}{D} t \quad \text{Or} \quad D = -\frac{t}{\log N / No} \qquad (1.06)$$

where N is enzyme/microbial concentration at time *t*; N_o is initial concentration, "*t*" is the pasteurization/sterilization time and D is the decimal reduction time (the time to reduce 90% of enzyme or microbial concentration at a specific temperature).

In many cases, the Bigelow (TDT) model (Ball and Olson, 1957) is frequently employed especially in the microbiology studies.

$$D = \ln(10)/k \qquad (1.07)$$

$$D = D_{Tref} * 10^{(T\,ref - T)/z} \qquad (1.08)$$

where D is the decimal reduction time (time required for the concentration of microbial spores to be reduced by a factor of 10 at a given temperature, min), D_{Tref}, the decimal reduction time at reference temperature (min), T_{ref}, the reference temperature (^oC) and z, the z-value (number of degrees celsius required to reduce the D value by a factor of 10).

In thermal death time studies on spore suspension, the logarithmic survival curve is used to calculate this decimal reduction value. In reality, the criterion of process adequacy is based on the reduction of the bacterial population to a tolerable level. In low acid canned foods (pH<4.5) the organism of primary concern is the pathogenic anaerobe *Clostridium botulinum*. It has been established that the minimum safe heat process given to low-acid food should decrease the population by 12 logarithmic cycles (from an initial spore level of one spore per gram of food) the basis of the 12D concept or “Botulinum Cook”. The D value for *C. botulinum* is estimated as 0.21 min (1D at 121.1^oC) with a z-value of 10 ^oC.

2.2.4 Evaluation of thermal destruction rates

Two systems are used to evaluate the impact of temperature on the thermal destruction of food components: the D and z model (or, the TDT model), based on decimal reduction; and the Arrhenius model, which is based on thermodynamic concept of chemical reaction rate constant, which relate the reaction rate constant, activation energy and absolute temperature. The systems are of practical purposes equivalent. The D and z system has the advantage of allowing the direct calculation of accumulated lethality (F_o) of complex temperature histories. Clifcorn et al. (1950) reported that the destruction of bacteria increases tenfold for each 18 ^oF (10^oC) rise in temperature while the reaction rate responsible for quality deterioration is only doubled. However, this situation may pose a problem in optimizing the process since enzymes are also inactivated more slowly than microorganisms. Consequently, there is a possibility of having residual enzymatic activity, which by itself or by regeneration of the enzyme negatively influence the quality during storage. Lund (1977) has compiled, generalized and tabulated the thermal resistance of various food components. The table is presented in Appendix-1. Examination of these data conveys two points of great practical significance:

Nutrient and quality factors are upto six orders or more of magnitude more resistant to thermal destruction than spores and vegetative cells.

Nutrient and quality factors show markedly less temperature dependence than spores or cells.

These two features allow for the possibility of optimization of canned foods.

2.2.5 Heat penetration in foods in rigid containers

Numerous works have been carried on the aspects of heat penetration and process evaluation with respect to canned foods. The design of the required thermal process for a given food product is affected by how the heat is transferred to the product and inside the food. The heat transfer inside the package depends on the properties of the food system and on the filling (headspace). The heat transfer from the retort heating or cooling medium to the product (surface of the containers) is determined by the heating medium temperature and the heat transfer coefficient.

2.2.5.1 Measurement of heat penetration in rigid containers

An attempt to determine the temperature of the slowest heating part in canned food (called the cold spot) by placing a small maximum thermometer inside the can was made by Prescott and Underwood (1898). Bitting and Bitting (1917) were the first to use thermocouples for this purpose. Ecklund (1949) and Alstrand and Ecklund (1952) developed non-projecting, plug-in type thermocouples. They also described the fundamental techniques of heat penetration testing. Ball and Olson (1957) and Stumbo (1965) have compiled information on the basic heat penetration studies. Bee and Park (1978) have outlined the contemporary equipments and techniques of conducting heat penetration tests. Developments in heat penetration testing include elimination of conduction errors by thermocouples and wires, attachment to digital thermometers, using computers for retort control, and employing time-temperature integrators (TTIs) whose response can be related to their time-temperature history (Nott and Hall, 1999).

2.2.5.2 Factors influencing the rate of heat penetration

Various factors have been studied and shown to influence the rate of heat penetration into canned foods. The characteristics of the container, contents, retort, heating medium and mode, arrangement of cans inside the retort, steam distribution and all such factors have been studied (Balachandran, 2001). Some of the important works are as follows:

Prescott and Underwood (1898) observed that irrespective of the temperature of the retort, centre of the can reached the retort temperature in approximately the same time. Effect of processing temperature on the rate of heat penetration was studied by Duckwall (1905). Kochs and

Weimhausen (1906) gave detailed information on the effect of filling media on the rate of heat penetration in several canned food items. Ingredient related factors also affect heat penetration in cans, where fatty tissues are poor conductors of heat. Solids with gelling properties also absorb water and change solid liquid ratio thereby affecting heat transfer. Liquid and semi-liquid foods are mainly heated by convection while solid foods are heated by conduction. In semi-liquid products heating is by both convection and conduction implying a longer process time due to the slow rate of heat transfer (Clifcorn et al. 1950). Zavalla (1916) reported that the concentration of syrup seems to exert definite action on the rapidity of heat penetration. Penetration of heat into the cold spot of food is confronted by convective resistance, from heating medium to outer surface of the container and from inner surface to product, as well as the resistance of the packaging material. The internal resistance depends on the thermo physical properties, geometry and dimensions of the product (Silva et al. 1992). The mechanism of heat transfer through the container wall is by conduction. For metallic containers of normal thickness and thermal conductivity, there is no appreciable resistance to heat transfer. With regard to the heat transfer from the container wall into the product the mechanism largely depend on the consistency of the food. Foods behave differently during processing. However, increase in viscosity and presence of solid particles in semi liquids retard the rate of heating and make the process more complex. Consequently, semi-liquid products are heated by both convection and conduction implying a longer process time due to the slow rate of heat transfer. In such instances, movement of contents along the can wall is usually slow resulting in over cooking and scorching of the product (Clifcorn et al. 1950). In general the foods nearest to the can surface will sterilize before the food at slowest heating point. In canned solid foods heated by conduction, the slowest heating point is at the geometrical center of the can while in convection heating foods; the cold point is below the centre of the can. To ensure that adequate sterilization is achieved, sufficient time must be allowed for the cold point to reach the desired temperature and lethality.

2.2.6 Thermal process evaluation

The basic objective of process calculation procedure is to establish the time at a reference temperature that will result in the reduction of a hypothetical population of spores to some small (although infinite) value. Assuming that an end point of reduction to an assumed population of spores can be established, the calculation process is then one of determining the combination of time and temperature necessary to accomplish that objective, given the heating characteristics of the product and the thermal inactivation characteristics of the spores in the product. When these calculations are made, specific values of parameters that characterize the product with respect to heating response and heating inactivation are necessary. These values then must be determined experimentally (Lund, 1978). Many works have been done in the area of process evaluation and these have been reviewed critically. The two well-established techniques for evaluating thermal processes are the *in situ* approach and the physical-mathematical method. In the *in situ* method, changes in the actual quality or safety attribute are determined before and after processing to have a reliable estimate on the status of the attribute of interest. On practical ground, however, measurement of microbial counts, texture, and vitamin content and organoleptic quality by *in situ* method is usually slow, costly and sometimes unfeasible due to detection limit or sampling difficulties.

2.2.6.1 Fo-value

In the physical-mathematical method, the time-temperature profile is integrated to evaluate the impact of a thermal treatment on the parameter of interest. The exercise is carried out either to determine the F-value for a given process time or to calculate the process time for a given F-value. F-value is defined as the number of minutes at a specific temperature required to destroy a specific number of organisms having a specific z value. The required information is the time-temperature history of the product at the slowest heating point and the "f_h" and "j" values. The calculation requires solution of the basic integral equation of Fo or its Arrhenius counterpart.

$$F_o = \int_0^t 10^{(T - Tref)/z} dt \qquad (1.09)$$

$$F_o = \int_0^t e^{2.303(T - Tref)/z} dt \qquad (1.10)$$

Lethality (F-value) is a measure of the heat treatment or sterilization processes. To compare the relative sterilizing capacities of heat processes, a unit of lethality needs to be established. For convenience, this is defined as an equivalent heating of 1 min at a reference temperature, which is usually taken to be 121 °C for the sterilization processes. Thus the F value would represent a certain multiple or fraction of the D-value depending on the type of the microorganism.

2.2.6.2 Cook value

Another closely related parameter for evaluating a thermal process impact on food is the cook value. Cook value is the measure of heat treatment with respect to nutrient degradation and textural changes that occur during processing. Hersom and Hulland (1980) defined it as a "food quality related heating effect that results from 100^o C for one minute". It is given by

$$C = \int_0^t 10^{(T - Tref)/z_c} dt \qquad (1.11)$$

where T_{ref} is the reference temperature of 100 ^oC and z_c is usually taken as 33 ^oC, which is the thermal destruction rate for quality factors analogous to z-factor for microbial inactivation. Similar equation has been developed for pasteurization value but with a different reference temperature and z value.

2.2.6.3 Heating and cooling rate indices (f_h, f_c, j_{ch}, and j_{cc})

These indices are considered as prerequisite tools for proper calculation of process time. They can be evaluated from the temperature-time profile. It has been shown that when the logarithm of the temperature difference between the retort and the product center known as temperature deficit (T_r –T) during heating is plotted against time on a linear scale, a straight line is obtained after the initial lag. The intercept is obtained by extending the straight line portion of the curve to the y axis representing T_{pih} such that

$$T_r - T_{pih} = j_{ch}(T_r - T_o) .$$

Or

$$j_{ch} = \frac{T_r - T_{pih}}{T_r - T_o} \qquad (1.12)$$

where j_{ch} is the heating lag factor, which is a measure of the thermal lag (or delay) of the beginning of uniform heating in the product. The corresponding value during the cooling period is j_{cc} and is given by

$$j_{cc} = \frac{T_{pic} - T_w}{T_{ic} - T_w} \qquad (1.13)$$

Part of the lag is due to the slow come-up time of the retort and this is accounted for by determining the new zero time for the process. Ball and Olson (1957) used 58% of the come-up time as useful contribution to the process and this is widely accepted (Holdsworth, 1997). This implies that 42% of the come-up time should be added to the process time at retort temperature. The slope of the line is given by the tangent of the angle between the line and the t-axis, which represents time for the curve to traverse one log cycle. The negative reciprocal of this slope for the heating part is referred to heating rate index (f_h) and the corresponding value for the cooling period is the cooling rate index (f_c). f_h is an indicator to the heating rate. The higher this value the longer it takes for the line to traverse one log cycle indicating slow rate of heat penetration.

2.2.6.4 Process time determination by formula method

The starting point of all formula methods is a formula which gives the temperature of the food as an explicit function of time. The Ball formula method is the simplest and also the most widely used (Stoforos, 1995). Using formula methods for process time is also considerably faster than using the general method. It is also versatile in that it can be used to determine both the process time and lethality of a given thermal process, whichever is the one to be determined.

The data recorded by the data-logging system were fed to and analyzed using a computer. The heat penetration data were plotted on an inverted semi log paper with product temperature (PT) on vertical log scale against time on the linear horizontal scale as described in NCA manual (1968). Lag factor for heating (J_{ch}), slope of the heating curve (f_h), time in minutes for sterilization at retort temperature (U) and lag factor for cooling (J_{cc}) were determined. Cooling curve was plotted and cooling process parameters were determined as described by Ramaswamy and Singh (1997). The process time was calculated by mathematical method described by Ball and Olson (1957). Actual process time is determined by adding process time (B) and the effective heating period during come-up time i.e. 42% of the come up time.

$$B = f_h \times \log (j_{ch} \cdot I / g_c) \qquad 1.14$$

$$T_p = B - (0.42 \times t_c) \qquad 1.15$$

$$T_B = B + (0.58 \times t_c) \qquad 1.16$$

It is based on the equation-1.14 established on the heat penetration curve the parameters described previously. This formula gives the Ball Process Time (B), which is inclusive of the effective come-up time. To determine the Operator's Process Time (T_p), this effective come-up time is to be subtracted as shown in equation 1.15. To arrive at the total process time (T_B), 58% of the come-up time is added to the ball process time (Equation-1.16). Operator's process time is the time interval measured from the time the retort or autoclave reaches the design process temperature to the time steam is turned off. Total process time is measured from the time of steam-on to the time of steam-off.

Stumbo formula method is essentially similar to the Ball formula method except that it is somewhat more versatile in accounting for the thermal effects of cooling when the cooling lag factor (j_{cc}) differs from equation- 1.41 as assumed by Ball. The results obtained by the Stumbo's formula are found to show better agreement with the ones obtained by the General method of calculation than the ones from Ball's formula method.

2.2.7 Optimization of thermal processing

Where safety is a desired effect of the thermal process, quality degradation is an undesired aspect. The objective of extending shelf life of foods through thermal processing is to make available a varied diet that provides adequate nutrients. Thus the process ultimately used should meet two criteria. It must accomplish the process objective from a microbial or enzymatic standpoint and, it should yield a maximum retention of nutrients. For commercial sterilization, optimization is not as easy as that for blanching or pasteurization. The mode of heating becomes an important factor. For those products that heat by convection, the high temperature short time processes may result in optimum nutrient retention. But a proper account of heat resistant enzymes should be taken in these products. The process may be adequate for destroying the microbes but not for these enzymes.

For the convection heating products, an assumption is made that solids in liquid receive the same lethal treatment as the liquid. The assumption is valid when the food particulates are sterile in the center and have a large heat transfer coefficients. In conduction heating products, each point in the cross section of the container receives a different thermal process than every other point, and the process is based on the slowest heating point. At the conclusion of heating and the start of cooling, a complexity arises since the slowest heating point continues to heat for a significant period. In this situation, the overall lethality for the process is the integrated effect of the heat treatment at every point in the container. The methods developed for the optimization are time consuming and apply only to conduction heating foods. Teixiera et al. (1969) have given one of the most widely used models of time-temperature treatments that provide equal microbial lethality and retention of nutrients with different z values. If the product receives sufficient mixing or when processed in scraped surface heat exchangers, the HTST technique can be applied. When optimization is to be applied for conduction heating products heated in classical heating techniques, the slow heating towards the interior of the product will result in surface quality degradation. In such cases the optimal temperature will depend on a number of factors including the heating rate of the product (the lower the heating rate of the product the lower the optimal temperature) and the temperature sensitivity the quality index (the less temperature sensitive the quality attribute, the higher the optimal temperature) (Silva et al. 1992). Optimal sterilization processes leading to a maximization of overall quality retention have been calculated using systematic search procedures, graphical optimization, and mathematical optimization techniques. A critical review of mathematical methods available to optimize heat sterilization of prepackaged foods is presented by Silva et al. (1993). The use of variable retort temperature (VRT) profiles to improve mass average quality retention has been investigated (Teixeira et al. 1975; Bhowmik and Hayakawa, 1983; Banga et al. 1991). It was concluded that optimal constant retort temperature (CRT) profiles are as good as optimal VRT profiles when the optimization of the overall quality is of concern, but VRT profiles show some advantages to minimize the processing time and the surface quality retention.

2.2.8 Effect of thermal processing on quality parameters

2.2.8.1 Biochemical changes

Thermal processing also increases the digestibility of foods by breaking down poorly digestible carbohydrates and proteins. Legumes are a good example of foods that demonstrate markedly improved digestibility with cooking (Liener, 1989). Digestive proteases and amylases produced in the human gastrointestinal tract cannot efficiently digest most raw foods. Heating partially denatures proteins, gelatinizes starches and softens cell walls allowing digestive enzymes better access to the food components. Heidelbaugh and Karel (1970) reported the quality changes in pouched foods. Probably this was the earliest report on the retortable pouches. Severe heat treatment and the presence of certain catalysts in the fish muscle favours lipid oxidation and hydrolysis resulting in off flavors and loss of nutrients (Hsieh and Kinsella, 1989: Harris and Tall, 1994). Aubourg et al. (1990) reported a general reduction in lipid content of canned and cooked samples. A significant increase in FFA and phospholipid was noticed during canning, while during storage both decreased. A decrease in TBA value, TMA and vitamin B1 (thiamin) for shrimp, rainbow trout and Alaska Pollock (Chia et al. 1983) and a decrease in the TMA-O content of squids (Kolodziejska et al. 1994) after heat processing, have been reported.

2.2.8.2 Texture

A major challenge facing food developers is how to accurately and objectively measure texture and mouth-feel. Texture is related to a number of physical properties. (e.g., viscosity and elasticity), and the relationship is complex. A general agreement has been reached on the definition of texture, which evolved from the efforts of a number of researchers. It states that ‘‘texture is the sensory and functional manifestation of the structural, mechanical and surface properties of foods detected through the senses of vision, hearing, touch and kinesthetic’’ (Szczesniak, 2002). Instrumental Texture Analysis is a multi parameter attribute, and the sensations involved are classified into different categories so as to have a proper description of texture. The classification of textural terms for solids and semi-solids gave rise to a profiling method of texture description (TPA) applicable to both sensory and instrumental measurements. Instrumental methods can give mechanical instrumental results. These are those attributes of food manifested by the reaction of the food to stress (Szczesniak, 1963). These include among others, hardness (force required to bite through), cohesiveness (deformation of the sample by the teeth before breaking), and springiness (rate at which a deformed food piece returns to its undeformed shape). The mechanical process of mastication has been simulated using Texture Profile Analysis (TPA). This objective method measures the compression force of a probe and the related textural parameters of a test food during two cycles of deformation. The TPA of various food stuffs including fruits, vegetables, bakery and meat products have been reported. Aitken and Connell (1979) reported that unless supported by sensory texture evaluations, instrumental methods are of limited use, and are of value only to processors and researchers for studying textural changes. With the sensory method, the evaluation includes several steps outside and inside the mouth, from the first bite through mastication, swallowing and residual feel in the mouth and throat. With the instrumental method, texture profiling involves compressing the test substance at least twice and quantifying the mechanical parameters from the recorded force-deformation curves. Its use is based on standard scales for the mechanical parameters (Szczesniak et al. 1963), which are also employed for selecting and training of panel members

2.2.8.3 Colour

Colour is a very important quality factor in thermally processed products, since it influences consumer acceptability. There are many reactions that can take place during thermal processing that affect colour. Among them, the most common are pigment degradation, and browning reactions such as the Maillard reaction (Mauron, 1981). Tarr (1952) reported a brown discolouration in white-fleshed fish upon heating. Moss (1971) distinguished different ways in quality of noodles. First, the whiteness or brightness of the dried noodle decreases with increasing protein level. Second, the color varies with textural changes during boiling and quality may be affected by the quality of the wheat from which they are prepared. As protein content increases, the eating quality becomes more attractive, yet the colour becomes more objectionable (Baik et al. 1994).

2.2.8.4 Sensory analysis

Objective of sensory testing is to measure the intrinsic sensory attributes of a sample through the analytic sensory perceptions of human assessors. The overall quality of seafood is comprised of both wholesomeness and sensory acceptability by the consumer (Sikorski and Sun Pan, 1994). The wholesomeness is affected by chemical and microbial factor where as sensory factors are determined by flavor and texture (Sawyer et al. 1988). Sensory analyses of fish and fishery products have always been a part of the production process (York and Sereda, 1994). Flavour development during heating involves the Maillard browning reactions, fatty acid oxidation and the formation of low molecular weight volatile compounds like ammonia and hydrogen sulfide. It involves inter and intra molecular cyclization, and reaction between intermediate products also. During the heating of meat, numerous volatile compounds are formed that contribute to the meaty flavour. Measurement of sensory properties of different types of fishery products was reviewed by different authors (Connell and Shewan, 1980; York and Sereda, 1994). Cooked instant noodles should have a relatively strong bite with a firm, smooth surface, and good mouthfeel (Hou, 2001).

2.3 Containers for packaging of thermal processed products

2.3.1 Rigid containers

2.3.1.1 Metal cans

Metal cans were first developed in the early 19th century. As with many technological advances, their development was hastened by military necessity; in this case Napoleon's interest in preserving foods for lengthy campaigns. In the years following the Napoleonic wars, can making begin in earnest in England and the first USA canning operation opened in 1819. Following the success of Nicholas Appert, “glass bottles” were extensively used in the early days of canning. Although the tin containers have been used from ancient times, it was in 1810 a patent for its use as a container for packing foods obtained by Peter Durand in England. The tin plate metal containers were called “canisters” from which the term ‘can’ is believed to have derived. Each container has certain exclusive uses; in the course of development we can see that one container is invading other fields. The selection of one container over the other is usually decided on the basis of process and product, cost of production etc. Today there are several choices are available i.e. Standard tin plates, light weight tin plate, double reduced tin plate, tin free steel and vacuum deposited aluminium on steel and aluminum. For food products packing they are coated inside to get desirable properties like acid resistance and sulphur resistance. But care has to be taken to avoid tainting of the lacquer.

2.3.1.2 Tin cans

Most frequently used container for packing food for canning is tin plate can. Tin plate containers made their appearance in 1810. The tin can is made of about 98% steel and 2% tin coating on either side. The base steel used for making cans is referred as CMQ or can making quality steel. Corrosion behavior, strength and durability of the tin plate depend upon the chemical composition of the steel base. The active elements are principally copper and phosphorous. The more of these elements present the greater the corrosiveness of steel. Depending upon the degree of workability, strength and corrosion resistance required in the case of tin plates four types of steel are specified. They are type L, type MR, type MC and type M. First three are produced by cold reduction process. Type M is similar to type MC in composition but produced by hot reduction process.

2.3.1.3 Aluminium cans

The organoleptic qualities of foods packed in tin containers gradually decreased when they are kept for longer periods. This led to the introduction of another important container, the aluminium alloy can. Aluminium containers were used for packing meat and fish products as early as 1918. These are now being used extensively in European countries because of the availability of the raw material and less cost for its production due to plenty of electricity in those countries.

2.3.1.4 Tin-free steel cans

This was developed in Japan under different names such as Can super, Hinac coat, Hi-top by different manufactures. They are prepared by electroplating cold roller steel sheet with chromium in chromic acid. TFS is an important alternative to tin can. TFS has a steel base with a chromium/chromium oxide coating on the surface replacing tin in conventional cans.

2.3.1.5 Glass containers

Glass containers have been used for many centuries and still are one of the important in food packaging. Due to its certain properties, glass has its unique place in food packaging. It is strong, rigid and chemically inert. It does not appreciably deteriorate with age and is an excellent barrier to solids, liquids and gases, and gives excellent protection against odour and flavor contamination. The transparency of glass provides product visibility. Glass can also be moulded to variety of shapes and sizes. But it has disadvantages like fragility, photo oxidation, heavier in weight etc. Glass containers include bottles, jars, tumblers and jugs.

2.3.2 Semi-rigid containers

Semi rigid plastic containers are thermoformed containers which are economical and offer convenience to the user. The containers are thin in profile and three dimensional in shape with a filling volume. The filling volume varies depending on the size and use of the container. The containers are produced by cold forming by using a vacuum forming die and compressed air (Conley and Cornmann, 1975). The heat setting fixes the shapes and can also facilitate sealing of the filled containers. The original semi rigid containers were made of aluminium coated on the interior with polypropylene films. The disadvantage of aluminium was that it was easily prone to denting. The plastic containers developed in the 1980's were laminates of polypropylene/EVOH or PVDC/polypropylene. The widely used high barrier retortable plastic containers consist of polypropylene or polyester/ PVDC or EVOH/polypropylene. Total thickness of these containers may be about 2 mm. Thermoformed containers can be made into various shapes and sizes and can be handled without the fear of breakage as in the case of glass. This makes it possible for convenient handling and built in safety. The plastics are light in weight, stable, can be combined with other materials and resistance to chemical attack. They are also recyclable and some energy can be recovered from the disposed material (Brown, 1992).

The major advantages of the trays over other rigid and flexible containers as per Hoddinott, 1975 are as follows

- Easy to open and cheap and economical
- High barrier properties and wide variety of shape and sizes
- Vacuum filling and gas flushing possible
- Easy to fill and use and transport
- The flat form helps in quick retorting
- Large surface area can be used for advertising
- Faster heat penetration rate during retorting due to the thin profiles
- Microwave-ovenable

Physical properties required for semi rigid containers as per Long (1962)

- Oxygen transmission rate less than 1cc/100 inch^2/24hrs /1atm

- Water vapour transmission rate less than 0.05 g/100 m^2/ 24hrs / 90±2% RH/ 37°C
- Temperature resistance from 32ºF to 25ºF
- Low hydrophilic properties
- Low cost of material and production cost
- Heat sealability over a wide temperature range
- Should meet FDA standards
- Resistant to penetration of oil, fat or other foods component.
- Dimension stability and chemical inertness, with no tendency to impart objectionable odour or flavor to foods.
- Physical strength to resist any handling abuse.
- Consumer appeal; transparency (or opaqueness, depending on product) gloss, agreeable feel.
- Capability of being handled on automatic fabrication and filling equipment.
- Good ageing properties.
- Good printability.

2.3.3 Opaque and see through retort pouch

The concept of pouch as a container was developed by the US Army Natick Laboratories and a consortium of food packaging companies in the early 1960s (Herbert and Betteson, 1987). The technical and commercial feasibility of using retort pouches for thermo-processed products have been proven by (Hu et al. 1955). In 1967, Chinese dumplings and curry were packed in aluminum foil containing retortable pouches and marketed. In the year 1968-69 commercialization of curry in foil free and aluminum foil containing pouches were undertaken and this started the era of retort pouches in Japan (Tsutsumi, 1972). The boil in bag concept of warming the food before consumption gives an edge for pouches over cans (Arya, 2001). Retort pouched products are shelf stable ready to eat products which can be used as per the convenience of the consumer (Rangarao, 2002). The most comprehensive work on flexible packaging for thermal processed foods was prepared by Lampi (1977). Heat sterilized low acid solid foods in pouches created a new segment within the canned foods category (Brody, 2003). Sara et al. (1989) studied the effect of increased over pressure levels, entrapped air and temperature on the heat penetration rates in flexible packages. Sacharow, (2003) did market studies in USA and Europe and reported a bright future for retortable pouches.

2.3.4 Thermoforming

Thermoforming is a generic term encompassing many techniques for producing useful plastic articles from flat sheet. Thermoforming is simply the manual dropping of a temporary soften sheet over a simple mould shape. For thermoformed trays, polyvinyl chloride (PVC), high impact polystyrene (HIPS) and high density polythene (HDPE) are mostly used. Thermoformed trays can be produced from a variety of materials including both single thickness and laminated structures. Thermoforming offers processing advantages over competitive processes such as blow molding, rotational molding and injection molding. Relatively low forming pressures are needed and so mold costs are low and parts of relatively large size can be economically fabricated. Parts with very small thickness-to-area ratio can be fabricated. For thin wall parts, fabrication time is extremely short, making the process very economical for many parts. Since the molds see relatively low forces, molds can be made of relatively inexpensive materials and mold fabrication is very short. Thus lead time is very short. Thermoforming is the method most usually selected for prototype and display parts to be made by other processes. There are basically three types of thermoforming namely, vacuum forming, pressure forming and matched mould forming.

2.3.4.1 Different types of thermoforming

2.3.4.1.1 Vacuum forming

In its simplest form, vacuum forming equipment consists of a vacuum box with an air outlet and a clamping frame, a mould, a heating panel and a vacuum pump. The mould, which is partly hollow underneath and is perforated, is placed over the air outlet. The thermoplastics sheet is then placed over the open top of the vacuum box and securely clamped by means of frame giving an airtight compartment. The sheet is heated until rubbery, the heater is withdrawn, and the air in the box is rapidly evacuated by the vacuum pump. Atmospheric pressure above the sheet forces it down into close contact with the mould where it is cooled sufficiently to retain its shape. The clamping frame is then released, the formed sheet is removed from the mould, and the excess material trimmed off. The sequence is shown in Figure-4(Gopal et al. 2007).

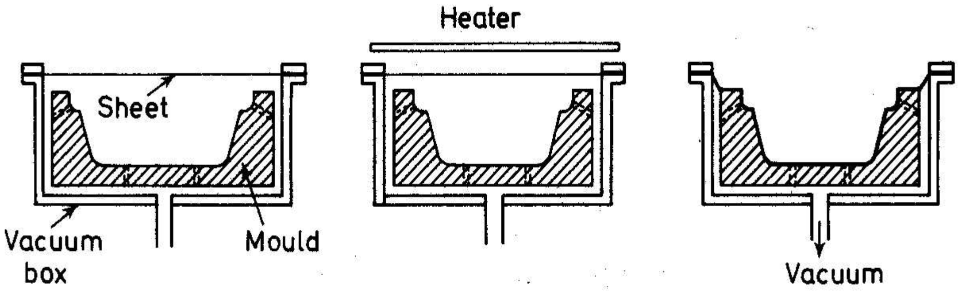


Figure-4. Vacuum forming sequence

2.3.4.1.2 Drape forming

Here the mould is mounted on a piston within the vacuum box. The piston rises and pushes the mould into the heat softened sheet, immediately prior to the vacuum being applied. This gives a certain amount of pre-forming and so lessens thinning of the sheet at the corners of the mould Figure-5.

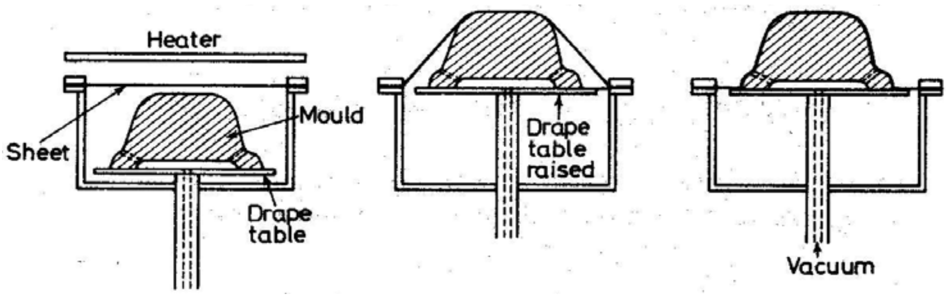


Figure-5. Drape forming sequence

2.3.3.1.3 Pressure forming

Similar to vacuum forming with the exception that a positive air pressure is applied to the top surface of the sheet. As in vacuum forming, this has the effect of forcing the heat softened sheet into contact with the mould. The main advantage is that the pressure on the sheet can be greater than in the case of vacuum forming which is of course, limited to atmospheric pressure. Pressure forming thus gives reproduction of mould detail (Gopal et al. 2007).

2.3.4.1.4 Matched die moulding

The heated sheet is formed into shape by trapping it between matched male and female moulds. The mould detail as one would expect, is even better using this technique but it is more expensive in tooling costs and the mould halves have to be made to tight tolerances.

Only the HDPE and PP trays offer a reasonable water barrier whilst only the PVC and PS trays offer reasonable oxygen barriers. As in the case of flexible materials, the properties of trays can be tailored, to some extent, by using composite materials. Laminates such as PVC/Polythene and Polystyrene/Polythene are used to produce trays having improved water barrier, sealability and strength, compared with trays made from non-laminated PVC and PS sheeting. Trays are also available, made from co-extruded structures containing an ethylene/vinyl alcohol layer, which provides improved oxygen barrier characteristics. For the packaging of battered and breaded fish products conventional packaging materials like flexible plastic films alone are not suitable for these products as they provide little mechanical protection to the products and as a result the products get damaged or broken during handling and transportation. Hence thermoformed containers are commonly used for this purpose

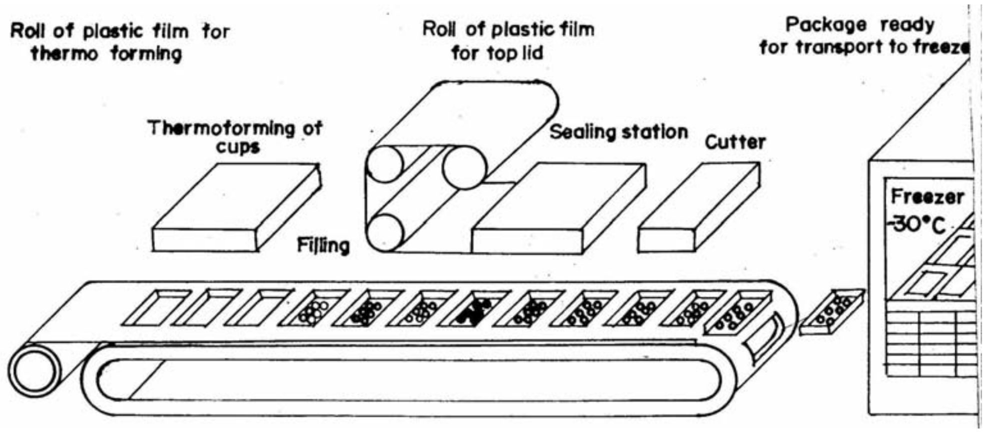


Figure-6. Schematic diagram for thermoformed tray packaging

2.3.4.2 Lids for thermoformed containers

High barrier Lidding material is also available for top sealing of the trays. They can be used for single or multi compartment plastic trays and can be used for protection of ready to eat, thermal processed meals. The outer polyester layer and the metallic layer can be used for printing. Easy to open lids and closures are available in the market (Gerald, 1978)

2.4 Thermal process operation of food in retortable trays

2.4.1 Filling

The filling operations are to be very carefully done to avoid contamination of the heat seal area. Both volumetric and gravimetric filling can be done by the nozzles and controlling the dosage automatically. Correct positioning of the trays on the filling line and sealing station should be maintained.

2.4.2 Vacuumisation or air removal

The air and gases present inside the container is removed by applying vacuum. This is made effective by using a vacuum sealing machine, wherein the air is removed and simultaneously the lid is sealed on to the container. The removal air is necessary to counter the internal pressure developed in the container due to the heating and expansion of the gases and to ensure a uniform heat transfer during retorting. In addition to vaccumisation steam flushing can also be done to remove the air, hot steam displaces the air inside the container.

2.4.3 Sealing

There are two methods of sealing; hot bar sealing method and thermal impulse sealing method. In the hot bar sealing, a constant temperature, resistance heated metal bar sealing against a rubber fixture helps in sealing.

Thermal impulse sealing, the seal areas are held together by a pair of jaws, heated to fusion temperature by short electrical impulses and simultaneous cooling under pressure is done .The main problems with impulse sealing are wrinkles to the top film, seal contamination and imperfect surface due to impulse sealing.

2.4.4 Retorting

Retorting is done in over pressure autoclave which may be a steam air or steam water mixture retort. Counter air or pressure is used to counter balance the internal package pressure and seal integrity (Yamaguchi et al. 1972).

2.4.5 Cooling

Cooling is done within the retort itself by pumping in chill water and at the same time maintaining the pressure. Once the product is sufficiently cooled it is removed with the help of trolleys or pulleys

2.4.6 Racking or stacking

The containers are then wiped clean, checked for any deformation, seal integrity and labelled and packed. They are then stacked before final inspection and distribution.

2.5 Migration of constituents

A number of resins and adhesives are used during the manufacture or lamination of the different layers of the containers. The overall migration in the containers into the food may be higher at 121.1°C or higher temperatures when the food is retorted. Different materials have different solvents and conditions for extraction of stimulants into solvents to pass the criteria of being used as a material for thermoform containers(Gopal et al. 2007). .

Physical properties: The containers should be heat sealable, retain its shape and dimensions after retorting. It should not loose the material inertness and barrier properties which were originally present in the container.

All plastics, apart from the basic polymeric resin, usually contain several components (additives or adjuvants) either present as impurities or deliberately added for, in ppm to several percent. The final processed plastics is a somewhat different material compared to the virgin polymer and it is only natural to expect that it is the finished plastic material that needs to be evaluated by end tests. To minimise the risk factor due to transfer of polymer additives and also to restrict the ingress of non-nutritive substances into the food, the need for the formulation of guidelines for proper use of plastics for food packaging applications has been realized all over the world, and in view of the increasing use of plastics in food contact applications, guidelines are necessary to curb the indiscriminate use or abuse of plastics. Basically, regulations on food packaging materials comprise:

- Regulations for adjuvants (antioxidants, colourants, plasticisers etc.) used in food packaging materials.
- Specification for the basic polymeric resin used.
- Extractive limits for the final food contact article.

Therefore, a plastic material intended for food contact application must be of food grade, which means that only resins conforming to relevant specifications and only permitted adjuvants must be used in the manufacture of packaging material. For testing the maximum estimated daily intake, ideally, migration tests for adjuvant transfer into foods should be conducted with each type of food in a given package under normal conditions used for an expected contact of time. However, apart from being economically prohibitive, this type of evaluation with actual foods is analytically difficult because of their complex nature. Further, the duration involved makes long-term tests with foodstuffs impractical. Accordingly, special extracting liquids, called food-simulating liquids have been recommended to be used in place of actual foodstuffs. Extraction experiments are conducted which are known as migration tests. Global migration considers the total amount of the adjuvants migrating while specific migration is concerned with specific adjuvant. The global migration tests are mandatorily prescribed in the specifications of all countries in food packaging materials. Global migration tests are important to test the compliance of a food packaging material to the extractive limits called Global Migration Limits in relevant specification. All plastic materials intended for food contact applications need to be first evaluated by migration tests before subjecting to shelf life studies etc. The global migration limits should be 60 ppm or 10 mg/dm^2 as prescribed by Bureau of Indian Standards (BIS, India), British Plastic Federation (BPF, UK) and 50 ppm in case of Food and Drug Administration (FDA, USA) standards for all polymers for which specifications are available.

Chapter 3

OPTIMISATION OF PHYSICAL PROPERTIES OF READY TO COOK FISH INCORPORATED NOODLES USING RESPONSE SURFACE METHODOLOGY

Contents

3.1 Introduction

Noodles are traditional ready to cook food product, which originated in China and gradually spread into other Asian countries. Nowadays, noodles having a special place in global food market due to various formulations for handmade noodles from China along with advanced processing techniques from Japan and other countries. Hatcher (2010) and Hou (2001) suggested that globalization of this food was mainly due the improvement of quality and processing of noodles. In Asia, major ingredients used for manufacturing of noodles are rice, buckwheat and starches derived from the mung bean and potato etc. (Fu, 2008). Whereas, basic ingredients for wheat based noodles were flour, water and salt. Fish protein is considered as a good source of lysine with high biological value (Balachandran, 2001). Moreover, cereal flours contain high amount of carbohydrate and lower protein content (Bent, 1986). Hence, a combination of fish meat and cereal was used for the preparation of noodles for enhancing its nutritional quality. Several studies have conducted for developing high protein rich extrudate from various sources i.e., live-stocks, microbial cells and oil seeds etc. (Binoy et al. 1996; Suknark et al. 1998; Choudhury et al. 1998; Prabhasankar et al. 2009; Choo and Aziz, 2010; Kruger et al. 1998).

Extrusion is a promising technology in food, feed and polymer industry. It is a multivariable unit operation in which raw materials undergoes various operations like mixing, shearing, cooking, puffing and drying in one energy efficient rapid continuous process. Product characteristics of extrudates made from cereal flour depend on the physicochemical changes that take place by the effect of extrusion variables (Pansawat et al. 2008). Banerjee and Chakraborty (1998) reported that the ingredients used for the production of extrudates were strongly affected its physical properties. Effects of extrusion variables on structural changes and product properties of starchy materials have been reported (Kadan, et al. 2003; Sacchetti et al. 2004; Titus and Glory, 2011). Research on different combination of ingredients for the preparation of noodles was conducted by several authors, like Panlasigui et al. (1992) who studied the effect of starch digestibility and glycemic response of extruded rice noodles, Development of nutrient rich noodles by supplementation with malted ragi flour was studied by Kulkarni et al. (2012). Texture of sweet potato starch noodles were studied by Seung-Young, et al. (2005). Consumer acceptability of a novel extrusion-cooked salmon snack was reported by Kong et al. (2008).

Response Surface Methodology (RSM) is a statistical tool for modelling and optimization of multiple responses for predicting the best performance conditions with a minimum number of experiments (Giovanni, 1983). RSM has been used for many years in physical sciences and the objective was to optimize the output variables (response) which was influenced by several input variables (independent variables) by careful design of experiments. Thakur and Saxena (2000) used RSM for the optimization of ingredient levels for the formulation of extruded snack. Effect on extrusion conditions like barrel temperature, screw speed, moisture and fish flour on the physical properties of extruded ready-to-eat snacks were standardized using RSM (Ratankumar et al. 2014).

3.2 Objective of the study

The present study was conducted to find a suitable combination of fish mince and refined wheat flour to optimize the process parameters and determine the changes on physical properties of ready to cook fish incorporated noodles by RSM.

3.3 Materials and Methods

3.3.1 Raw material

Fresh pink perch (*Nemipterus japonicus*) obtained from the landing centre at Thoppumpady were brought to the laboratory in iced condition was used for the study.

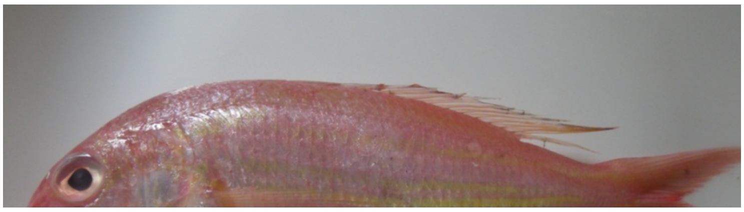


Plate-3. Pink perch (*Nemipterus japonicus*) used in the study

3.3.1.1 Mince production

The fish was washed in potable water and dressed. Dressing involves heading, gutting, scaling and removal of fins. The dressed fish were washed with potable water and drained. It was then fed into the mincing machine manually. The flesh is separated by rotating perforated drum and belt assembly using meat bone separator (Model SF-6, Safe World Enterprises (M), SDN, BDH, Malaysia). The fishes get squeezed between the drum and belt and the meat comes out. The meat collected in trays, weighed and packed in LDPE bags were used for the study.

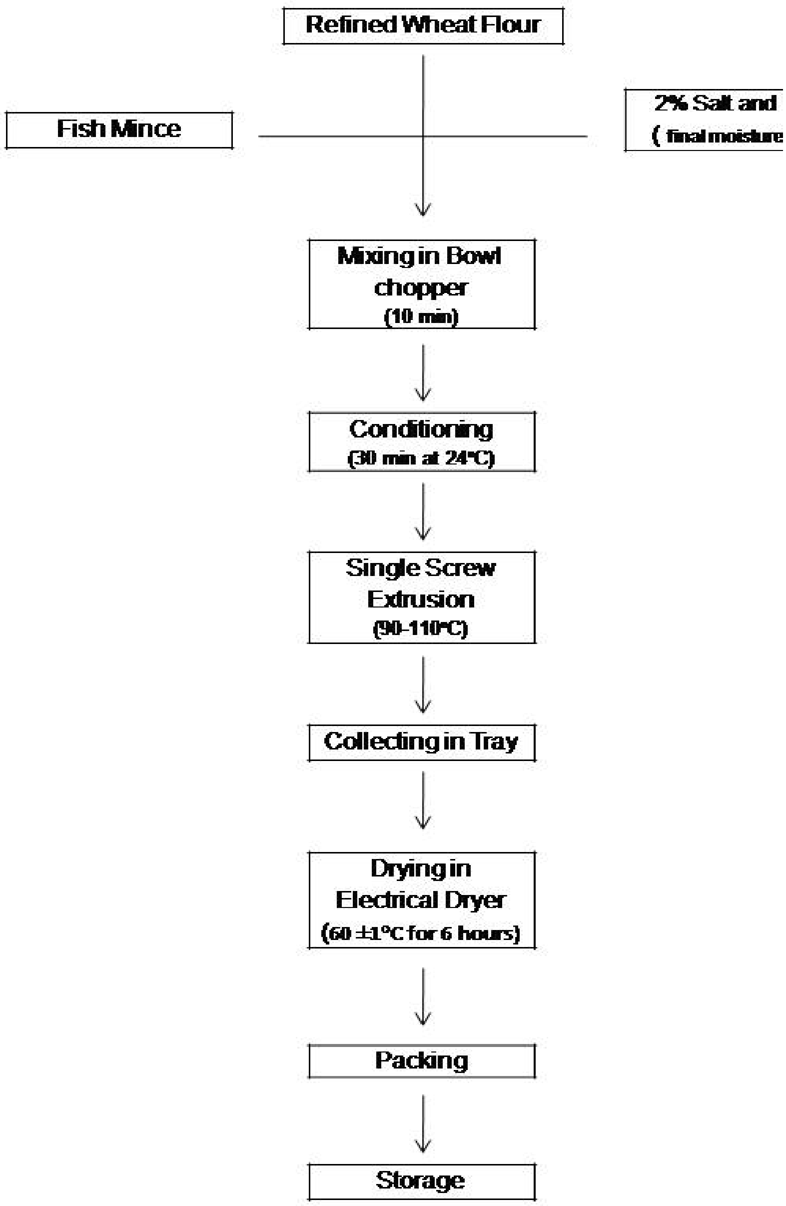
3.3.2 Refined wheat flour (maida)

Branded maida named Elite maida manufactured by M/s Yamuna Roller Flour Mills Pvt. Ltd., was used for the preparation of noodles.

3.3.3 Preparation of fish noodles

Flow chart for the production of fish noodles is represented (Flow chart -1). Fish mince in the ratio of 5%, 10%, 15% and 20% were incorporated with maida in the ratio of 95%, 90%, 85% and 80%. The mixture containing the ingredients was mixed in a bowel chopper along with 2% salt and moisture was adjusted to 30% by the addition of water. The mixed dough was transferred into a tray and kept at air conditioned room maintained 24 °C for 30 min for conditioning. Control was also prepared without fish mince.

For extrusion, single screw extruder with noodle die of 1.5 mm diameter was used. The dough was fed into the feeding hopper at 200 g/min manually. The screw speed was 60 revolutions per minute (RPM). Initially to attain temperature inside the barrel, extrudate were collected and fed into the hopper, till the barrel temperature attained a temperature of minimum of 90°C. When the temperature is attained inside the barrel, collection of the noodles is carried out in a steel tray. It was then transferred into an electrical drier maintained at 60°C and dried for 6 hours. Noodles prepared without fish mince was kept as control. Products obtained were used for the preparation of ready to eat fish noodles.



Flow chart -1 for the production of extruded noodles

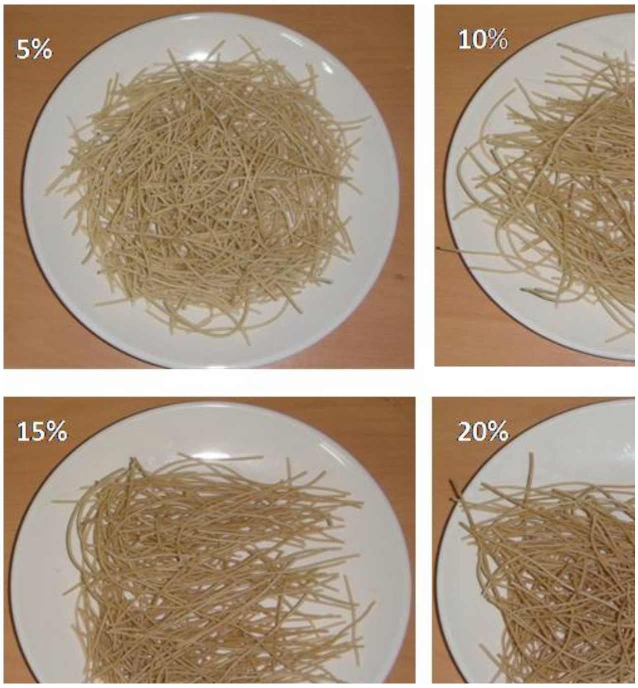


Plate-4. Fish noodles with increasing concentration of fish mince

3.3.4 Machineries and accessories

3.3.4.1 Single screw extruder

The extrusion equipment consisted of a single screw (G.L. Extrusion Systems Pvt. Ltd., KHSRA No. Rz172/12, Durga Park. New Delhi, India) with a noodle die of 1.5 mm diameter. The L/D ratio of the extruder barrel was 5.1 with 100 rpm screw speed. The length of the screw was 380 mm with a helical angle of 42.1º. The fish maida mixture was fed into the extruder manually at a feed rate of 200 g/min, extruded at a temperature ranging from 90-110 ºC.

Plate-5. Single screw extruder used for the study

3.3.4.2 Die

The die of the noodle is made of Teflon. In a single die there are three holes symmetrically arranged in the centre of the die. The diameter of the orifice is 0.15 cm. The dies are held in a metal casing. Dies are inserted into the metal casing and fitted into the barrel prior to extrusion.

Plate-6. Die used for the extrusion of noodles

3.3.4.3 Electrical dryer

The electrical dryer supplied by G. L. Extrusion Systems Pvt. Ltd., KHSRA No. Rz172/12, Durga Park, New Delhi, India was used to dry the noodles. The dryer has a capacity of 100 kg. The equipment can be operated as continues as well as batch.

Plate-7. Electrical dryer for drying the extruded noodles

3.3.4.4 Bowl chopper

Mixing of the ingredients were done in a bowl chopper (Mado Garent, Type MTK 661, Maschinfabrik Dornhan, D-72175-Dorhan)

Plate-8. Bowl chopper for mixing the ingredients

3.3.5 Proximate composition

3.3.5.1 Determination of moisture

A known weight of the sample (10g) was weighed in a pre-weighed clean petridish on an electronic balance. Dishes were placed in hot air oven at 100 ± 1°C for 16 hours, cooled in a desiccator and weighed. This was repeated until a constant weight was obtained and moisture content was calculated and expressed as percentage (AOAC, 2000).

3.3.5.2 Determination of ash content

About 1-2 g of the moisture free sample was transferred into a pre-heated, cooled and weighed silica dish and the sample was carbonized by burning at low red heat and was placed in a muffle furnace at 550°C for about 4 hours until a grey / white ash was obtained (AOAC, 2000). It was then cooled in desiccators, weighed, and percentage of ash was calculated.

3.3.5.3 Determination of crude fat

Crude fat content was analyzed as per AOAC (2000). About 2-3 g of accurately weighed moisture free sample was taken in a thimble plugged with cotton. The extraction thimble was placed in the extraction unit of soxhlet apparatus with an attached receiving flask (previously weighed) and petroleum ether (40-60^{0}C boiling point) was poured washing into the thimble through a glass funnel. Connected the extraction unit and receiving flask to the soxhlet condenser. The flask was heated on a boiling water bath. Extraction was continued at a condensation rate of 5-6 drops per second, till the solvent in the extraction unit becomes clear (10 h). After completing the extraction the flask was removed, dried in an air-oven maintained at 100±1°C and weighed. The crude fat was calculated and expressed as percentage.

3.3.5.4 Determination of crude protein

Crude protein content was analyzed by digesting and distillating the sample (AOAC, 2000). About 0.5-1 g of the moisture free fish sample was transferred into a Kjeldahl flask of 100 ml capacity. A few glass beads and a pinch of digestion mixture (K_2SO_4: $CuSO_4$ (8:1)) and 20 ml concentrated sulphuric acid were added. It was digested over a heating coil until the solution turned colourless. To the digested and cooled solution distilled water was added in small quantities with intermittent shaking and cooling until the addition of water did not generate heat. It was transferred quantitatively into a 100 ml standard flask and made up to the volume. About 2-5 ml of the made-up solution was transferred to the reaction chamber of the Micro-Kjeldahl distillation apparatus. 5 ml sodium hydroxide (40%) and two drops of phenolphthalein indicator were added and washed with distilled water. Distillation was carried out and the ammonia liberated was collected in a 100 ml conical flask containing 10 ml 2 % boric acid with few drops of Tashiro's indicator. Distillation was continued for 4 min once the solution turns from pink to green colour and the amount of ammonia liberated was determined by titrating with 0.01N standard sulphuric acid. Crude protein content was calculated by multiplying total nitrogen content with conversion factor of 6.25 and expressed as percentage.

3.3.6 Determination of volatile base compounds

3.3.6.1 Preparation of trichloro acetic acid (TCA) extract

About 10g of accurately weighed homogenized sample was extracted thrice with 10 % trichloroacetic acid (TCA) by grinding in a mortar and pestle. The content as filtered quantitatively through Whatman Filter paper No.1. Filter paper was thoroughly washed with TCA and filtrate was made up to 100 ml. This extract was used to measure total volatile base nitrogen and trimethyl amine nitrogen.

3.3.6.2 Determination of total volatile base nitrogen (TVB-N)

Total volatile base nitrogen (TVB-N) of the sample was determined by micro diffusion method (Conway, 1950). 1 ml of standard N/100 sulphuric acid was taken in the inner chamber of the diffusion unit. To the outer chamber 1 ml of TCA extract was added and the glass lid applied with vacuum grease was covered over it, leaving a small space. Through this space 1ml of saturated potassium carbonate was added and the unit was sealed immediately with the glass lid, rotated slowly to mix the contents and kept undisturbed overnight. The amount of unreacted acid in the inner chamber was determined by titrating against standard N/100 sodium hydroxide using Tashiro's indictor. Similarly a blank was also run using

10% TCA instead of sample extract. TVB-N was calculated and expressed as mg N_2 100 g^{-1} of the sample.

3.3.6.3 Determination of tri-methyl amine-nitrogen (TMA-N)

TMA was determined as trimethyl amine nitrogen (TMA-N) by the micro diffusion method (Conway, 1950). 1 ml of standard N/100 sulphuric acid was added in the inner chamber of the diffusion unit. To the outer chamber 1 ml of TCA extract was added followed by 1 ml neutralized formaldehyde. This was kept for 3 min to ensure the binding of formaldehyde with all the primary and secondary amines and ammonia contained in the extract. To this, 1ml saturated potassium carbonate was added and the analysis was further carried out as explained in TVB-N determination. TMA-N was calculated and expressed as mg $N_2$100 g^{-1} of the sample.

3.3.7 Lipid oxidation-hydrolysis products

3.3.7.1 Determination of thiobarbituric acid (TBA) value

About 10 g of homogenized fish sample was mixed with 100 ml 0.2 N HCl and homogenized to slurry. This slurry was then poured in to a round bottom flask and connected to the TBA distillation apparatus. Distillation was done to collect 50 ml of the distillate within 10 minutes. 5 ml of the distillate was taken in a test tube and 5 ml of TBA reagent (0.288g TBA reagent in 100 ml acetic acid and heated gently to dissolve) was added and heated in boiling water for 35 min. A blank was carried out with distilled water. Colour developed was measured in a spectrophotometer at 538 nm and TBA value was determined as described by Tarladgis et al. (1960) and expressed as mg malonaldehyde kg^{-1} of fish sample.

3.3.7.2 Preparation of chloroform extract for free fatty acid (FFA)

About 10 g of the homogenized fish sample was taken into a mortar and mixed with anhydrous sodium sulphate to remove the moisture content. It was transferred to an iodine flask and to this 100 ml of chloroform was added, mixed well and kept under dark for overnight. Chloroform extract was filtered into another iodine flask and 20 ml was taken in a small beaker to find out the amount of fat present in it.

3.3.7.3 Analysis of free fatty acid (FFA)

For this, 20 ml of chloroform extract was taken in a conical flask and placed on the water bath to evaporate chloroform completely. To this 10 ml of neutralized alcohol(few drops of phenolphthalein indicator was added to the absolute alcohol and to that 1N NaOH was added till it turns slightly pinkish) and kept on water bath for few minutes to dissolve the fat. It was cooled and titrated with 0.01 N NaOH using phenolphthalein indicator till it turns slightly pinkish and FFA was calculated and expressed as mg % oleic acid (AOCS, 1989).

3.3.8 Measurement of physical properties of noodles

3.3.8.1 pH measurement

About 5 g of the sample was dispensed in 10ml of distilled water and pH was measured by using pH meter according to APHA (1998).

3.3.8.2 Texture profile analysis (TPA)

Texture profile analysis was measured with a Universal Testing Machine (Lloyd instruments LRX plus, UK) with a cylindrical probe of 10mm diameter. The load cell used was of 50 N capacity, 12mm/min. speed, with a trigger force of 0.05 kgf/mm. It consisted of two compressions of the product with the product being compressed to 40% of the initial size. Hardness, cohesiveness, adhesiveness, springiness and other parameters were calculated using the Nexygen software (Bourne, 1982).

Plate-9. Texture Analyser

3.3.8.3 Shear strength (SS)

The Warner-Bratzler shear stress was measured by Universal Testing Machine (Lloyd instruments LRX plus, UK) using a 90° blade of 1mm thickness. The speed of the blade was 500mm/min with a load cell of 100N. The peak force divided by the cross sectional area of the noodles to obtain the shear values (Gogoi et al. 1996).

3.3.8.4 Determination of bulk density (BD)

250ml acid washed sand was taken in a measuring cylinder and then placed on the vibrating apparatus. The contents were left to vibrate for 5 minutes and transferred into a petridish and noted the weight. Similarly, 180-190 ml of extruded product was taken in a measuring cylinder and made up the volume to 250 ml by using the previously weighed acid wash sand. It was then vibrated so as to avoid void space between the contents and sand was added simultaneously to maintain the amount. Weight was noted after transferring into a petri plate. The weight of the petri plate along with the sand and extruded product was recorded. The difference in weight between the petri plates filled with sand plus extrudate and with only sand was used to determine the volume displaced by the extrudate pieces. The bulk density was expressed as the ratio of the weight of pieces to their volume in g/cc (Anon, 1998).

3.3.8.5 Determination of water absorption index (WAI)

1.5 g sample was taken and transferred in to a plastic centrifuge tube. 25 ml distilled water was added and with a glass rod, stir for 1 minute and kept for 10 minutes and the process was continued 2 to 3 times. After 45 minutes it was then centrifuged for 25 minutes at 3500 rpm. The water was decanted and the remaining water is removed by using a filter paper. After removal of complete water weight of material was done. Water absorption was calculated as gain in weight to that of weight of sample expressed in percentage (Sosulusky, 1962).

3.3.8.6 Determination of sorption characteristics

To study the influence of moisture on the product, the humidity moisture relationship was studied at ambient temperature. Noodles were powdered and sieved in standard test sieves and humidity moisture relationship was studies at ambient temperature (27-30°C) by exposing weighed quantities of the sample to different relative humidity ranging from 12% to 94% in desiccators using appropriate salt solutions (Rockland, 1960). Triplicate samples were periodically weighed and the gain/loss in weight of samples was noted till they attained equilibrium moisture content. Equilibrium moisture content was calculated based on the equation mentioned below. Graphs are plotted on graph paper with Relative Humidity on X-axis and equilibrium moisture content on Y-axis. Critical moisture was determined by the development of mould growth.

$$\text{Equilibrium moisture content} = \frac{\text{Initial moisture content} \times \text{Weight of the sample} \pm 100\ (\text{gain / loss in weight of sample})}{\text{Initial weight} \pm \text{gain / loss of weight}}$$

Table-1 showing the saturated salt solution and their relative humidity

Salt	Relative Humidity (%)
Lithium chloride	12%
Potassium acetate	20%
Magnesium chloride	32%
Potassium carbonate	38%
Sodium dichromate	53%
Sodium nitrite	64%
Sodium chloride	75%
Ammonium sulphate	80%
Potassium nitrate	94%

3.3.9 Cooking characteristics

3.3.9.1 Estimation of cooking time (CT)

To determine the cooking time, 10 g of noodles were dipped in 500 ml of boiling distilled water and cooked till the disappearance of white core, as judged by squeezing between two-glass slides (Kawaljit et al. 2010).

3.3.9.2 Determination of cooking loss (CL)

25 g of noodles were cut into 5 cm length and put into 250 ml boiling water in a beaker. They were stirred gently with a glass rod. After cooking for 10 min, noodles were filtered. The beaker, noodles and the mesh used for straining were washed with distilled water and collected. The filtrate is drained off till constant weight and computed according to Li and Chang (1981) and expressed in percentage.

3.3.9.3 Rehydration capacity (RT)

3 g of noodles were placed in strainer dipped in 250 ml of boiling water in a beaker. It was then cooked for 1 to 11 min. The noodles were washed with water at room temperature 4 to 5 times. The water was removed by filtering through Whatman number 1 filter paper. The rehydration ratio was calculated as weight of cooked noodles divided by weight of noodles before cooking (Von-Loesecke, 1945).

3.3.10 Colour measurement

The Hunter Lab MiniScan® XP Plus spectro colorimeter, model No D/8-S (Hunter Associates Laboratory Inc., Reston, VA, USA) with geometry of diffuse 80 (Sphere-8 mm view) and an illuminant of D 65 optical sensor and 100 standard observer was used to measure instrumental colour. The colour values were expressed using the standard CIE L*, a*, b* system. The colour values are expressed using the standard CIE L*a*b* system. L*, a* and b* values (non dimensional units) refer to the three axis of the system: a lightness axis (white 100 – black 0; L*) and two axes representing hue and chroma, (a*) one red (positive)-green (negative) and the other (b*) blue-yellow. This system provides an unambiguous description of colour and has the advantage that colour differences between samples can be determined using simple computer programs. The sample to be measured is placed in a circular transparent holder with zero refractive index and measured by moving the bottom of the sample holder to all sides.

Plate-10. Hunterlab colour measurement device

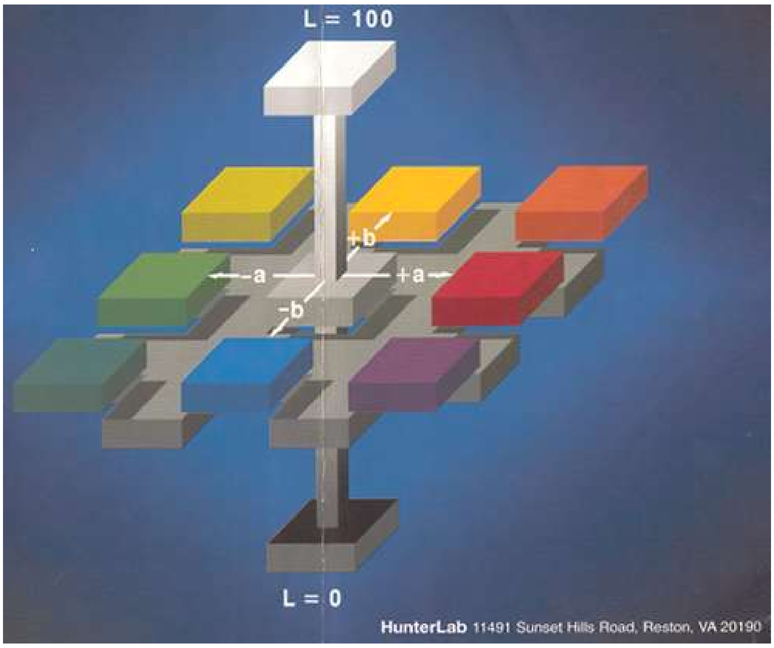


Plate-11. Hunterlab colour chart

3.3.11 Enumeration of total plate count

10 g of the sample was weighed aseptically into a sterile sample dish and transferred into a sterile polythene pouch and soaked in 90 ml normal saline for 15 minutes, after which it was blended in a stomacher blender (Stomacher 400 Circulator) for 60 seconds at normal speed. Using a sterile pipette, 1 ml of the supernatant was aseptically transferred into a 9 ml saline tube and mixed well using Vortex mixer. Similarly further dilutions were prepared for the inoculation.

1 ml each of the appropriate dilutions was pipetted to appropriately marked sterile petridishes taken in duplicates for each dilution. About 15-18 ml of molten plate count agar medium cooled to 45 °C, was poured to each plate, mixed well with the inoculum and allowed to set for 30 min. The plates were incubated at 37 °C for 48 hours in an inverted position. After the incubation period, the individual bacterial colonies were counted. The average counts of the triplicates were taken and the counts were calculated as cfu/g of the sample (Hitching et al. 1995).

3.3.12 Sensory analysis

Sensory characteristic of the thermally processed noodles were evaluated by trained taste panel member on a ten-point scale (IS: 6273 [II], 1971). Scores were assigned with 1 being the least and 10 being the greatest for attributes described by Vijayan (1984). A sensory score of 4 was taken as the limit of acceptability. The characteristics covered under the taste panel were colour, odour, flavour, taste, texture, and overall acceptability.

3.3.13 Chemicals used

The chemicals used were of AR grade, from the manufacturers of Merck and Qualigens.

3.3.14 Glassware used

The glasswares manufactured by Borosil were used for the study.

3.3.15 Experimental design using response surface methodology

D-optimal mixture experimental design with 9 runs was formulated to optimize the different levels of fish mince (ie., 5, 10, 15 and 20 %) and refined wheat flour (ie., 95, 90, 85, and 80 %). The experimental data on water absorption index, bulk density, colour (L*, a* and b* values), cooking time, cooking loss, rehydration test, shear strength and sensory analysis were generated to fit linear, quadratic and cubic response surface mixture models of the form given in equation 1, 2 and 3, respectively. Desirability function score was computed for multiple responses and the level at which fish mince and wheat flour produced highest function score was considered as optimum combination. A validation study was also carried out at optimum level of fish mince and wheat flour and measured the physical properties of the fish noodles. The model was fitted using Design Expert 7.1.5.

Linear: $y = \sum_{i=1}^{q} \beta_i x_i + e$ (1)

Quadratic: $= y = \sum_{i=1}^{q} \beta_i x_i + \sum_{i<j=2}^{q} \sum \beta_{ij} x_i x_j + e$ (2)

Cubic: $y = \sum_{i=1}^{q} \beta_i x_i + \sum_{i<j=2}^{q} \sum \beta_{ij} x_i x_j + \sum_{i<j=2}^{q} \sum \delta_{ij} x_i x_j (x_i - x_j) + e$ (3)

Where y is the response and $x_i = 0, \frac{1}{m}, \frac{2}{m}, \cdots\cdots, 1,\ \ i = 1, 2, \cdots\cdots, q$ (components x_1 and x_2), β_i is linear regression coefficient, β_{ij} is quadratic regression coefficient, δ_{ij} is cubic regression coefficient and e is error term.

3.4 Results and Discussion

3.4.1 Characteristics of pink perch

The mean weight and length of the fish are presented in Table-2. The weight of fish ranged between 156-406g. The length of the fish ranged from 19-32 cm, respectively. The length and weight of pink perch observed was similar to the report of Joshi (2010) caught off Cochin. The yield after dressing was 55.36%. The yield of mince from the whole fish was 40.23%. The yield of mince from the dressed fish was 72.65% (Table-3). Muraleedharan et al. (1996) reported the yield of mince from different species in Indian water to vary from 27% in *Tachysurus spp*. to 56% in *Saurida tumbil*.

Table-2. Weight and length of pink perch

Weight (g)	285.67 $\pm$ 92.60
Total length (cm)	26.22 $\pm$ 4.44

Table-3. Yield of fish mince from pink perch

Stages	Weight (kg)	Yield (%)
Fish weight	34.61	-- --
Dressed	19.16	55.36
Mince	13.92	40.23
Yield of mince to dressed fish		72.65

3.4.2 Proximate composition of pink perch

Table-4. Proximate Composition of Pink perch

Paramters (%)	Whole fish (Wet Weight Basis)	Fish mince (Wet Weight Basis)
Moisture	78.67 ± 0.32	80.57±0.37
Crude Protein	18.58 ± 0.30	16.56±0.29
Crude Lipid	1.49 ± 0.04	1.36±0.06
Ash	1.26 ± 0.005	1.51±0.02

The proximate composition of the fish and mince are represented in Table-4**.** Fresh fish had moisture content of 78.67%, crude protein 18.58%, crude fat 1.49% and ash content of 1.26%. Minced meat had a moisture content of 80.57%, crude protein of 16.56%, crude fat of 1.36% and ash content of 1.51%. Parvathy et al. (2014) reported similar result in *N. japonicus* mince for the production of surumi.

3.4.3 Biochemical and microbiological characteristics of pink perch meat

The freshness of the fish assessed by biochemical and microbiological parameters are given in Table-5. The pH of the fish was 6.03 which indicated that fish is a low acid food. Nitrogenous compounds like TVB-N and TMA, and lipid quality parameters like free fatty acid and TBA determined are presented in the Table-5. Result indicated that all the parameter was within the prescribed limit indicating the freshness of fish used in the study. Ramesh et al. (2013) reported an initial value of 6.10 mg% of total volatile nitrogen and trimethylamine nitrogen of 0.88 mg% for surumi prepared from Japanese threadfin bream meat.

Table -5. Biochemical and microbial count of pink perch

Sl No.	Parameter	Value
1	pH	6.03±0.03
3	TBA (mg malonaldehyde/kg)	0.60±.01
4	TVB-N(mg N/100g)	15.97±0.4
5	TMA (mg N/100g)	2.91±0.05
6	FFA (% oleic acid)	0.19±0.04
7	Total Plate Count (cfu/g)	$5x10^4$

3.4.4 Proximate composition of refined wheat flour

Table -6. Proximate composition of refined wheat flour

Paramters (%)	Flour Wet Weight Basis
Moisture	10.55 ± 0.03
Crude Protein	8.85 ± 0.25
Ash	0.52 ± 0.01
Crude Fat	0.73±0.03
Carbohydrate	79.35 ± 0.27

Table-6 shows the proximate composition of refined wheat flour used in the study. The moisture content of the flour was 10.55%. The flour had a protein content of 8.85%. Ash content was 0.52%. Fat content was 0.73%. The protein content of wheat grains may vary between 10%-18% of the total dry matter. Cereal grains store energy in the form of starch. The amount of starch contained in a wheat grain varies between 60% and 75% of the total dry weight of the grain. The moisture of cereal grains usually ranged between 11-14%. The second important constituents is the proteins which fall within an average range of about 8-11%; whereas, minerals accounts1-3% (Souci et al. 2008; Belitz et al. 2009). Alais and Linden (1991) reported proximate of 12% moisture, 10.6% crude protein, 1.4% ash and 69.7% of available carbohydrate in wheat. Morrison (1978) reported a crude fat of 0.75-2.2% in endosperm of wheat grain.

3.4.5 Proximate composition of fish incorporated noodles

Control (without fish mince) sample had the least moisture content of 5.56%. As the percentage of fish mince increased, there was an increase in the moisture content from 6.42% for 5% fish mince incorporated noodles to 7.18%, 8.72% and 8.86% for 10, 15, 20% fish mince incorporated noodles (Table-7). The protein content also increased from 9.51% for control to 14.36%, 19.61%, 21.87% and 25.24% for 5, 10, 15 and 20% fish mince incorporated noodles. Increase in the moisture content and protein content was also reported by Dileep et al. (2010) in extruded product prepared from ribbon fish of varying concentration and rice flour. Fat content was 0.49% for 5% fish mince incorporated noodles. It slightly increased to 0.52%, 0.74% and 0.83% for 10, 15 and 20% fish mince added noodles. Control had an ash content of 0.43%. There was an increase in the ash content of 0.92% for control to 0.99%, 1.02% and 1.21% for 5%, 10%, 15% and 20% fish mince incorporated fish noodles. The increase in the ash content could be due to the bones present during the mincing operation. Homchoudhury et al. (2011) reported a protein content of 23.06%, moisture 6.87% and lipid content of 0.9% in extruded product prepared from rice and 20% shrimp.

Table-7. Proximate composition of fish noodles prepared from varying percentage of fish mince

Noodles	Moisture (%)	Protein (%)	Fat (%)	Ash (%)	Carbohydrate
Control	5.56±0.1	9.51±0.06	0.21±.02	0.43±0.01	84.27±0.06
5% fish mince noodles	6.42±0.2	14.36±0.02	0.49±0.06	0.92±0.01	77.81±0.08
10% fish mince noodles	7.18±0.1	19.61±0.01	0.52±0.02	0.99±0.03	71.70±0.06
15% fish mince noodles	8.72±0.09	21.87±0.02	0.74±0.02	1.02±0.01	67.65±0.05
20% fish mince noodles	8.86±0.05	25.24±0.01	0.83±0.04	1.21±0.02	63.86±0.03

3.4.6 Optimisation of physical properties of ready to cook fish incorporated noodles using response surface methodology

Effect of different level of pink perch mince on the physical properties like water absorption Index, bulk density, colour values, cooking time, cooking loss, rehydration capacity, shearing strength and sensory score were presented in Table-8 and 9.

Table-8. Experimental design and output for WAI, BD, CT, CL, RT and SS

Runs	Fish Mince (%)	Flour (%)	Water Adsorption Index	Bulk Density (%)	Cooking Time (min)	Cooking Loss (%)	Rehydration Capacity (%)	Shearing Strength (N)
1	5	95	1.78	3.7	7.1	1.56	3.65	5.66
2	10	90	1.53	3.69	7.3	0.98	4.39	8.88
3	15	85	1.36	3.62	7.2	1.21	3.53	8.03
4	20	80	1.01	2.88	7.4	1.11	3.12	3.88
5	0	100	1.92	3.72	7	1.47	3.59	3.19
6	0	100	1.91	3.72	7	1.45	3.51	3.2
7	20	80	1.03	2.89	7.4	1.1	3.11	3.81
8	0	100	1.93	3.73	7	1.47	3.55	3.21
9	10	90	1.49	3.66	7.3	0.99	4.33	8.55

Table-9. Experimental design for colour and sensory evaluation

Runs	Fish Mince (%)	Flour (%)	L* value	a* value	b* value	Sensory Analysis
1	5	95	81.54	1.19	13.87	8.6
2	10	90	80.36	1.32	14.59	8.7
3	15	85	79.98	1.38	16.25	8.8
4	20	80	77.39	2.38	18.77	8.3
5	0	100	82.19	1.03	12.88	8.6
6	0	100	82.16	1.05	12.59	8.6
7	20	80	77.36	2.35	18.66	8.3
8	0	100	82.19	1.03	12.69	8.6
9	10	90	80.36	1.33	14.63	8.7

Table-10. Regression coefficients of fitted model with R^2 values

Response	Fitted Model	A-Fish mince	B-Flour	A*B	AB(A-B) A^2B-AB^2	R^2
Water Absorption Indexl	Quadratic	-0.079703	0.019215	6.78545E-004	-	0.9927
Bulk Density	Cubic	-3.57270	0.037274	0.058128	2.25432E-004	0.9920
L*value	Quadratic	-0.039776	0.821450	7.86964E-003	-	0.9764
a*value	Cubic	4.95591	0.010296	-0.079889	-3.14940E-004	0.9898
b*value	Cubic	7.20676	0.12729	-0.10953	-4.13180E-004	0.9981
Cooking Time	Linear	0.089454	0.070175	-	-	0.8750
Cooking Loss	Linear	-5.91340E-003	0.014406	-	-	0.5346
Rehydration Capacity	Quadratic	-0.63966	0.035152	8.16719E-003	-	0.7905
Shearing Strength	Cubic	-23.63280	0.031700	0.37840	1.37000E-003	0.9903
Sensory	Cubic	-3.50134	0.086033	0.058623	2.32787E-004	0.9791

3.4.6.1 Changes in water absorption index (WAI) in fish incorporated noodles

The water absorption index of extruded products from refined wheat flour with varying percentage of fish mince given in Figure-7. Quadratic model was found suitable to explain the effect of percentage of fish mince on WAI with an R^2 value of 0.99 (Table-10). WAI indicates the part of starch that was not affected by the extrusion process and maintained its internal structure (Mason and Hoseney 1986). Gomez and Aguilera (1983) suggested that WAI depends on the availability of hydrophilic groups and on the capacity of gel formation of the macromolecule. There was a significant reduction of WAI of noodles with increase in percentage of fish mince. This could be due to the decrease in starch content and denaturation of protein during extrusion and drying (Anon, 1998). Water absorption for noodle is affected by protein content, protein quality, damaged starch, and other physical properties of flour (Park and Baik, 2002). Park et al. (1993) reported an increased WAI of final extrudates because of the higher content of corn starch. Clayton and Miscorides (1992) found that starch molecules contribute for water absorption index. However, gelatinized starch molecule may not contribute significantly for the water absorption in the extruded products (Anon, 1998). WAI of control sample was 1.92%; whereas at 5, 10, 15 and 20% fish mince incorporated noodles showed a value of 1.78, 1.53, 1.36 and 1.03%, respectively.

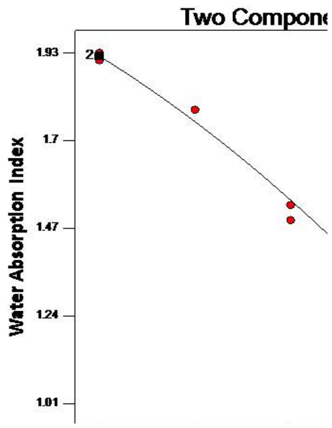


Figure 7. Changes in WAI of extrudates as a function of fish-flour combination

3.4.6.2 Changes in bulk density (BD) in fish incorporated noodles

The bulk density of extruded products from refined wheat flour with varying percentage of fish mince given in Figure-8. Cubic model was fitted to the experimental data on changes in BD of noodles with respect to varying concentration of fish mince and wheat flour with a coefficient of determination of 0.99 (Table-10). There was slight reduction of BD in control, 5, 10 and 15% fish mince incorporated noodles; whereas, drastic reduction of BD was observed for 20% fish mince incorporated noodles (Figure-8). Bulk density is the ratio of mass of extrudates to the apparent volume of a specific container. Hence, it directly influences the storage space of manufacturing unit and shipping containers (Guy, 2001). Case et al. (1992) suggested that reduction of bulk density of the extrudates was due to the enhancement of gelatinisation. Suknark et al. (1998) found that BD in extrudates varied due to the screw speed, which produces smaller diameter extrudates with increased length and volume. Reduction of starch content as the percentage of fish mince increased mainly accounted for the reduction of bulk density of the product. Clayton and Miscourides (1992) reported that protein content in fish encloses available starch and causes limiting the expansion of product. Bulk density of control and 20% fish mince incorporated noodles was 3.73 and 2.89 g/cc, respectively.

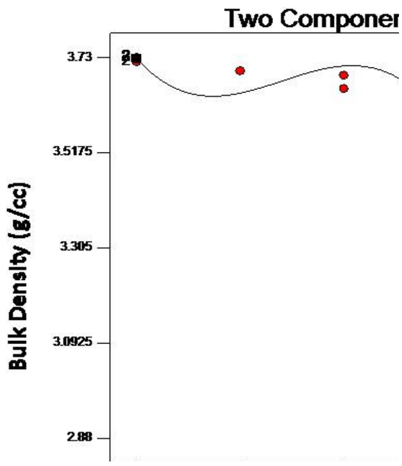


Figure 8. Changes in BD of extrudates as a function of fish-flour combination

3.4.6.3 Changes in colour values in fish incorporated noodles

The colour values of extruded products from refined wheat flour with varying percentage of fish mince is given in Figure-9, 10 and 11. Colour is one of the most important quality parameters of the noodles determining the acceptability. Quadratic model (R^2 = 0.98) was fitted to explain the changes of lightness (L* value) of the noodles with respect to changes in the fish mince and wheat flour (Table-10). Figure-9 clearly depicts that L* value of the samples was significantly reduced with respect to increase in the percentage of fish mince. Decrease in the lightness of extruded cereal based fish products may be due to the Maillard browning reaction. Lightness of control sample was 82.2, which reduced to 77.3 in 20% fish mince incorporated noodles. Yun et al. (1997) suggested that protein and ash content causes significant changes in the colour of noodle. Cubic model was fitted with an R^2 value of 0.9898 and 0.9981 for the changes of redness (a*value) and yellowness (b*value) of the noodles with respect to changes in the concentration of fish mince and refined wheat flour (Table-10). It was found that yellowness and redness of noodles enhanced with percentage of fish mince (Figure 10 and 11). Increase in the redness may be due to the presence of careteniod pigment in fish mince (Skrede and Storebakken, 1986). Factors affecting the colour of fish incorporated food were fish carotenoid pigments (ie., astaxanthin and canthaxanthin), water content, raw ingredients and processing conditions etc. (Hutchings, 1999). Redness of control and 20% fish mince incorporated noodles was 1.03 and 2.38, respectively; whereas, yellowness showed a value of 12.88 and 18.77 for control and 20% fish mince incorporated noodles, respectively.

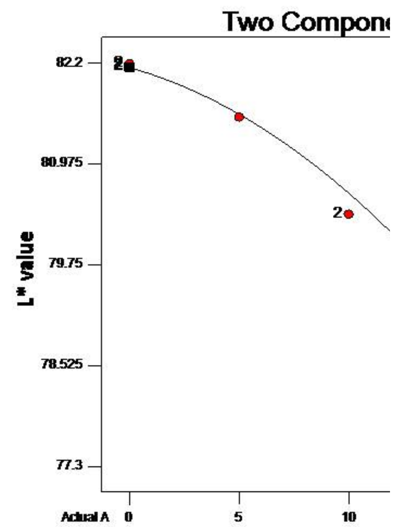


Figure 9. Changes in L* value of extrudates as a function of fish-flour combination

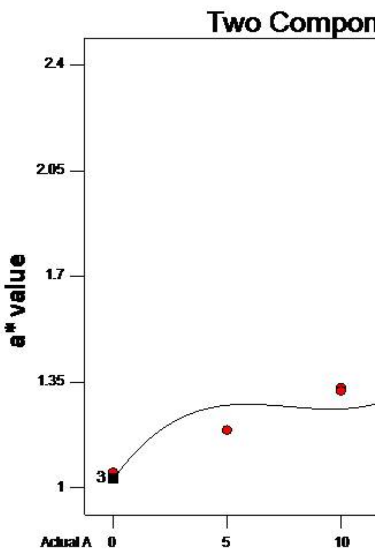


Figure 10: Changes in a* value of extrudates as a function of fish-flour combination

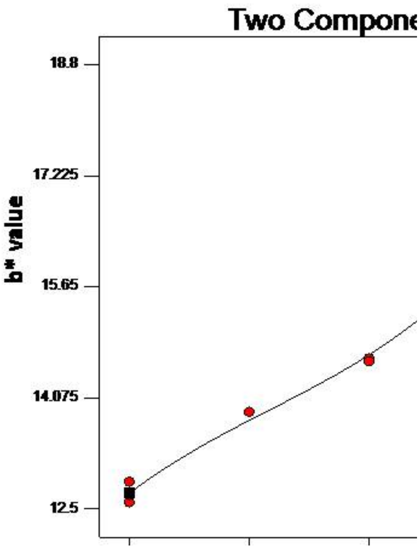


Figure 11: Changes in b* value of extrudates as a function fish-flour combination

3.4.6.4 Changes in cooking time (CT) in fish incorporated noodles

The cooking time of extruded products from refined wheat flour with varying percentage of fish mince given in Figure-12. Linear model was found to be most suitable for explaining the changes in cooking time of the noodles as a function of different levels of fish mince and refined wheat flour (R^2 value of 0.87). The coefficients of the fitted model were given in Table-10 and the predicted and observed values of cooking time of noodles were presented in Figure-12. Cooking time is considered as the important parameter in commercial point of view, which depends on the ingredients of the extrudates. Kawaljit et al. (2010) found that lowest cooking time in potato starch incorporated noodles than rice starch noodles. Cooking time of the extrudates was increased with the concentration of fish mince. Control sample showed 7 min to attain the optimum cooking time; whereas, 7.4 min for 20% fish mince incorporated noodles. This could be due to the increased fish protein content, which take longer time for cooking. The influence of flour protein on the quality characteristics of dry noodles was investigated by Oh et al. (1985a) who found that the optimum cooking time of dried salt noodles increased linearly with flour protein content.

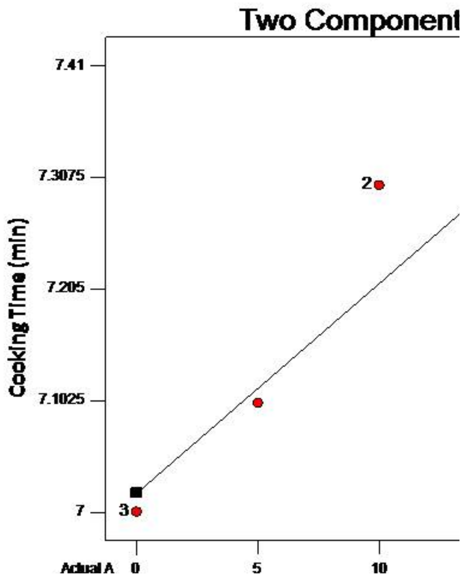


Figure 12. Changes in cooking time of extrudates as a function fish-flour combination

3.4.6.5 Changes in cooking loss (CL) in fish incorporated noodles

The cooking loss of extruded products from refined wheat flour with varying percentage of fish mince is given in Figure-13. Cooking loss was mainly influenced by dissolving and releasing of gelatinized starches from the noodle surface during cooking (Chang and Wu, 2008). Figure-13 clearly depicts the cooking loss of the samples as a function of fish-flour combination. Linear model was used to explain the changes of cooking loss with respect to changes of fish mince and wheat flour with an R^2 value of 0.53 (Table-10). The model (Figure-13) implies a significant decrease in cooking loss from

1.47% for 5% fish meat incorporated noodles to a value of 1.1% for 20% fish incorporated noodles. Cooking loss of the noodles was mainly depends on the combination of ingredients. Young et al. (1996) found that highest cooking loss in mung bean starch based noodles than those made from potato starch. Cooking loss of the noodles was mainly due to the solubilisation of loosely bound gelatinized starch on the surface of the noodles (Chansri et al. 2005). Hence, reduced cooking loss in fish incorporated noodles might be due to the low content of starch. However, cooking time directly influences the cooking loss of the noodles (Young et al. 1996).

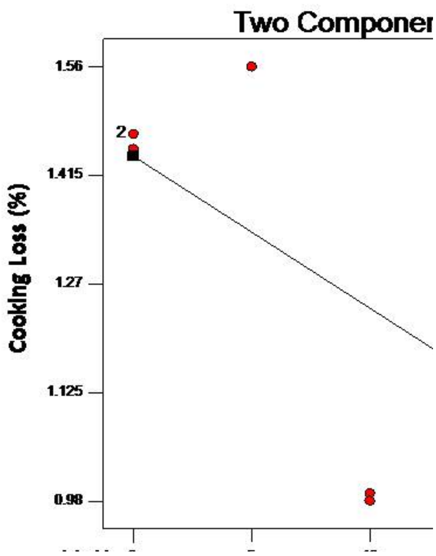


Figure 13. Changes in cooking loss of extrudates as a function of fish-flour combination

3.4.6.6 Changes in rehydration capacity (RT) in fish incorporated noodles

The Rehydration capacity of extruded products from refined wheat flour with varying percentage of fish mince given in Figure-14. Quadratic model with an R^2 value of 0.79 was fitted to predict the trend of rehydration test (RT) of noodles in terms of different levels of fish mince and wheat flour (Table-10). The fitted values of rehydration ratio were given in Table-8 and the parameter of the fitted model is shown in Table-10. During cooking of noodles, initially its surface gets cooked then it proceeds towards the centre. If it is overcooked, the outer surface of the noodles gains too much water which causes significant reduction of firmness and stickiness. Rehydration capacity of the noodles could be used as a parameter to predict the cooking quality of the noodles because the lesser the degree of rehydration, the stronger the noodles texture (Chansri et al. 2005). Control, 5, 10 and 15% fish mince incorporated samples revealed rehydration ratio of 3.59, 3.65, 4.39 and 3.53%, respectively. Least rehydration value (3.11%) was observed in 20% fish mince incorporated noodles.

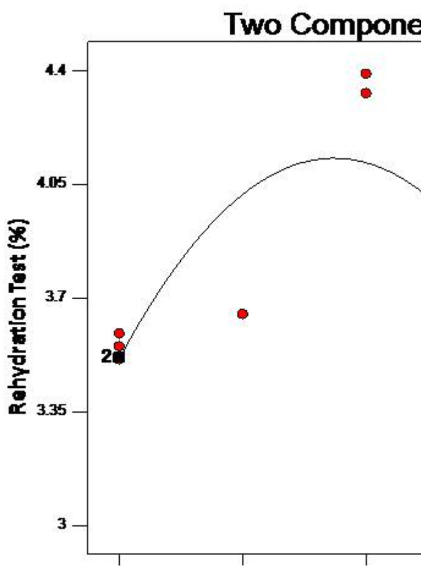


Figure 14. Changes in rehydration capacity of extrudates as a function of fish-flour combination

3.4.6.7 Changes in shear strength (SS) in fish incorporated noodles

The shear strength of extruded products from refined wheat flour with varying percentage of fish mince given in Figure-15. Cubic model was most suitable model to explain the changes in shear strength of noodles in terms of different levels of fish mince and wheat flour. The model was fitted with an R^2 of 0.99 and parameters of the fitted model were presented in Table-10. The observed and predicted values of shear strength of the noodles were given in Figure-15. The force required to break the noodles was 8.88 and 8.03N in 10 and 15% fish mince incorporated noodles. There was a decrease in shear strength for 20% fish mince incorporated noodles as the amount of starch molecule decreases and facilitates easy breaking of the product. Decreased breaking strength was reported for hydrolyzed Arrowtooth flounder muscle by Choudhury and Gautam (2003).

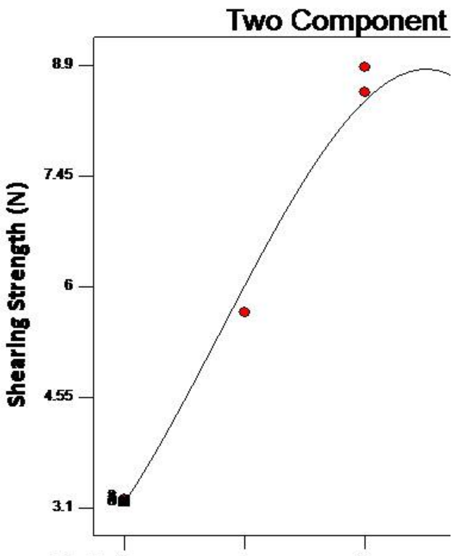


Figure 15. Changes in shear strength of extrudates as a function of fish-flour combination

3.4.6.8 Changes in sensory quality in fish incorporated noodles

The sensory evaluation of extruded products from refined wheat flour with varying percentage of fish mince given in Figure-16. Cubic model was fitted to predict the changes of sensory score of the noodle with respect to fish mince and wheat flour (Table-10). Figure-16 clearly depicted that there was no significant difference for the sensory score of control and 5% fish mince incorporated sample. Whereas, at 10 and 15% fish mine incorporated samples revealed better sensory acceptability than 20% fish mince incorporated sample. However, among the samples, 15% fish incorporated noodle was found to be most acceptable by considering physical properties and sensory score. It was observed that the level of fish mince content was responsible for the significant changes in cooking, colour and textural property of the noodles. Textural properties of noodle were mainly affected by the matrix structural network of starches, glutens, proteins, fibers, and other additional ingredients. These may either weaken or strengthen formation of hydrogen bonds within the noodle structure network (Kong et al. 2012).

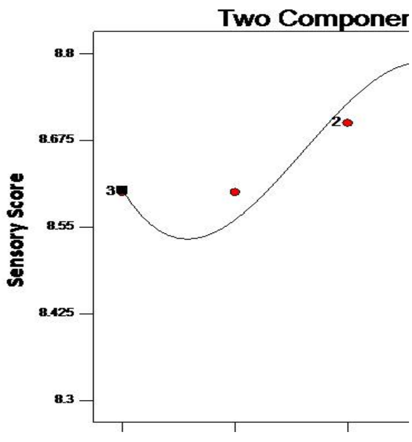


Figure 16: Changes in sensory score of extrudates as a function of fish-flour combination

3.4.6.9 Optimization of fish-flour combination

Desirability function score was computed by simultaneous evaluation of multiple responses to optimize the combination of different concentrations of fish-flour incorporated noodles. The desirability function graph is given in Figure-17. The maximum desirability function score was 0.522 at 15% of fish mince and 85% of refined wheat flour.

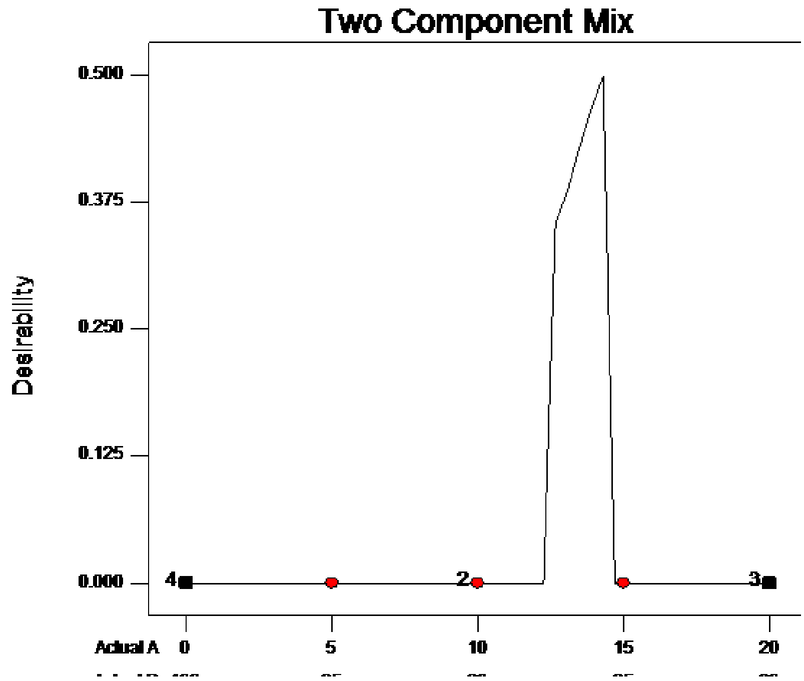


Figure-17. Desirability function score of fish mince and flour

A validation study also was carried in the optimum level of fish mince and refined wheat flour and response of different physical properties of the fish noodles was in the desired predicted limits of the actual study.

3.4.7 Sorption characteristics of standardised noodles

The sorption characteristics of the standardised fish noodles are represented in Figure-18. It was found that the product had a water activity of 0.48. Fish noodles equilibrating to 12, 20, 32, 38, 53, 64, 75 and 80% RH had equilibrium moisture content of 4.22, 6.25, 6.90, 7.96, 8.87, 11.30, 13.71 and 15.33%, respectively. The sorption isotherm studies showed that at 21.57% moisture (as on basis) equilibrating to 94% relative humidity (RH) is critical with respect to the development of mould growth. The Equilibrium Relative Humidity of the sample was 48.5%. The sigmoidal-type sorption suggests that the product is sensitive to changes in humidity, absorb or desorbs moisture at different humidity conditions, the temperature remaining constant. Above 64% R.H. the equilibrium moisture content of the product increases. Hence, the packaging material should have low water vapour and oxygen transmission rate are for obtaining longer shelf-life of the product.

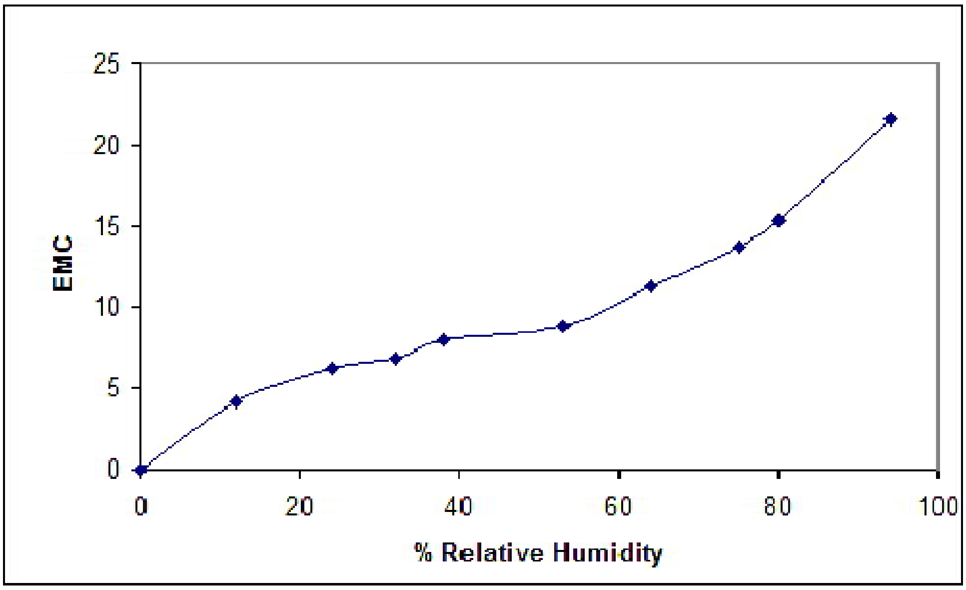


Figure-18. Sorption characteristics of 15% fish incorporated noodles

3.5 Conclusions

Fish noodles were prepared with mince from pink perch meat and refined wheat flour using single screw extruder. Increasing concentration of fish mince from 5, 10, 15 and 20% were carried out. Proximate composition of the fish noodles revealed that there was an increase in protein content with the addition of fish mince. The physical and sensory properties of the noodles were studied and result obtained in the present study revealed the combination of fish mince and refined wheat flour significantly altered the physical properties of fish noodles. Water Absorption Index reduced when the fish mince concentration increased. Noodle cooking quality was affected due to the differences in protein content in fish noodles. Significant colour changes were found to affect the appearance of the noodles. Linear model was found to be most suitable for explaining the changes in cooking time and cooking loss of the noodles as a function of different levels of fish mince and refined wheat flour (R^2 value of 0.87 and 0.53, respectively). Quadratic model was found suitable to explain the effect of percentage of fish mince on WAI, L* value and rehydration test with an R^2 value of 0.99, 0.97, and 0.79, respectively. Cubic model showed an R^2 value of 0.99, 0.99 and 0.97, respectively for BD, a*value, shearing strength and sensory. From the physical properties and sensory evaluation point of view, 15% fish incorporated noodle was found to be superior among the samples. 15% fish mince noodles had a water activity of 0.48. Desirability function score was computed by simultaneous evaluation of multiple responses to optimize the combination of different concentrations of fish-flour incorporated noodles. The maximum desirability function score at 15% of fish mince and 85% of refined wheat flour was identified.

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Chapter 4

THERMOFORMING AND PHYSICAL PROPERTIES OF THE PACKAGING MATERIALS FOR THERMAL PROCESSING

Contents

The standardised fish noodles was thermal processed in containers, which can withstand thermal process temperature and suitable for consumption. The containers and allied packaging materials should be tested for its end use. The flexible high impact polypropylene container was used for packing the fish noodles. The top of the container is vacuum sealed with polyester/cast polypropylene film. The sealed trays are further packed in see through retort pouch. In this chapter packaging materials are tested to evaluate their suitability for thermal processing and its food grade quality.

4.1 Introduction

A food package usually provides a number of functions like protection; convenience for consumers that allows for easy opening, pouring, serving, carrying, reclosing and storage. Proper packaging will minimize spoilage and wastage of food. The innovations in packaging technologies and packaging materials have brought about a number of convenience foods in the market. In the past, packaging emphasized the expectations of the producers and distributors but it has now shifted towards the consumer since they are becoming more demanding and aware of the choices available (Piergiovanni, 1991). The use of flexible packaging material for the thermal processing of food material was reported earlier by Hu et al. (1955) and Nelson et al. (1956). Thermoformed containers are semi rigid plastic containers which are economical and offer convenience to the user. The containers are thin in profile and three dimensional in shape and faster heat penetration rate during retorting due to the thin profiles. Thermoforming is done by vacuum forming, pressure forming and matched mould forming. The major advantages of the trays over other rigid and flexible containers are easy to use, cheap and economical. Different products have different packaging requirements and it is important to choose suitable packaging material accordingly. It is important to know the intended storage conditions of the product, i.e., temperature, relative humidity and expected shelf life. For a prolonged shelf life of processed product, the materials should provide superior properties, seal integrity, toughness, and puncture resistance and must also withstand the rigors of thermal processing. Plastic films used for over pressure autoclaving should have good heat resistance and heat sealing property, high barrier property towards oxygen, carbon dioxide and water vapour. All types of packaging materials cannot be used for food contact application. Migration of materials from plastics to food can cause toxic effect upon consumption. The overall migration residue limit value should be tested for food application. Packaging materials used for common noodles are polypropylene/polyethylene film and for high-quality noodles, PP/polyester/AI/PE (Tsui-Shan, 2000**)**. Rho et al. (1986) examined the retardation of rancidity in deep-fried instant noodles and reported that coating 200 ppm Tertiary Butylhydroquinone or TBHQ on the inner surface of the polyethylene package extended shelf-life of 19 days, while increasing the quantity of TBHQ on the surface of the bag to 500 and 1000 ppm gave 22 and 27 more days without rancidity compared to the control.

4.2 Objective of the study

The main intention of the study was to evaluate the physicochemical properties of high impact polypropylene containers (HIPP), PEST/CPP film and see-through silicon dioxide incorporated retort pouch for packaging of fish noodles.

4.3 Materials and Methods

4.3.1 Packaging materials

4.3.1.1 High impact polypropylene (HIPP) tray

Thermoformed container made of High Impact Polypropylene of size 12.5 x 9.2 x 2.5 cm (length x breadth x height) having 220 ml capacity was prepared using 1.2 mm HIPP sheet.

Plate-12. Thermoformed HIPP trays

4.3.1.1.1 Thermoforming of high impact polypropylene tray

Thermoformed containers are made by vacuum forming equipment (K. L. Thermoformers Private Limited C-67/2, Okhla Industrial Area, Phase-II, New Delhi-110029, India). The equipment consists of a vacuum box with an air outlet and a clamping frame, a mould, a heating panel and a vacuum pump. The mould, which is partly hollow underneath and is perforated, is placed over the air outlet. The thermoplastics sheet is cut and placed over the open top of the vacuum box and securely clamped by means of frame giving an airtight compartment. Provision to set the heating temperature and time of holdings and can be adjusted. The sheet is heated until rubbery. The heater is withdrawn, and air in the box is rapidly evacuated by the vacuum pump. Atmospheric pressure above the sheet forces it down into close contact with the mould where it is cooled sufficiently to retain its shape. The clamping frame is then released, the formed sheet is removed from the mould, and the excess material trimmed off manually by an attachment provided with blade to cut the excess sheet.

Plate-13. Die used for thermoforming

Plate-14. Thermoforming machine

4.3.1.2 Manufacture of thermoforming of semi-rigid containers

Table-11. Process parameters for thermoforming of HIPP trays

Process Parameters	Setting limit
Heater -1	398°C
Heater-2	395°C
Heater-3	389°C
Heating time	30 sec
Holding time	15 sec
Forming time	20 sec
Cooling time	10 sec
Ejection Time	10 sec

The optimum temperature for melting the HIPP roll was 398, 395 and 389°C for the three heaters. The heating time was found to be 30 sec. Holding time of 15 sec was ideal before thermoforming. A forming time of

20 sec is necessary to complete the shape of the mold. 10 sec of cooling time was given before ejection.

4.3.1.3 Flexible packaging material for top sealing the trays

12µ polyester laminated with 300 gauge cast polypropylene (PEST/CPP) was used for sealing the top of the tray. To improve the barrier properties of the tray, again the tray is packed see through retort pouch.

4.3.1.4 See through retort pouch

Retort pouch having transparency made of outer polyester, middle nylon coated with silicon dioxide and inner of cast polypropylene having a size of 19.7 x 29.9 cm manufactured by M/s Pradeep Lamination, Pune, India was used for study. Physical properties of the pouch is presented in Table-12.

Plate-15. See through retort pouch

4.3.1.5 Physico-chemical properties of packaging material

Before testing, all the samples were conditioned at 64% relative humidity (RH) at 25 ± 2 °C for 24 h using Gallenkamp Sanyo humidity oven.

4.3.1.5.1 Thickness of retort pouches

The total thicknesses of pouches were determined as per ASTM (1964).

4.3.1.5.2 Tensile strength and elongation at break

The tensile strength and elongation at break was determined using Universal Testing Machine (Lloyd instruments LRX plus, UK) (IS: 2508-1984). 5 numbers of strips were cut into suitable size (15 mm width X 50 mm Length) in both machine and cross direction. Tightly grip one end of each strip in the upper clamp after placing the grip loosely in the lower clamp and checking its alignment. Total length should be at least 50mm longer than the guage length. The machine was switched on at the pre-adjusted speed (500 mm min^{-1}). The load range was such that the breaking load of the test pieces falls between 15-85% of the full scale reading. Record the result of each individual reading to three significant figures in case of tensile strength. Test at least ten, preferably twenty strips cut in each principal direction. The tensile strength at break was calculated in kg cm^{-2} from the original area of cross section.

Elongation at break is expressed as % of the original length between the reference lines.

4.3.1.5.3 Heat seal strength

After sealing, the heat seal strength was determined by measuring the force required to pull apart the pieces of sealed film (ASTM, 1973). The breaking strength of the heat sealed seams was determined using Universal Testing Machine (Lloyd instruments LRX plus, UK). The specimen was cut into suitable size (25 mm width x 50 mm length) and clamped between the jaws. The sealing width should be 25mm. The machine was switched on at the pre-adjusted speed (300 mm min^{-1}). The maximum stress applied to the specimen at yield or breakage was noted as heat seal strength. Heat seal strength of both the direction (machine and cross) was recorded from minimum of 10 readings and the results are expressed as kg cm^{-2}.

4.3.1.5.4 Bursting strength

The pouch lips were clamped to the bursting strength measuring equipment around the air inlet and between the rubber jaws (Lampi, 1977). Air was released gradually for 30 sec. If the pouch could hold air for 30 seconds without bursting it passes the test. It also shows absence of pinholes in the pouch.

4.3.1.5.5 Bond strength

The layers were delaminated using chloroform or diethyl ether or toluene at the pouch strip end and the bond strength of the films was measured by tensile strength as per ASTM (1972).

4.3.1.5.6 Water vapour transmission rate (WVTR)

WVTR was analyzed by the method of IS: 1060 Part II (1960). The packaging material was cut using a template, which is of such diameter that the edge of the test piece covers half the annular recess of the shallow aluminium dish (50 cm^2) meant for the test. The dish was filled with desiccant (fused Calcium Chloride) up to 1 to 2 mm of the supporting ring. The test piece was placed on the supporting ring and centered. The waxing template was placed centrally over the dish and test piece, and molten wax was poured into the annular recess until the wax is level with the top surface of the template. Break any air bubbles in the wax with a small gas jet, allow the wax to harden and remove the template. Inspect the dish to ensure that the seal is satisfactory and remove any wax on the outside. Filling and sealing of the dish is carried out as rapidly as possible so that the desiccant absorbs minimum of water vapour from the atmosphere. Care must be taken not to damage the test area during the operation or to allow the desiccant to come into contact with it. To facilitate the removal of the template from the wax, apply a thin film of petroleum jelly to the bevelled edge before sealing, remove any surplus on the lower surface.

Seal the open end of the dish containing the desiccant by the test specimen and exposing the dish to the desired RH and temperature conditions. This condition is 37 °C and 92% RH, when the desiccant used exerts 2% RH. Prepare the required number of dishes and place in the humidity cabinet. Make successive weighing at suitable intervals, which must be sufficiently frequent to complete the test before the relative humidity in the dish rises above 2%. Increase in weight of the desiccant over a known period of time gives the amount of water vapour transmitted by the specimen and is expressed as g m^{-2} $24h^{-1}$ at 90 ± 2% RH and 37 °C.

4.3.1.5.7 Gas transmission rate (GTR)

Oxygen permeability of the film and tray was carried out using gas permeability apparatus (Gas and steam permeability, AtsFaar, Societa' Per Azioni, Milano, Italia) (ASTM-1982). The test material is cut into suitable size (10 cm dia). B, C and D valve of the instrument was opened and the upper half of the permeability cell was removed. A dried circular filter paper (Whatman No. 1) was placed on the top of the insert after applying vacuum adhesive grease and the sample of film spread over the filter paper. An added mass was placed into the mould. The upper part of the permeability cell was then replaced. All the valves (A, B, C and D) were closed and the vacuum pump was switched on. Then valve C was opened to create the vacuum in the lower portion and it was checked by tilting central vacuum gauge. It should be preferably 0.2 mm Hg. Now the D valve was opened for purging and A valve for removing the atmosphere gas if any. Then the A and D valves were closed. Transfer mercury (Hg) into the cell by tilting the outer portion and wait for few minutes to attain 0.2 mm Hg vacuum. Open valve A to apply the test gas (O_2 or CO_2) and adjust the pressure using the gas cylinder valve. Turn on the timer and allow 15 min for stabilization. Note the initial vacuum reading either in the vacuum gauge or in the Eurotherm Chassell and note the reading at particular interval and the gas transmission rate was calculate and expressed as mL m^{-2} 24 h^{-1} at 1 atm pressure at 20°C.

Plate-16. Gas transmission rate apparatus

4.3.1.5.8 Overall migration residue study

Overall migration test was analyzed as per IS: 9845 (1998). For the determination of migration of constituents from plastic materials which come in contact with foodstuffs, the choice of simulating solvents and test conditions (time-temperature) depends on the type of food and condition of use of food products. For this the simulating solvents recommended by the standard (IS: 9845- 1998) are distilled water and 3% acetic acid (121 °C for 2 hours), *n*-heptane (66 °C for 2 hours)**.**

The pouches were carefully rinsed with water (25–30 °C) to remove extraneous materials prior to actual migration test. The pouches were filled to their filled capacity with preheated stimulant at test temperature (1ml/cm^2 of contact area) and seal it excluding air as much as possible. Each aliquot sample should consist of a number of containers with the total area of 1000cm^2. Expose the filled pouches to specified temperature maintained in retort/oven/ water bath for specified duration of time. Transfer the contents into a clean Pyrex beaker along with three washings of the specimen with small quantity of the fresh simulant. Evaporate the dish until contents in pyrex beaker to about 50-60 mL and transfer into a clean tarred stainless steel dish along with 3 washings of pyrex beaker with small quantity of fresh simulant and further evaporate the concentrate in the dish to dryness in an oven at 100 ± 5 °C. Cool the dish with extractive in a desiccator for 30 min and weigh to nearest 0.1 mg till constant weight of residue is obtained. Calculate the extractives in mg dm^{-2} or mg kg^{-1} or mg L^{-1} or ppm of the food stuff with respect to the capacity of pouch used. Blank was also carried out without the sample and the amount of extractives was calculated as given below. In case of heptane as solvent, divide the amount of extractive by a factor of five in arriving at the extractivity for a food product.

Calculation:

Amount of extractives = (M/A) x 100 (mg dm^{-2}) and

(M/V) x 1000 (ppm),

Where,

M = mass of residue in mg minus blank value

A = total surface area in cm^2 exposed in each replicate

V = total volume in mL of simulant used in each replicate.

4.4 Results and Discussion

4.4.1 Physical properties of the packaging material used

The physico-chemical properties of the packaging materials used in the present study are presented in Table-12.

Table-12. Physico-chemical properties of the packaging materials

Properties	PEST/CPP	PEST silicon dioxide/ Nylon/ CPP	HIPP Trays
Thickness (μm)	87±.01	100 ± 0.01	996±1.2
Tensile strength (kg cm^{-2})			
Machine direction (MD)	372±1.2	782±0.01	332±1.6
Cross direction (CD)	354±1.6	615±0.01	306±1.1
Heat seal strength (kg cm^{-2})			
Machine direction	224±1.2	562±1.1	-
Cross direction	186±1.1	439±1.3	-
Elongation at break (%) (MD)	73±0.3	82±0.02	92±3.54
Elongation at break (CD)	81±0.9	96±0.03	98±2.25
Bursting strength (psig)	22±.3	30±0.02	----
Bond strength (g / 10 mm)	112±0.6	132±0.3	----
WVTR (g m^{-2} 24 h^{-1} at 37°C and 92% RH)	3.2±0.1	0.95±.01	0.76±0.05
OTR (cc m^{-2} 24 h^{-1} at 20°C, 1 atm. pressure)	56±2.4	2.14±.01	9.5±0.14
Food contact application tests (overall migration residue test, mg L^{-1})			
Water extractives	4.97±0.09	4.5 ± 0.16	5.4 ± 0.32
n-heptane extractives	2.13±0.3	1.3 ± 0.11	3.6 ± 0.16
3% acetic acid extractives	1.67±0.2	1.88±0.23	2.14±0.21

4.4.1.1 Thickness of the packaging materials

The top sealing of the tray was done by PEST/CPP. The film had a thickness of 87 µm. See through retortable pouches made of laminate of polyester coated with silicon dioxide/ nylon/cast polypropylene had a thickness of 100 µm. The High Impact Polypropylene containers had a thickness of 996 µm. Hemavathi et al. (2002) reported that the thicknesses of material is influenced the mechanic performance, product protection and integrity of the pouches.

4.4.1.2 Tensile strength and elongation at break

The tensile strength and elongation at break of the packaging materials determines the resistance of rupture and breakeage when subjected to tensile force. PEST/CPP material had a tensile strength of 372 and 354 kg/cm^2 along machine as well as cross direction. See-through retort pouch had a value of 782 and 615 kg/cm^2, respectively. The HIPP trays had tensile strength of 332 and 306 kg/cm^2 along machine and cross direction. It has been observed that laminates had good tensile strength and elongation at break for both machine direction and cross / transverse direction.

4.4.1.3 Heat seal strength

Heat seal strength provides the pouches good package integrity and self-life. The CPP material had heat seal strength of 224 kg/cm^2 along machine direction and 186 kg/cm^2 for cross direction. See through retort pouch had 562 kg/cm^2 along machine direction and 439 kg/cm^2 along cross direction. It was difficult to conduct the heat seal strength of the HIPP trays. CPP and See through retort pouch had good heat seal strength.

4.4.1.4 Bursting strength

When the pouches are subjected to air pressure inside, the PEST/CPP laminate was able to hold an air pressure test of 22 psig only. However, see through retort pouch was able to hold a pressure of 30 psig. It was observed that a pouch which can holding at above 25 psig for one minute should be considered as passed for the test.

4.4.1.5 Bond strength

Bond strength is one of the most important requirements for retort pouch, which access the delamination of laminates during thermal processing. Lower value indicates easy delamination of the layers during thermal processing, which results in physical destruction of pouches and reduction of barrier properties of retort pouches. PEST/CPP had bond strength of 112 g/10mm. See through retort pouch had bond strength of 132 g/10mm. The values clearly indicated that the packaging material withstand retorting temperature.

4.4.1.6 Barrier properties

The water vapour and oxygen transmission rate are represented in Table-12. PEST/ CPP material had a water vapour transmission rate of 3.2 $g/m^2/24h$ at 90±2% RH & 37°C and oxygen transmission rate of 56 $cc/m^2/24h$ at 1 atmosphere pressure at 20°C respectively. See-through retort pouch had a water vapour transmission rate of 0.95 and oxygen transmission rate of 2.14; whereas HIPP trays had a value of 0.76 $g/m^2/24$ h at 90 ± 2 % RH & 37°C of water vapour transmission rate. Oxygen transmission rate was recorded to be 9.5 $cc/m^2/24$ h/ 20°C at 1 atmosphere pressure. High barrier for oxygen and carbon dioxide of retort pouch reduces rancidity in food product inside the processed pouch. Low barrier properties allow gases to pass inside the pouch or from inside the gas and water vapour escapes resulting in deterioration of the packed commodities.

4.4.1.7 Overall migration test

Migration is mass transfer of materials from plastics to foods under specified conditions. This test is usually done to asses the toxic effects of packaging material when comes in contact with foods when packed. Since the packaging material are to be thermal processed at 121°C, water and heptane extractives are required according to the procedure. Bureau of Indian Standard specify 10 mg/dm^2 or 60 ppm for finished materials (IS: 10910, 1984). The levels of water extractives, n-heptane extractives and 3% acetic acid extractives for PEST/CPP film were 4.97, 2.13 and 1.67 mg L^{-1} respectively. See through pouches had a level of 4.5, 1.3 and 1.88 mg L^{-1}. In case of HIPP trays the values were 5.4, 3.6 and 2.14 mg L^{-1}. The values obtained for the packaging materials were below the limits. Plastic material contains some non-polymeric components, may leach out from plastic to foods whenever direct contact occurs between food and plastics, thereby contaminating food product with the consequent risk of toxic hazard to the consumer (Gopal, 2005).

4.5 Conclusions

The packaging materials used for the study were tested for its integrity for thermal processing and for food grade quality. It was found from the physical properties that the packaging material can withstand thermal processing temperature of 121.1°C. The result also revealed that it can withstand a working pressure of 28 psig. The HIPP trays were ideal for thermal processing and do not change the shape during retorting. PEST/CPP film for top sealing for trays and see through retort pouch (PEST silicon dioxide/ Nylon/ CPP) can be used for food contact application. See through pouches were made of three layers viz., outer polyester, middle nylon coated with silicon dioxide and inner of cast polypropylene. The silicon dioxide is a nano particle capable of enhancing good barrier properties.

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Chapter 5

OPTIMIZATION OF THE THERMAL PROCESSING CONDITION FOR READY-TO-EAT FISH NOODLES

Contents

5.1 Introduction

Thermal processing is the most common sterilization method for microbial destruction in food preservation. The pioneering investigation on the effect of heat on microorganisms and enzymes was investigated by Louis Pasteur in 1860, form the basis of pasteurization. Foods are heat processed for four main reasons viz. to eliminate pathogens, to eliminate or reduce spoilage organisms, to extend the shelf life of the food and to improve palatability of the food. Heat may be transferred to the food product by three ways that are conduction, convection and radiation. Canning is a well-known method employed in food preservation. It involves hermetically sealing food in a container, and then inhibiting pathogenic and spoilage organisms with the application of heat. Nicholas Appert (1752–1841) is credited with the thermal process of canning, which was discovered (1809) as a result of a need to feed Napoleon's troops. Food is placed inside a cylinder or body of a can, the lid is sealed in place, and the can is then heated in a large commercial pressure cooker known as a retort. Heating times and temperatures vary, but the heat treatment must be sufficient to sterilize the food (Jackson, 1979). Temperatures in the range 116–121°C are commonly used for canning. The main purpose of canning is to achieve commercial sterility and extension of shelf life of the product. Commercial sterility is the condition achieved by the application of heat sufficient to render the processed product free from viable microorganisms (including those of known public health significance), capable of growing in the food under normal non-refrigerated temperatures at which the food is likely to be held during distribution and storage. Commercially sterilized foods may contain a small number of heat-resistant bacterial spores that are unable to grow under normal conditions. Bacteria are destroyed at a rate proportional to the number present in the food. This is known as the logarithmic death rate, which means that at a constant temperature, the same percentage of a bacterial population will be destroyed in a given time interval, irrespective of the size of the surviving population. In low acid canned foods (pH <4.5) the organism of primary concern is the pathogenic anaerobe *Clostridium botulinum*. It has been established that the minimum safe heat process given to low-acid food should decrease the population by 12 logarithmic cycles (from an initial spore level of one spore per gram of food) the basis of the 12D concept or "Botulinum Cook". The D value for *C. botulinum* is estimated as 0.21 min (1D at 121.1°C) with a z value of 10 °C. Heat penetration and thermal process evaluation are the two features allow for the possibility of optimization of canned foods. The characteristics of the container, contents, retort, heating medium and mode, arrangement of cans inside the retort, steam distribution and all such factors Influencing the rate of heat penetration in canned foods. Thermal process calculation procedure is to establish the time at a reference temperature that will result in the reduction of a hypothetical population of spores to some small (although infinite) value. However, the quality of the product is the major concern in canned product. The quality must be preserved, unaltered as possible, from production to storage, distribution and purchase, that is, throughout the entire shelf life of product. Generally, heat accompanies the changes in the appearance, smell, taste, texture and nutritive value of food. Excessive heat treatment may cause undesirable protein denaturation, non-enzymatic browning and loss of vitamins and volatile flavour compounds in food. Hence, the heat treatment should be given in such a way that minimum destruction to the sensory quality. Texture of thermally processed food has been recognized as an important criterion for determining the overall sensory quality. In low acid foods, textural changes are likely to be pronounced. Usually meat pieces processed under UHT (Ultra High Temperature) conditions show toughening after processing. Colour of the product is also mainly affected by thermal processing, which also directly influence the consumer acceptance. Maillard type of reaction occurs when amino acid react with carbohydrates during heating. Other types of browning are also seen in fish and all lead to a decrease in the quality of the fish product is occurred. Where safety is a desired effect of the thermal process, quality degradation is an undesired aspect. The objective of extending shelf life of foods through thermal processing is to make available a varied diet that can be stored at ambient temperature. Sterility and quality of thermally processed product is directly influenced by the level of temperature and processing time. Several authors optimized these parameters for thermal processing of ready to serve fish products like Kerala style fish curry (Vijayan et al. 1998), Rohu curry (Sonaji et al. 1998), Seer fish curry (Gopal et al. 2002), Seer fish moilee (Manju et al. 2004), ready to eat mussels (Bindu et al. 2004), Prawn kuruma (Mohan et al. 2006), Grey clams (Bindu et al. 2007), and Etroplus curry (Pandey et al. 2007). Hence, the present study was conducted to optimize the processing time for developing ready to eat fish noodles.

5.2 Objective of the study

From the previous chapter, the developed ready to cook fish noodles was thermally processed so as to be kept at ambient temperature for consumption. Where safety is a desired effect of the thermal process, process parameters has to be standardised for thermal processing. Further the quality of noodles should not be altered much by heat treatment. Hence, the experiment was to study the sterility and quality changes by sensory and instrumental methods of the fish noodles processed at different Fo values.

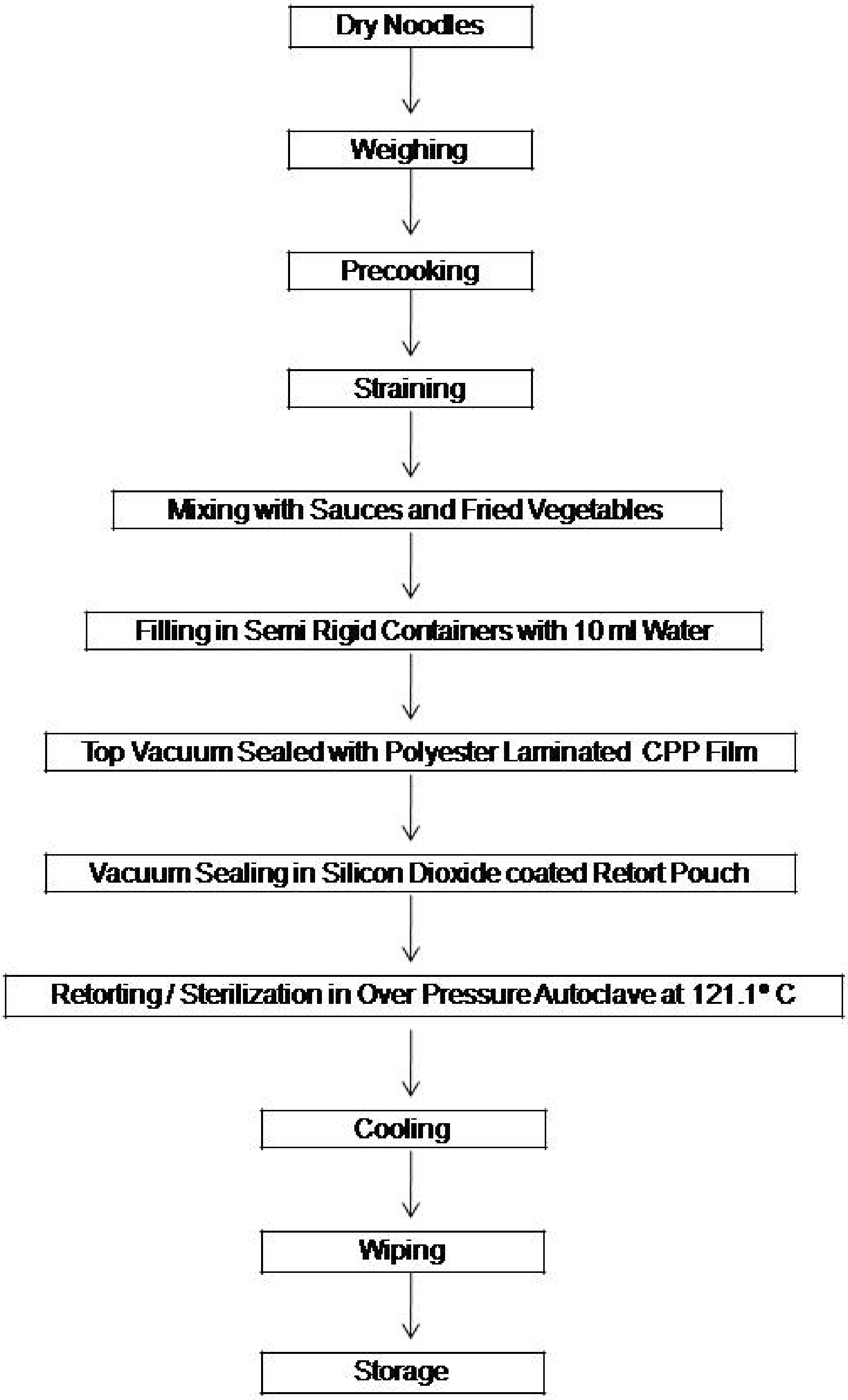
5.3 Materials and Methods

5.3.1 Preparation of fish noodles for thermal processing

Fish noodles were weighed and precooked in a vessel containing boiling water for 30 sec with 1 table spoon full of sunflower oil. It is then strained and spread into a tray. Refined oil was heated in a frying pan and sautéd chopped onion, green chilli and garlic till turns golden brown colour. Chopped vegetable and sauces were added and mixed well. To this, strained boiled noodles were added. HIPP trays (size 12.5 x 9.2 x 2.5 cm length x breadth x height, 220 ml capacity) were used to pack 150g of fish noodles with 10 ml water. The top of the tray was vacuum sealed using tray sealing machine (Dynopack 500VG machine) with PEST/ CPP film. It is then re-packed in pouches made of silicon dioxide coated retort pouch (100µm thickness) and vacuum sealed at 80% vacuum (vacuum sealing machine model QS 400 VD). The packed fish noodles are kept in racks of over pressure autoclave for thermal processing. For measuring the core temperature of the product, pouches were put specialised glands on the centre of the tray and connected to the temperature reading device through thermocouple wire (Ellab SSA-12050-G700-TS) before retorting. Temperature was recorded using Eval Precision Thermometer and Process Value Integrator. After retorting the trays were cooled with chilled water, taken out, wiped using dry cloth and stored at ambient temperature for further analysis. The flow diagram of the entire process is presented in Flow chart-2.

Table-13. Ingredients used for the production of ready to eat fish noodles

Fish noodles	1 kg
Chopped beans	100g
Chopped carrot	100g
Onion	150g
Green chilli	20g
Garlic	20g
Capsicum	50g
Chilli sauce	30g
Tomato sauce	10g
Soya sauce	4ml
Sunflower oil	50ml



Flow chart-2. Production of ready to eat noodles

Plate-17. Ready to eat fish noodles

5.3.2 Machineries and accessories

5.3.2.1 Tray sealing machine

Top sealing of the tray was carried out by modified atmosphere packaging machine (Dynopack 500VG machine imported from Norway). The two-line display incorporated in the front face of the DYNO 500VG enabled the user to visualize the sequence of the machine cycle and to adjust its parameters. Machine cycle visualization and cycle parameters modification were possible with this instrument. Machine operation included vacuum adjusting and sealing. Trays are manually loaded into the machine and the PEST/CPP film for top sealing is pulled forward and the cycle is operated.

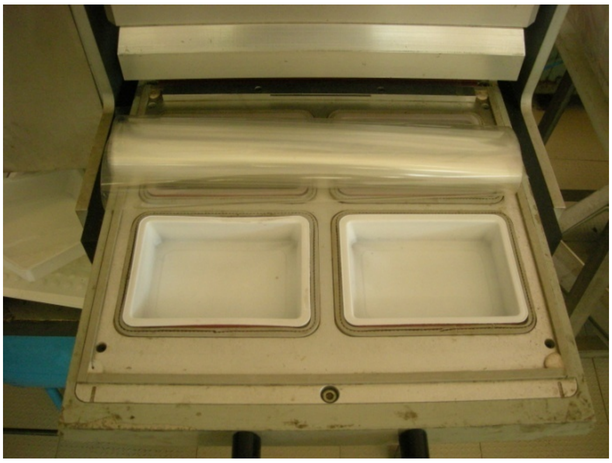


Plate-18. Tray Sealing Machine

5.3.2.2 Vacuum sealing machine

The vacuum sealing machine (Model QS 400 VD) supplied by M/s Sevana Electrical Appliance Pvt. Ltd., Box No. 2, Kizhakkambalam, Kerala, India, was used for sealing the pouches.

Plate-19. Vacuum sealing machine

5.3.2.3 Over pressure autoclave

The pilot scale retort of model 24 rotary retorting systems (John Fraser and sons Ltd, UK. Model No.5682) was used for the study. The retort is constructed of mild steel and pouches withstand a working pressure of 50 psig. This pilot scale retorting system performs laboratory scale thermal processing in a manner which ensures close simulation with commercial scale equipment and which produces a high degree of process reproducibility and accuracy. This system comprises three major components; the retort, the receiver and the control system. The retort provides a chamber in which the product is subjected to the required thermal process. The receiver provides a pressure to balance the overpressure in the retort during super heated water cooks and during overpressure cooling. The control system provides the means to sequence process events, regulate energy flows and document retort temperature and pressure.

Retort is constructed of mild steel which can withstand a working pressure of 3.5 bars having a dimension of 594 mm inside diameter x 650 mm inside length on parallel portion. It has a standard square cage, which is perforated with side slots. The speed of rotation of cage ranged from 0 to 51 rpm and was electronically controlled if necessary. Instrument pockets are provided on the right side of the shell. These include pressure gauge, retort thermometer, pockets for thermocouple glands and petcock at the rear end. A water gauge is provided on the right hand side of the retort to know the water level inside the retort. A safety valve is provided on the retort to release the pressure if it is above 55 psig. The pressure gauge was having reading range of 0 to 60 psig. A 4-blade stainless steel fan is fitted to the retort to circulate steam inside the retort and that no stagnant air pockets were allowed to exist. The retort is connected to a water cooling system. As soon as the process is over, steam can be switched off and water can be allowed to enter into the retort using water pump from the water-storing tank. This will provide a very efficient cooling mechanism by spraying water from the top of the retort. The same water can be recirculated with the help of a recirculating pump (Myson MSK 50 – 2/2090).

The receiver is also constructed of mild steel and has got a working pressure of 50 psig having a dimension of the receiver is 594 mm inside diameter x 850 mm on parallel side. Water gauge is provided at the top which indicates the receiver is full and the gauge bottom which indicates receiver below overflow level. It has got a pressure release valve and the setting is on 55 psig and pressure gauge range of 0-60 psig. The pressure in the receiver is hydraulically and pneumatically transmitted to the retort at the points in the sequence when the retort is required to be at over pressures. Two modulating valves control the receiver pressure; one regulates air into the vessel and the other acts on the vent and regulates air out. The controller is designed with a dual output to operate the system. The pressure control valve is connected to the vent valves on the receiver. The transfer line between the two vessels must be open when the pressure is controlled with the sensor mounted on the retort.

The control systems has a Programmable Logic Controller (PLC) assisted manual controls i.e. retort operation performed manually but with the help of discrete electronic programmable input detector controllers for temperature and pressure. The control system has got a digital temperature indicator and pressure indicator. A digital three-pin circular chart recorder is fitted to record retort temperature and pressure and receiver pressure. A eurotherm digital indicator is fitted to display cage rotation speed. The instrument is connected to the 0-10 V output of the motor control unit and is scaled for 0-51 rpm. A digital electronic timer is provided to assist the timing of the cook period. The timer is integrated into the PLC (Mitsubishi FI series 60 I/O) monitor system and is used to prompt the operator to begin cooling. The PLC system is provided to monitor system safety. It observes retort door interlocks and temperature and pressure alarms and acts upon the automatic valves pump.

Plate-20. Over pressure autoclave

5.3.2.4 Eval precision thermometer and process value integrator

Eval TM9616 (M/s. Ellab, Denmark) was used to record core temperature, retort temperature, Fo value and cook value at a specific time interval of 60 sec. Temperature range of the instrument is –100 to +350 °C with resolution of 0.1 °C. The Fo constants are programmed at T=121.1 °C, z=10 °C and Cook value constants at T=100 °C.

Plate-21. Eval precision thermometer and process value integrator

5.3.2.4.1 Thermocouple probes

The probes used for measuring the temperatures were copper/cupronickel thermocouples of Ellab SSA-12050-G700-TS stainless steel electrode with a length of 50 mm and diameter 1.2 mm (Ellab GKM-13009-C000) packing glands with washers were used for inserting the thermocouple into the product.

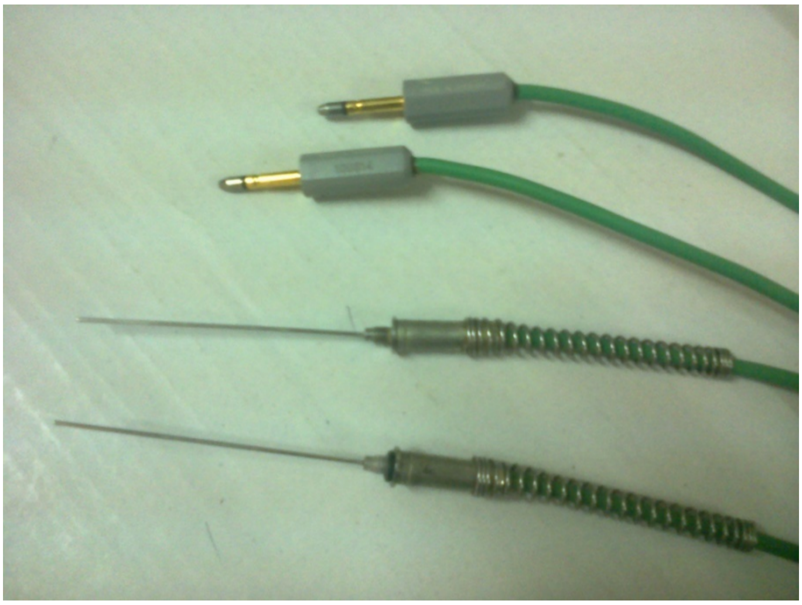


Plate-22. Thermocouples

5.3.3 Calculation of heat penetration data

Heat penetration data were plotted on a semi log paper with temperature deficit i.e. retort temperature - core temperature (RT-CT) on log scale against time. Lag factor for heating (J_h), slope of heating curve (f_h), time in min for sterilization at retort temperature(U), lag factor for cooling (J_c), final temperature deficit (g) and cook value (C) were determined. The process time (B) was calculated by mathematical method (Stumbo,1973). Total process time was determined by adding process time (B) and the effective heating period during come up time i.e. 58% of come up time of the product. The come up time should be as short as possible. The F value is used as a basis for comparing heat sterilisation procedures. It represents the total time-temperature combination received by a food and is quoted with suffixes indicating the retort temperature and the z value of the target microorganisms. Fo value is used to describe the processes that operate at

121°C, which are based on a microorganism with a z value of 10°C. This value is used in canning industry when food processing times are being calculated. In the present study Fo values of 5, 7 and 9 min were used for optimisation.

5.3.4 Commercial sterility test

The thermal processed samples at different Fo value were incubated at 37°C for 15 days and 55°C for minimum of 5 days. The incubated samples were aseptically opened and 1-2 g of the samples were taken by a sterilized forceps and inoculated into the sterilized thioglycolate broth in test tubes. 1 cm height of sterilized liquid paraffin was poured on to the top of the broth to create anaerobic condition and incubated at 37°C for 48 hrs and at 55°C for 4 days (IS: 2168, 1971). Turbidity in the broth indicates the non sterility of the processed product.

5.3.5 Analysis of colour value

Procedure for the estimation of colour of the sample is described in Chapter 3, section 3.3.10

5.3.6 Sensory analysis

Sensory analysis of the sample was carried out by the procedure described in Chapter 3, section 3.3.12

5.3.7 Statistical analysis

The sensory analysis of the samples were carried out by using Kruskal Wallis one way ANOVA to find the significant difference of responses on the sensory parameters after thermal processing at different Fo values. One way analysis of variance was carried out to find effect of Fo values on colour values. Once ANOVA was found significant, Tukey HSD test was performed to compare the means of different levels of Fo value as a post hoc analysis. All the statistical analyses were carried out by using Statistical analysis software (SAS 9.3).

5.4 Results and Discussion

5.4.1 Process standardisation by retorting

Noodles packed in thermoformed containers were processed in an over pressure retort at 121°C to an Fo value of 5, 7 and 9 min. The process parameters were calculated by plotting time-temperature data on a semi log paper which is given in Table-14. It was seen from the table-14, total process time taken for fish noodles in thermoformed containers to reach Fo value of 5, 7 and 9 were 29.37, 36.04 and 41.89 min, respectively. The commercial sterility test revealed that Fo values (ie., Fo 5, 7 & 9) were sufficient to get the product sterile. Sensory analysis indicated that products treated at different Fo values were in the acceptable range. The heat penetration data with regard to Fo value and cook value was given in Table-14. Since the product packed was in dry form, conduction type of heat transfer is only possible. A directly proportional relationship with Fo values and process time was observed. Come up time (time required to reach the reference retort temperature of 121.1°C) of Fo 5, 7 and 9 varied from 8 to 10 min. It was reported that the shortest cum-up time is advisable to attain the retort temperature (NCA, 1968).

The heating rate index (f_h) value for Fo 5, 7 and 9 was 18, 24 and 25 min, respectively. Since U value is the number of minutes for sterilization at the retort temperature, fh/U decrease with increased Fo value. The other parameters like lag factor of heating (J_h) lag factor of cooling (J_c), time in minutes for sterilization at retort temperature (U), final temperature deficit

(g) are also given in the Table-14. Highest value of lag factor of heating (J_h) is showed at Fo 9 treatment. Time in minutes for sterilization at retort temperature (U) also increased with Fo value. The graphs depicting the Fo value, cook value, retort temperature and core temperature for fish noodles processed at different Fo values are given in Figures 19, 20 and 21 respectively. Total process time (TPT) increased with Fo-values. Cook value is a measure of heat treatment (Cg) were 41.03, 74.78 and 93.99 minutes for Fo 5, Fo 7, Fo 9, respectively. Cook value represents the extent of cooking of the product. Cook values were significantly different at each Fo values and showed lowest value at Fo-5.

Table-14. Heat penetration parameters for fish noodles in thermoformed containers, Where, Jh= lag factor of heating, Jc = lag factor of cooling, fh = slope of heating curve, U= time in minutes for sterilization at retort temperature, g = final temperature deficit, B= Ball's process time, CUT = come up time, TPT = total process time and Cg = cook value

Parameters	*Fo* - 5	*Fo* - 7	*Fo* - 9
Jh	0.75±0.02	0.76±0.02	1.01±0.03
Jc	1.07±0.06	1.12±0.03	1.07±0.05
fh	18.00±0.21	24.00±0.38	25.00±0.41
U	5.208±0.15	7.105±0.32	9.12±0.07
fh/u	3.45±0.11	3.37±0.12	2.74±0.15
g	3.10±.05	3.84±0.12	2.97±0.35
B	24.16±1.1	30.24±0.95	37.25±.85
CUT	9.00±1.00	10.00±1.00	8.00±1.00
TPT	29.37±1.2	36.04±0.56	41.89±0.47
Cg	41.03±1.25	74.78±1.39	93.99±1.74

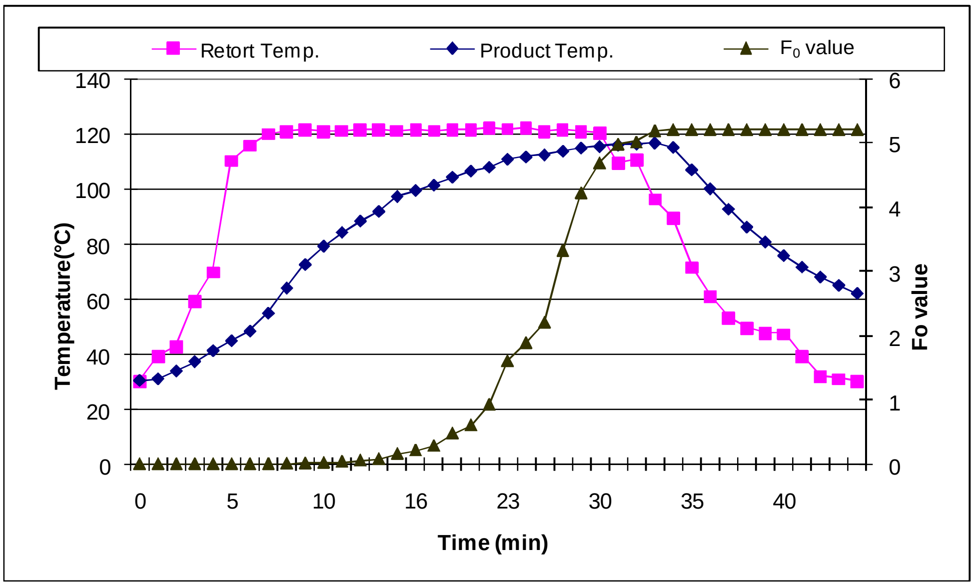


Figure-19. Heat penetration characteristics of fish noodles in semi rigid containers with Fo value of 5

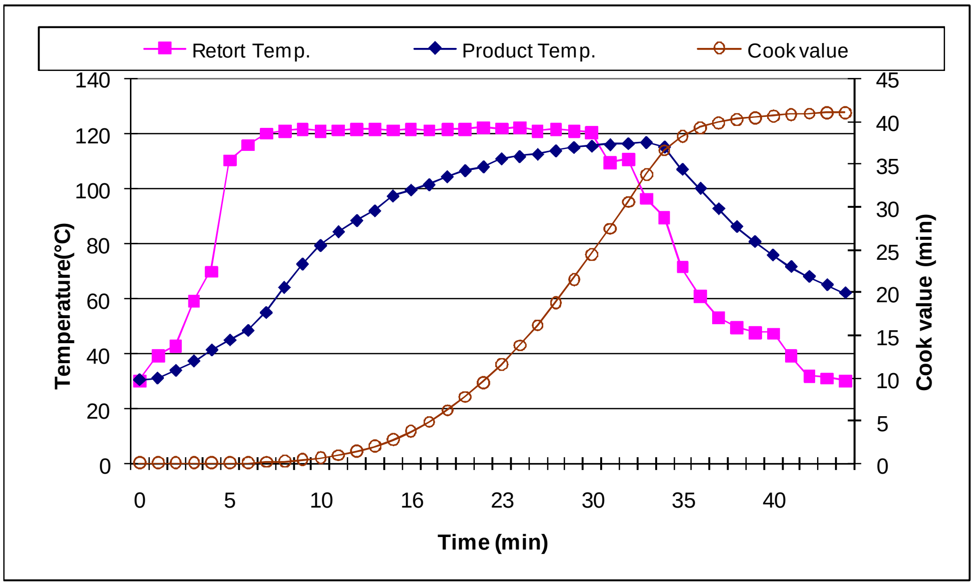


Figure-19a. Heat penetration characteristics and cook value of fish noodles in semi rigid containers

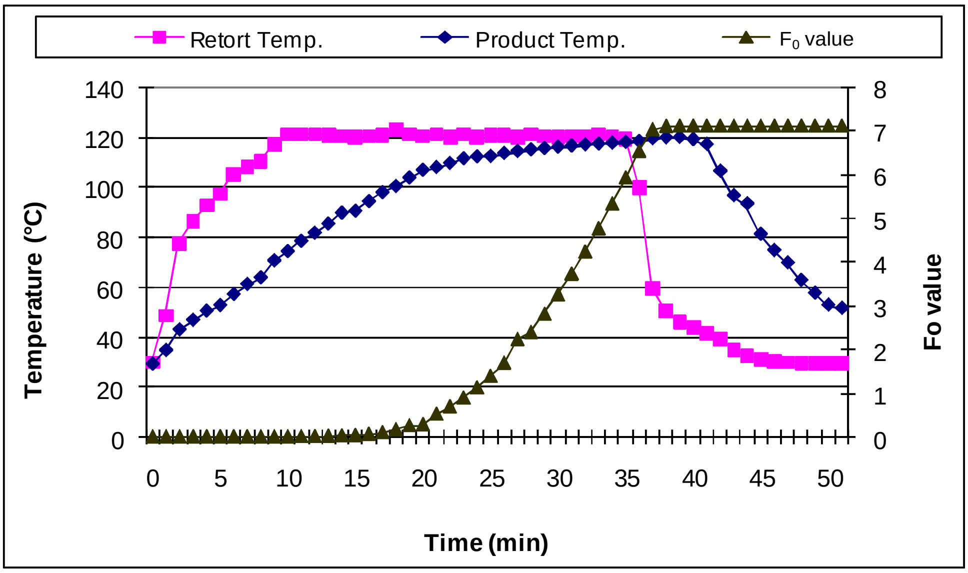


Figure-20. Heat penetration characteristics of fish noodles in semi rigid containers with Fo value of 7

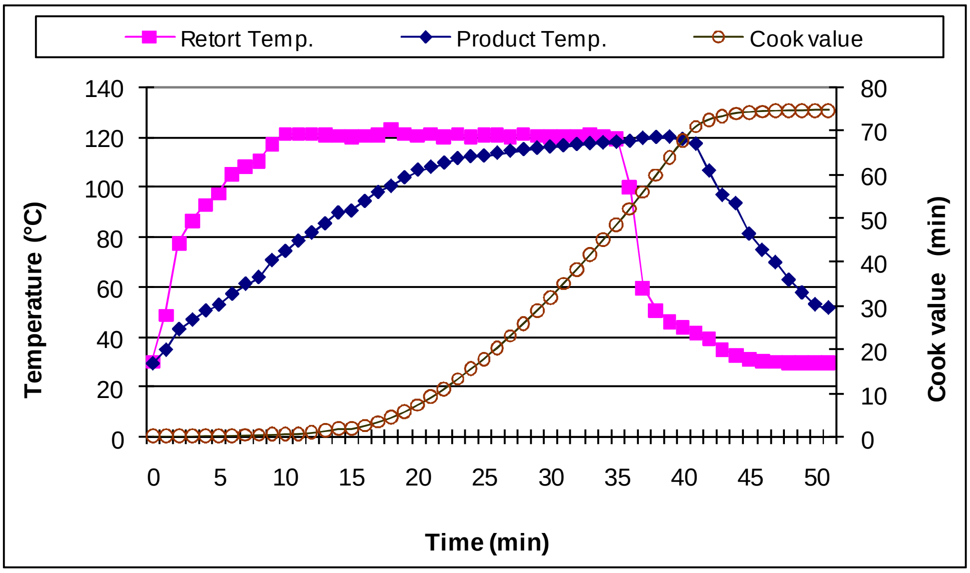


Figure-20a. Heat penetration characteristics and cook value of fish noodles in semi rigid containers

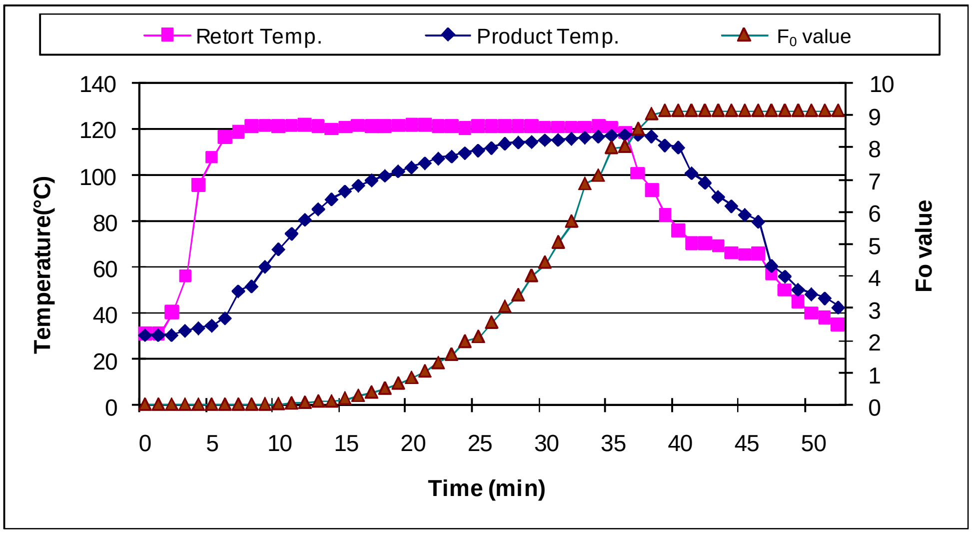


Figure-21. Heat penetration characteristics of fish noodles in semi rigid containers with Fo value of 9

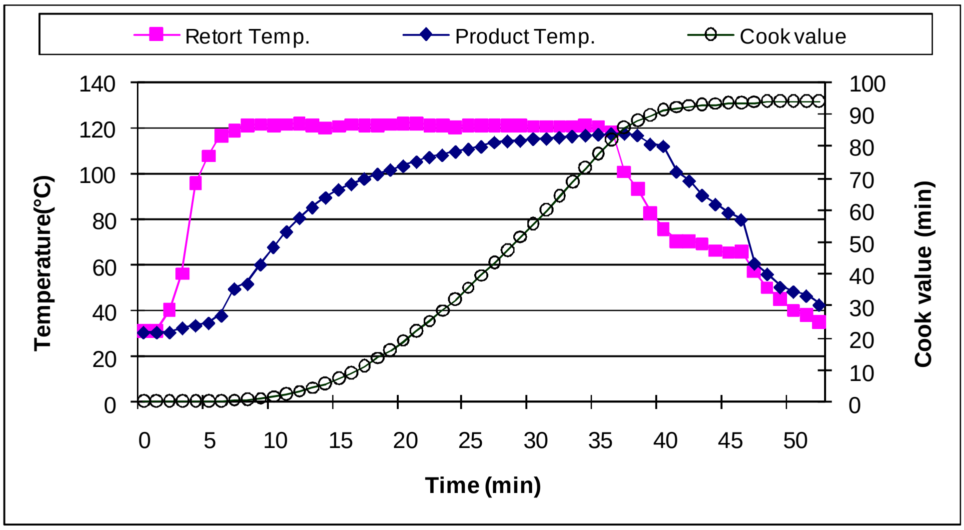


Figure-21a. Heat penetration characteristics and cook value of fish noodles in semi rigid containers

5.4.2 Effect of heat penetration parameters (Fo value of 5, 7 and 9) on sensory parameters

Table-15. Sensory scores of Fish noodles prepared at three different F_0 during standardization

Characteristics	F_0 5	F_0 7	F_0 9
Appearance	8.5 ± 0.04	8.4 ± 0.07	7.8 ± 0.04
Colour	8.2 ± 0.05	7.9 ± 0.04	7.5 ± 0.05
Odour	7.1 ± 0.04	7.1 ± 0.05	6.9 ± 0.04
Flavour	7.9 ± 0.07	8.2 ± 0.07	8.3 ± 0.08
Taste	8.2 ± 0.04	8.4 ± 0.05	7.8 ± 0.05
Texture	7.9 ± 0.07	8.2 ± 0.05	7.6 ± 0.13
Overall acceptability	7.96	8.03	7.65

After thermal processing, appearance and colour of fish noodles diminished with increase of Fo-values; whereas, flavour was enhanced. There was no significant difference for odour of fish noodles treated at Fo 5 and Fo 7. Better taste and texture score was obtained for the fish noodles treated at Fo 7. Among the treated sample, fish noodles of Fo 7 value was found better overall acceptability score.

5.4.2.1 Mean comparison of effect of Fo values on sensory properties of thermal processed fish noodles by qualitative descriptive analysis

Table 16. Ranked data of Fo values on sensory properties of thermal processed fish noodles

Characteristics	Treatments	Mean Rank
Appearance	Fo 5	12.60
	Fo 7	8.40
	Fo 9	3.00
Colour	Fo 5	13.00
	Fo 7	8.00
	Fo 9	3.00
Odour	Fo 5	9.50
	Fo 7	11.50
	Fo 9	3.00
Flavour	Fo 5	3.00
	Fo 7	8.60
	Fo 9	12.40
Taste	Fo 5	8.00
	Fo 7	13.00
	Fo 9	3.00
Texture	Fo 5	7.80
	Fo 7	13.00
	Fo 9	3.20
Overall acceptability	Fo 5	8.20
	Fo 7	12.80
	Fo 9	3.00

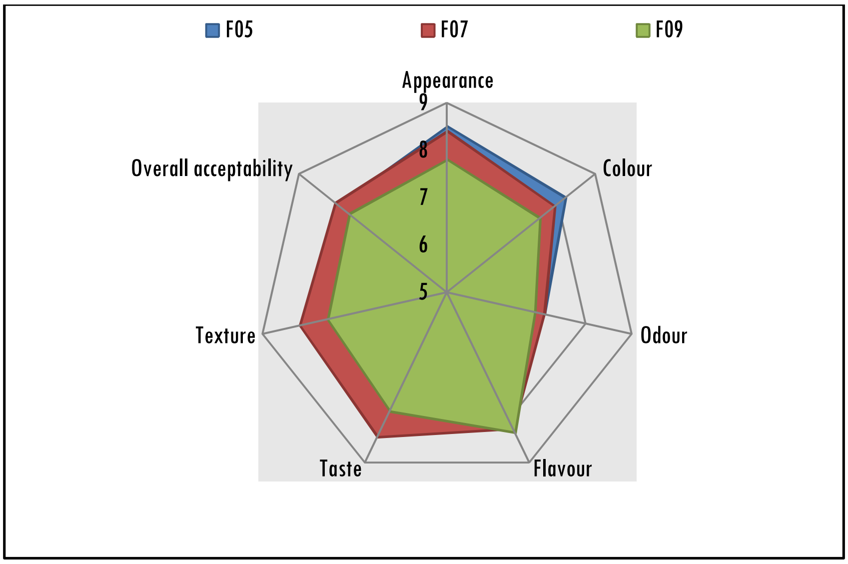


Figure-22. Radar diagram showing the acceptability score on different Fo values

The sensory acceptability of food is important because people obtain great sensory pleasure during the consumption. The sensory parameters were assessed on a 10 point hedonic scale and the measurements observed in the form of ranked scale. The mean ranking is given in Table-16. When comparing the appearance of the sample Fo 5 had a maximum rank of 12.60. For colour also Fo 5 scored the maximum value of 13.00. For the sensory parameters like odour, taste and texture Fo 7 had the maximum ranked value of 11.50 and 13.00 each, respectively. Only flavour part correlated best with Fo 9. Finally, the overall acceptability score was found to be good for Fo 7 and had a maximum mean rank of 12.80.

5.4.3 Effect of heat penetration parameters (Fo value of 5, 7 and 9) on colour values

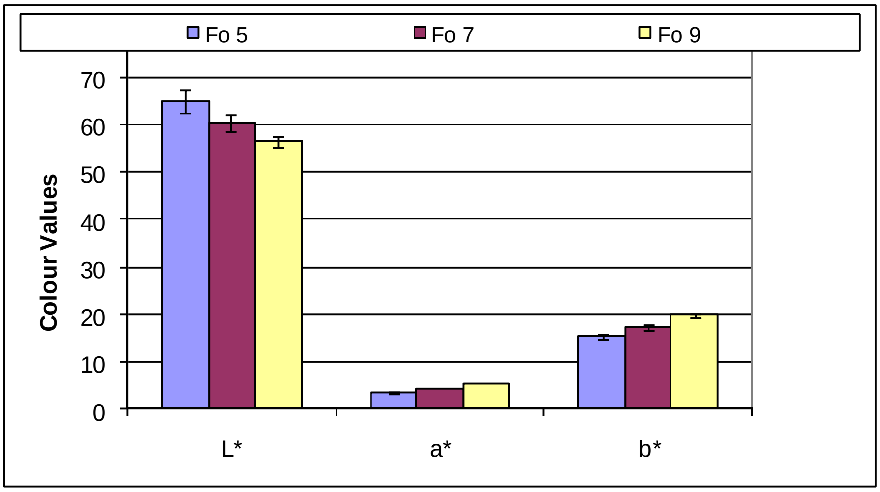


Figure-23. Hunter lab colour values on Fo values

The changes in colour values with different Fo values are presented in Figure-23. Colour values of fish noodles were significantly different with Fo-values. The effects of treatments (Fo 5, Fo 7 and Fo 9) on Hunter Lab colour values was analysed by one way analysis of variance and the treatment means were compared by Tukeys post Hoc test. Lightness (L* value) of thermally processed fish noodle was significantly reduced with increasing Fo values; whereas, yellowness (b*) and redness (a*) were increased significantly (p <0.05). Fanbin et al. (2007) reported an increase in the yellowness of salmon during thermal processing. Berset (1989) and Haard (1992) suggested that chemical reaction between amino acids and reducing sugars are responsible for colour changes of seafood which facilitate with thermal processing. When the fish noodles were thermally processed at Fo of 5, L* value was 65.14. As the thermal processing time increase the whiteness decreased to 60.55 and to final value of 56.71 for Fo

9. Redness (a*value) significantly increased as thermal processing time increased. It was found that redness value of 3.51 was reported for thermally processing fish noodles of Fo 5. It increased to 4.16 for fish noodles processed for Fo 7 and to a final value of 5.38 for Fo 9 processed fish noodles. The yellowness (b* value) also significantly increased from 15.39 for Fo 5. The changes in yellowness (b*) and redness (a*) during extrusion cooking of showed to represent only the effects of browning reactions as the thermal process time increased. Based on sensory property and Hunter lab colour measurement, it was found that thermally processed noodles at Fo 7 min was rated better compared to other two samples.

5.5 Conclusions

Fish noodles were successfully thermal processed by retorting in overpressure autoclave. Process parameters were standardised for the preparation of ready to eat fish noodles. Among the Fo value of 5, 7 and 9 min, Fo value of 7min and cook value of 74.78 min were found to be optimum for processing fish noodles in see through retortable pouch. The total process time taken for thermal processing of Fo 7 is 36.04 min. The product remained in good condition by visual appearance. Result of statistical analysis revealed that significant difference was observed on the effect of thermal processing time on colour values. Kruskal-Wallis non parametric ANOVA was carried out to find the significant changes in sensory score on different Fo values and It was found to be significant (p <0.05). The packaging material was ideal for thermal processing for fish noodles. The processing of the product to a Fo value of 7 min was found to be ideal to get desired colour, sensory characteristics and storage stability of the product.

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Chapter 6

STORAGE STUDY OF THE READY TO EAT FISH NOODLES AT AMBIENT TEMPERATURE CONDITION

Contents

6.1 Introduction

Most commercially sterile foods have a shelf life of 2 years or more. Any deterioration that occurs over time is due to texture or flavour changes (Vickie and Elizabeth, 2008). Spoilage in thermal processed foods arises by microbial action because of improper sterilisation. Since thermal processing is a heat intensive process resulting significant loss of colour and flavour. Textural changes also occur during thermal processing. Softening of the tissues due to physical and chemical changes may render the food unacceptable to the consumers (Rao and Lund, 1986). The quality during storage can be assessed in different ways. They are sensory assessment, chemical method, microbiological and instrumental method. Sensory method is used throughout the fish processing industry to judge the quality of the product. In chemical methods of quality, the various products of spoilage in fish muscle are quantitatively determined and correlated with sensory characteristics. In instrumental methods, texture of the fish products is often good measure of the quality. In thermal processed foods, bacterial spoilage is not common, unless it is under processed.

6.2 Objective

Present experiment was carried out to evaluate the shelf life of thermally processed (Fo 7) fish noodles packed in high impact polypropylene containers during ambient storage. The changes in physicochemical and sensory quality of the fish noodles were also determined.

6.3 Materials and Methods

6.3.1 Determination of pH

pH of the sample was estimated by the methodology described in the Chapter 3, section 3.3.8.1.

6.3.2 Determination of moisture content

Moisture content of the sample was estimated by the methodology described in the Chapter 3, section 3.3.5.1.

6.3.3 Determination of TBA value

Procedure for the determination of TBA content in the sample is discussed in Chapter 3, section 3.3.7.1.

6.3.4 Determination of FFA value

Methodology for the estimation of FFA content is described in Chapter 3, section 3.3.7.2.

6.3.5 Commercial sterility test

Procedure for the determination of TBA content in the sample is discussed in Chapter 5, section 5.3.4.

6.3.6 Amino acids analysis

Total amino acid composition was determined following the method of Ishida *et. al.*, (1981) using Shimatzu amino acid analyzer. About 100-150 mg of sample was weighed accurately into a heat sealable test tube. 10ml of 6N HCl was added and the tubes were heat sealed after filling pure nitrogen gas. Hydrolysis was carried out in a hot air oven at 110^{o}C for 24 hours. After the hydrolysis, the content were removed quantitatively and filtered into a round bottom flask through Whatmann filter paper No.42. The content of the flask were flash evaporated to remove trace of HCl and the process repeated for 2-3 times with added distilled water. The residue was made up to 10ml with 'C' buffer (0.05N HCl). The sample thus prepared was filtered again through a membrane filter of 0.45micron size. Of this 20µl was injected to Shimatzu amino acid analyzer equipped with an ion exchange column (Shodex CX Pak P-421S), fluorescence detector and post-column derivatization chamber. A binary gradient elution programming was used. Buffer-A, was prepared by dissolving 13.31 g of trisodium citrate in 70 mL ethanol, followed by addition of citric acid monohydrate (12.8 mL), NaCl (3.74 g) and Brij® (4mL). Finally the pH was adjusted to ~3.2 with drop wise addition of perchloric acid and volume was made up to 1 L. Buffer-B was prepared by dissolving tri-sodium citrate (117.6 g) and Boric acid (24.8 g) in 500 ml distilled water followed by addition of 45 ml 4N NaOH. Final volume was made up to 2L with distilled water (~pH10). Elution programme (flow rate 0.4 ml/min) started with 100% Buffer- A and was kept constant for 12 min, followed by stepwise gradient to 100% Buffer-B at 35th min. Buffer-B was kept constant up to 55th minute. Next 1 min, again 100% buffer-A concentration was achieved. Total run time was 70 min. Post-column derivatization with O-phthalaldehyde in the presence of sodium hypochlorite solution, amino acids were detected in fluorescence detector (Excitation 340 nm, Emission 450 nm). Quantification was done with the help of external standard mixture of amino acids (Sigma). The results were expressed in g/100 g of sample.

6.3.6.1 Determination of tryptophan

Total amino acid composition was determined following the method of Sastry and Tummuru (1985) using Shimadzu-UV spectrophotometer. About 200-300 mg of sample was hydrolyzed with 10 ml of 5% NaOH at 110ºC for 24 hours in a sealed tube filled with pure nitrogen. The hydrolysate was neutralized to pH 7 with 6 N HCl using phenolphthalein indicators. The volume was made up to 100ml with distilled water. The solution was then filtered through whatman filter paper No.1 and filtrate was used for estimation. To a test tube containing 4ml of 50% H_2SO_4, 0.1 ml of 2.5% sucrose and 0.1 ml of 0.6% thioglycolic acid were added. These tubes were kept for 5 min in water bath at 45-50 ºC and cooled. The sample was then added to the test tubes. A set of (0.1 to 0.8) standard tryptophan (10µg/ml) was treated similarly. The volume was made up to 5 ml with 0.1 N HCl and allowed to stand for 5 min. The absorbance was measured using Shimadzu-UV spectrophotometer at 500 nm. The concentration was obtained by drawing standard graph.

6.3.7 Determination of colour values

Procedure for the estimation of colour of the sample was described in Chapter 3, section 3.3.10.

6.3.8 Determination of TPA parameters

Procedure for the estimation of colour of the sample was described in Chapter 3, section 3.3.8.2.

6.3.9 Sensory score

Procedure for the estimation of colour of the sample was described in Chapter 3, section 3.3.12.

6.3.10 Statistical analysis

Physicochemical characters like pH, moisture, TBA, TVB-N, FFA colour values (L*, a* and b* values) and TPA were statistically analysed using one way ANOVA and mean values were compared using Tukey's post hoc test. Sensory Score was analysed by Kruskal Wallis one way ANOVA. Wilcoxon Scores (Rank Sums) were used for comparing significant difference during storage. Spearman rank correlation coefficient was computed for sensory parameters vs. texture profile analysis and sensory parameters vs. colour parameters. All the statistical analysis was done using SAS 9.3.

6.4 Results and Discussion

6.4.1 Changes in the pH

The change in pH of thermally processed fish noodles during storage at ambient temperature is presented in Figure-24. The initial pH of the sample was 6.41 which reduced to 6.32 on 10^{th} day of storage; whereas, on 80^{th} and 90^{th} day of storage it reached a value of 6.26 and 6.21, respectively. The slight decrease in pH value could be due to the oxidation of products. The changes in pH during storage days was statistically compared using one way ANOVA and the mean pH values were compared using Tukey's post hoc test. There was significant difference in pH of the sample was observed with storage days (p<0.05).

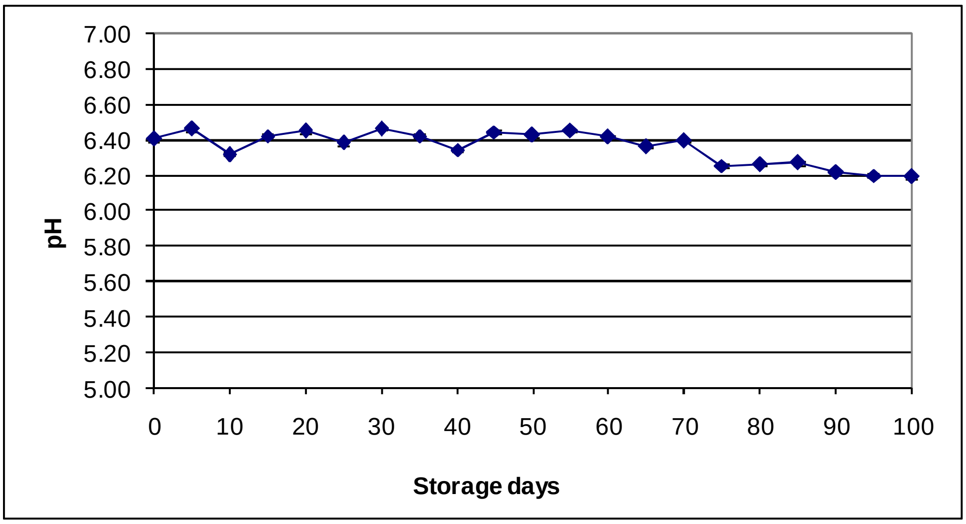

Figure-24. Changes in pH of thermally processed fish noodles during storage

6.4.2 Changes in moisture content

The changes in moisture content of thermally processed fish noodles during storage are presented in Figure-25. Initially the moisture content of the sample was 65.5%. During storage, there was loss in moisture content of the sample and it reached to 62.3% at the end of storage (p<0.05). The slight reduction in the moisture content of the fish noodle may be due to the presence of oil content in the pack, which penetrated into the sample during the storage which removes the moisture (Mohan, 2004) and also some extent to the permeability of the packaging material towards water vapour. Significant difference in moisture content of the sample was observed during storage days (p<0.05).

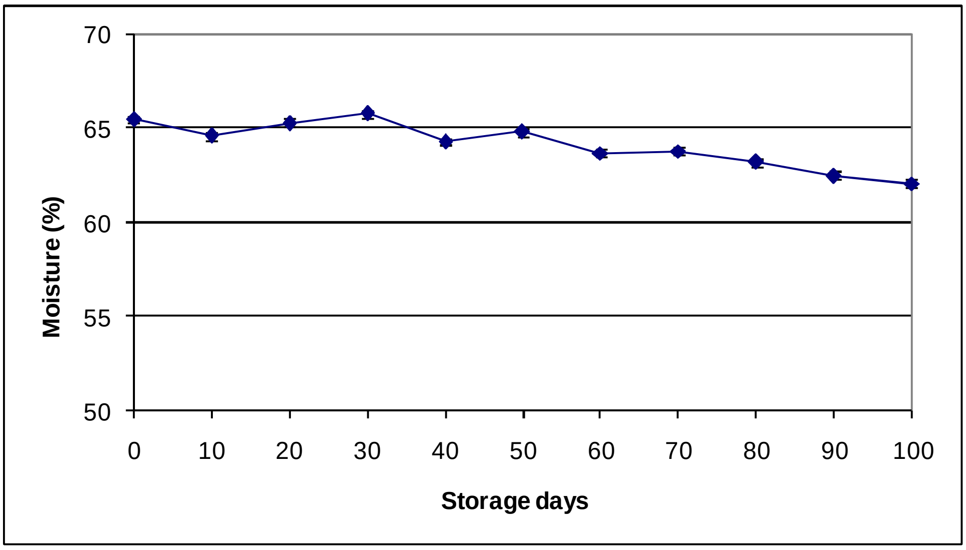

Figure-25. Changes in moisture content of thermally processed fish noodles during storage

6.4.3 Changes in TBA value

TBA measures the malonaldehyde formed during fat oxidation. Initially the TBA contents of the fish noodles were 0.124 mg malonaldehyde/kg of sample. Changes in TBA value of fish noodles with respect to storage period is depicted in Figure-26. TBA value significantly increased with storage time. One way ANOVA was performed and it was observed that there was significant difference in TBA values during storage ($p < 0.05$). 1-2 mg is the limit of acceptability. TBA values of 0.199 and 0.346 was recorded on 30 and 60th day of storage. It was found that on 90th day of storage, TBA value reached to 0.392 mg malonaldehyde /kg sample; this is well below the limit of acceptability.

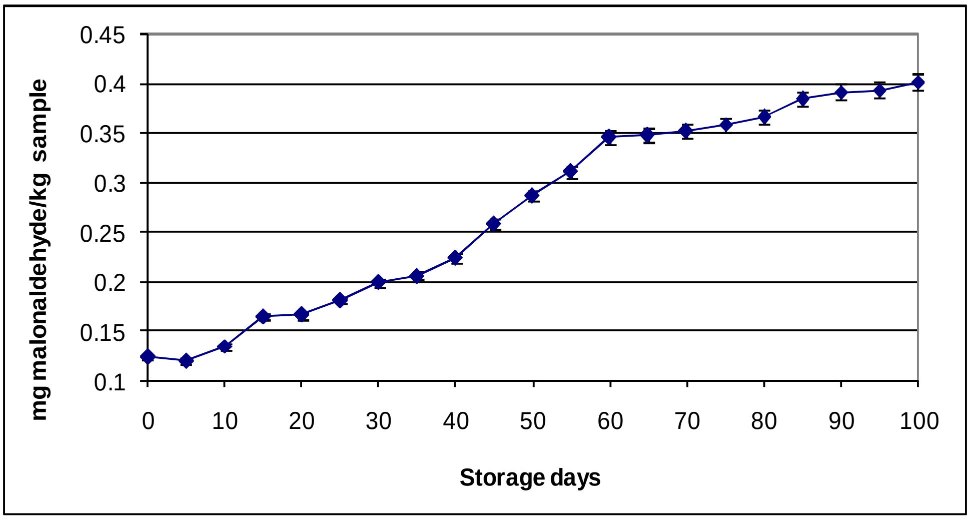

Figure-26. Changes in TBA value of thermally processed fish noodles during storage

6.4.4 Changes in FFA value

Initially the FFA content was 10.96% of oleic acid. The higher amount of FFA content accounts for the presence of oil added to the noodles for preparation. Hydrolysis of lipid releases FFA, which contribute significantly towards textural changes (Sikorski and Kolakowska, 1994) and lipid oxidation of seafood (Sequeira-Munoz et al. 2006). FFA also showed an increasing trend during storage (Figure-27). This could be due to the permeability of see through pouches during storage and this agrees with slightly increased OTR and WVTR value of see through pouches. One way ANOVA was performed and tukeys test was performed to find the significant difference in the FFA values during storage period. FFA attained a value of 14.36 % 17.79 and 19.85 % of oleic acid on 30th, 60th and 90th day of storage, respectively.

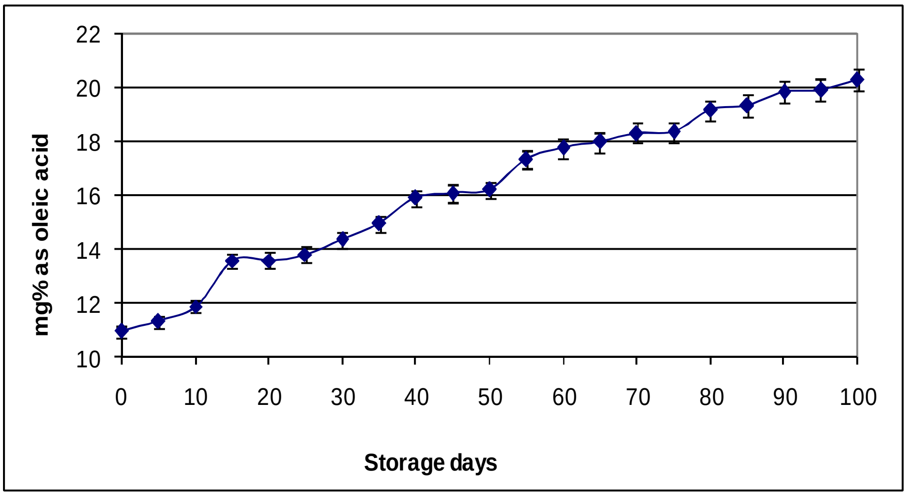

Figure-27. Changes in FFA value of thermally processed fish noodles during storage

6.4.5 Changes in amino acid content

The changes in amino acids content in raw fish noodles, thermal processed and during storage period is shown on Figure-28. Amino acid analyses of fish noodles from a mixture of refined wheat four-fish mince mixture showed a higher proportion of glutamic acid and lysine compared with other amino acids present in the sample. The high amount of the above mentioned amino acid content record the added fish mince. Because of the high content of glutenins and gliadines, wheat proteins are deficient in lysine, which is one of the essential amino acid (Ram and Mishra, 2010; Garrow and James, 1993). It can be noticed that after thermal processing also there was retention of amino acid. Several authors reported that commercial thermal processing will not destroy significant amount of amino acid in fish products (Neilands et al. 1949; Dunn et al.1949; Mohan et al. 2006. There were little changes in amino acid content during the storage of fish noodles at ambient temperature. The presence of all the essential amino acid in the sample emphasizes the nutritional value of fish noodles. No literature was available on the changes in amino acids profile of fish noodles during prolonged storage.

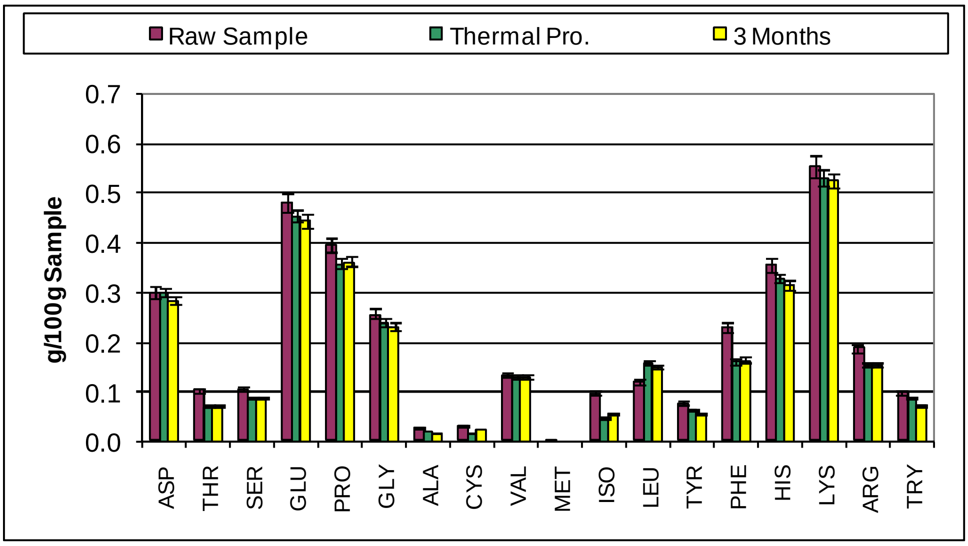

Figure-28. Changes in amino acid content during storage period

6.4.6 Changes in colour values

Colour and appearance of fish products have great role for consumer acceptability (Harada, 1991). The changes in the CIE L* a* and b* values of fish noodles and changes during storage are given in Figure-29. Colour is one of the most important aesthetic features in the quality of noodles. A decrease in the L* values (lightness) in the fish noodles was observed during storage. The initial L* values for fish noodles stored at ambient temperature were 60.73. During storage, it reduced to a value of 59.87 and 57.66 on 30th and 60th day of storage, respectively. Finally on 90th day of storage the L* value was 55.59. The decrease in the lightness value accounts for the see through pouch. Redness (*a**) values increased from initial value of 4.15 to 5.66 on 30th day of storage (Figure-30). As the storage days increased to 60th day and 90th day, the redness value was 5.83 and 6.66, respectively. The b* values (yellowness) increased during storage period (Figure-31). Initial value of 17.35 was recorded for thermally processed fish noodles. It increased to 17.45, 18.49 and

18.89 on 30th, 60th and 90th day of storage. One way ANOVA was performed and there was significant difference in colour values during storage. The increase in the b* value accounts for the maillard browning reaction that occur between the amino acid present in the fish and starch present in refined wheat flour. Although the maillard reaction is primarily responsible for much of the colour that develops when most foods are heated (Ames, 1992).

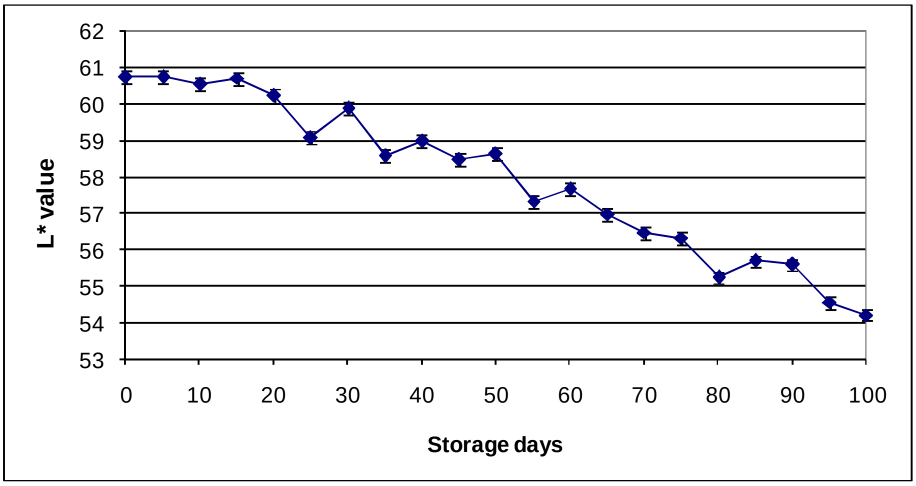

Figure-29. Changes in colour values (L*value) of thermally processed fish noodles during storage

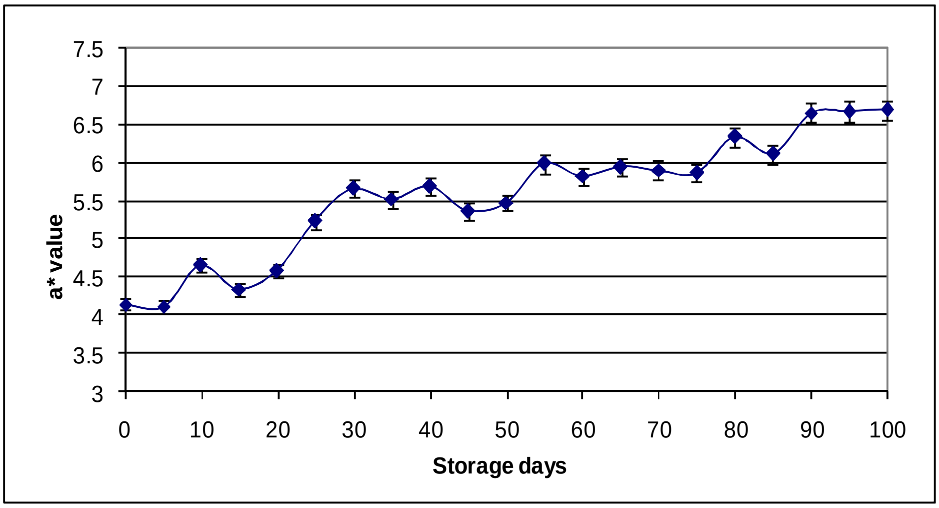

Figure-30. Changes in colour values (a*value) of thermally processed fish noodles during storage

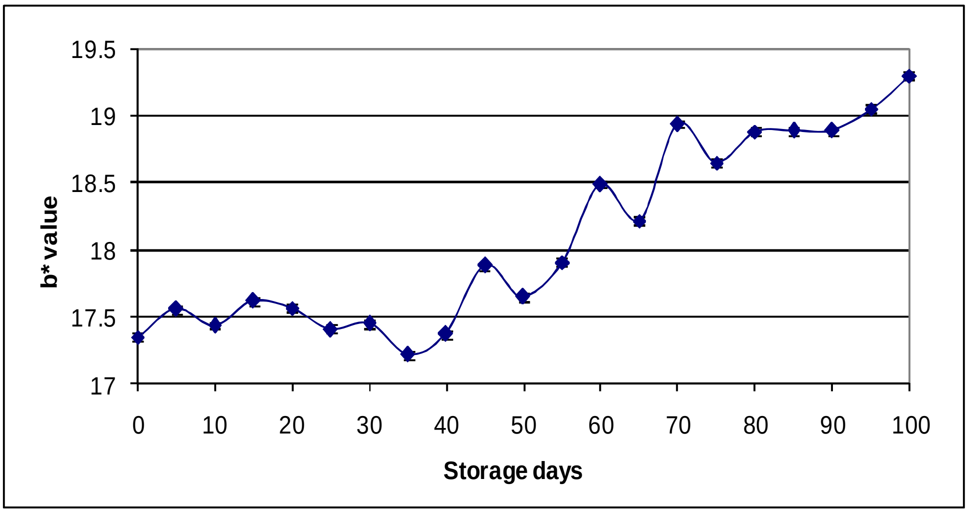

Figure-31. Changes in colour values (b*value) of thermally processed fish noodles during storage

6.4.7 Changes in texture profile analysis

Texture is defined as the sensory and functional manifestation of the structural and mechanical properties of foods, detected through the senses of vision, hearing, touch and kinaesthetic (Szczesniak, 2002). The peak force during the compression is known as hardness. It is identified as Hardness-1 for the peak during the first compression and Hardness-II for the peak during the second compression. It was found that there was slightly increasing trend for Hardness-1 and Hardness-II parameters during storage period (Figure-32). Cohesiveness, gumminess and chewiness follow the same trends as hardness-1 during storage period. One way ANOVA was performed for all the attributes and tukeys grouping was performed to find the significant difference during storage period. The noodles had an initial hardness of 5.55 N. The hardness-1 increased to 6.24 N after 30th days of storage. It further increased to 8.06 N and 8.71 N on 60th and 90th day of storage (p<0.05); respectively. The increase in the hardness could be due to decrease in the moisture content on storage. Cohesiveness refers to the visco-elasticity of the product. On the initial day, the cohesiveness was of 0.49 and It increased to 0.51, 0.70 and 0.78 on 30th, 60th and 90th day of storage ($p<0.05$), respectively (Figure-33). Springiness refers to elasticity of the sample, which was 0.116 mm on the initial day of storage (Figure-34). The product remained in elastic behaviour throughout the storage period. There was no significant difference in springiness during the storage ($p<0.05$). Gumminess also increased during the storage period (Figure-35). Gumminess refers to the quantity to stimulate the energy required to disintegrate the semisolid product. Gumminess values were 0.297kgf, 0.323kgf, 0.576kgf and 0.691 kgf on initial, 30th, 60th and 90th day of storage ($p<0.05$), respectively. Chewiness is the quantity to stimulate the energy required to masticate a sample and it is the product of hardness, cohesiveness and springiness. On the initial day, the chewiness value was 0.032 kgf.mm. It increased to 0.062 kgf.mm on 60th day of storage period. On the 90th day of storage, chewiness value was 0.074kgf.mm ($p<0.05$) (Figure-36). Adhesiveness is the force required to remove food that adheres to the mouth. The quantity to stimulate the work necessary to overcome the attractive force between the surfaces of the sample and the surface of the probe with which the samples comes into contact was -0.0152 kgf.mm on the initial day of storage. The values for 30th, 60th and 90th days of storage were found to be -0.0178, -0.0227 and -0.0212, respectively (Figure-37). Dexter et al. (1983) reported that surface stickiness of spaghetti was partly related to the semolina protein content. One way ANOVA revealed that there was significant difference of texture of thermally processed fish noodles during storage ($p<0.05$).

The value obtained for TPA indicated that the mechanical texture characteristics were in agreement with the same attributes analyzed by sensory panel.

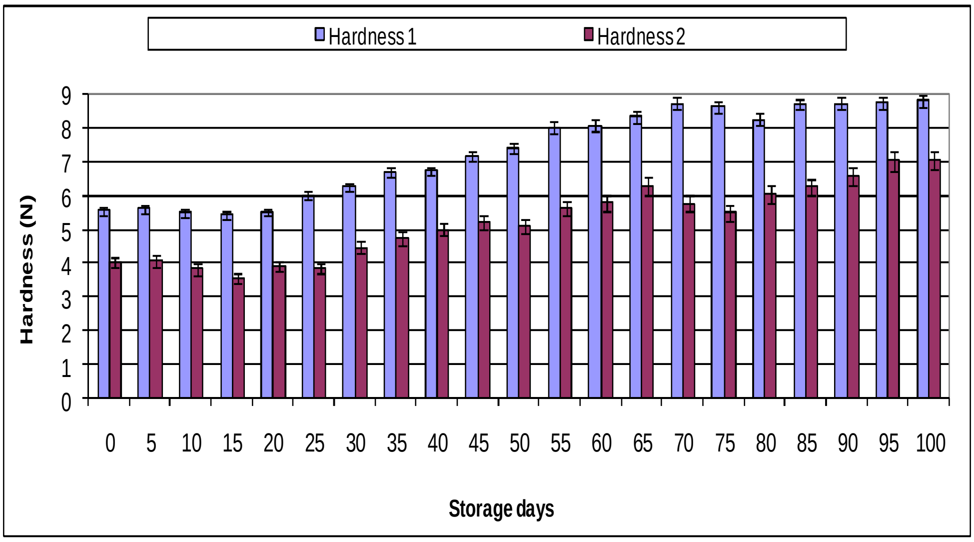

Figure-32. Changes in texture profile (Hardness-I and II) of thermally processed fish noodles during storage period

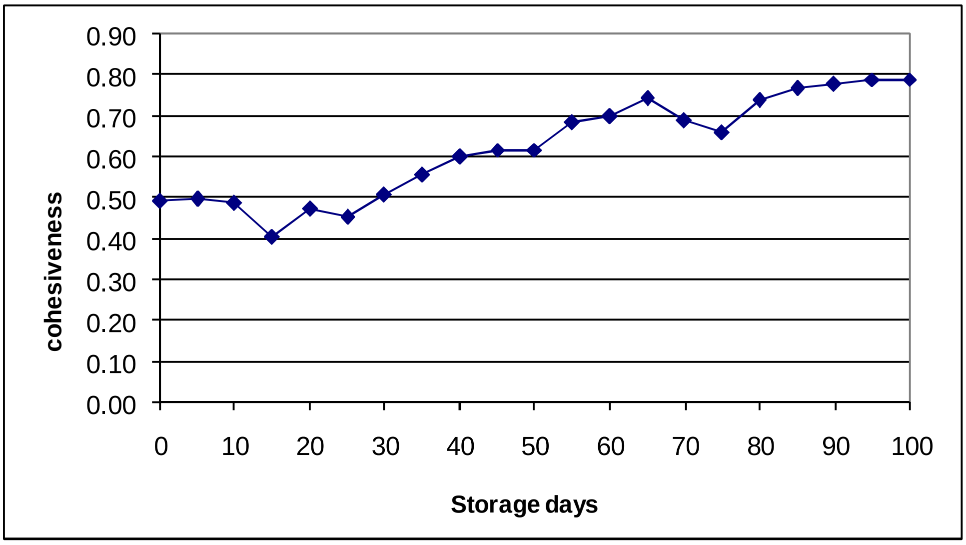

Figure-33. Changes in texture profile (cohesiveness) of thermally processed fish noodles during storage period

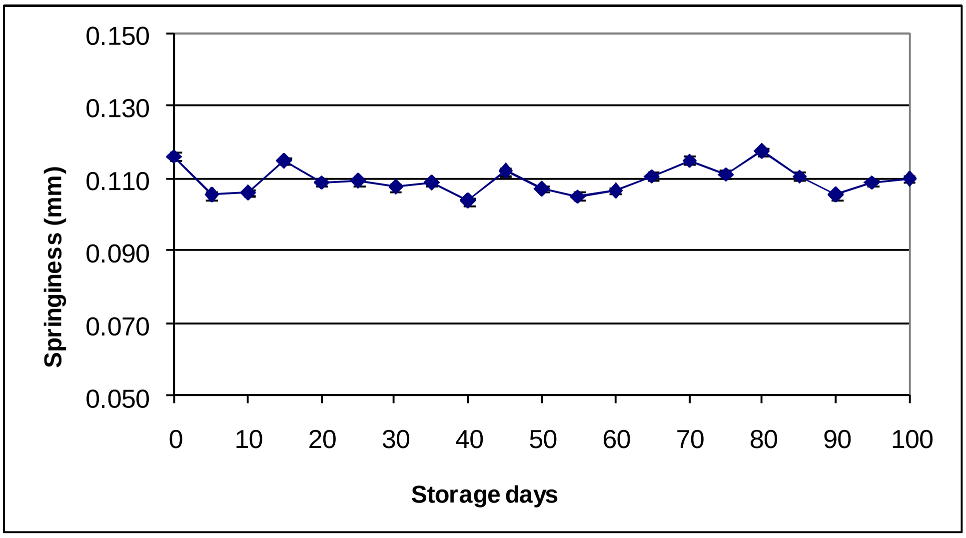

Figure-34. Changes in texture profile (springiness) of thermally processed fish noodles during storage period

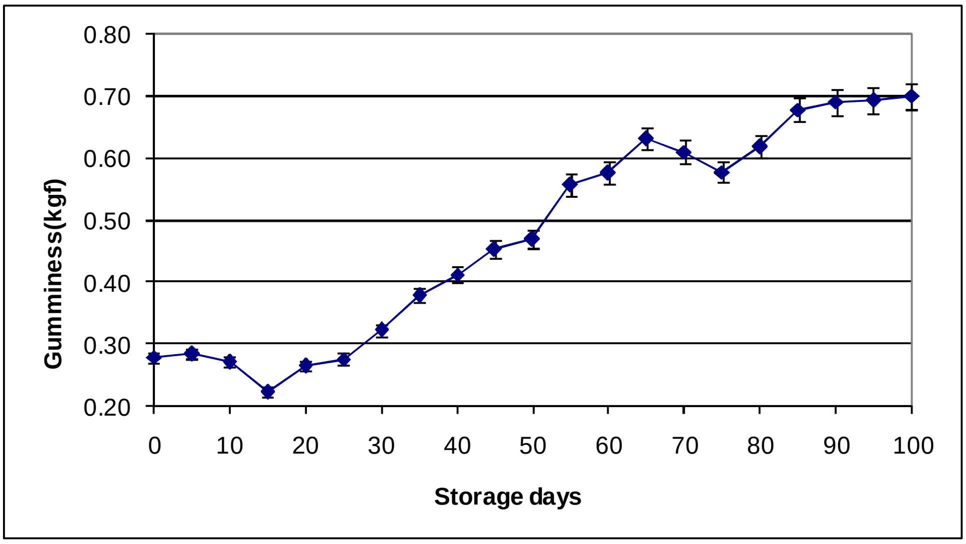

Figure-35. Changes in texture profile (gumminess) of thermally processed fish noodles during storage period

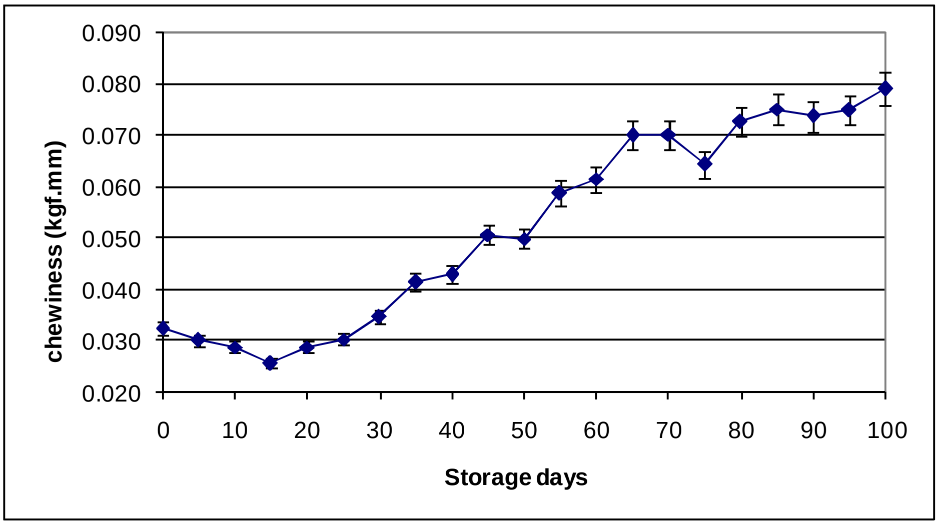

Figure-36. Changes in texture profile (chewiness) of thermally processed fish noodles during storage period

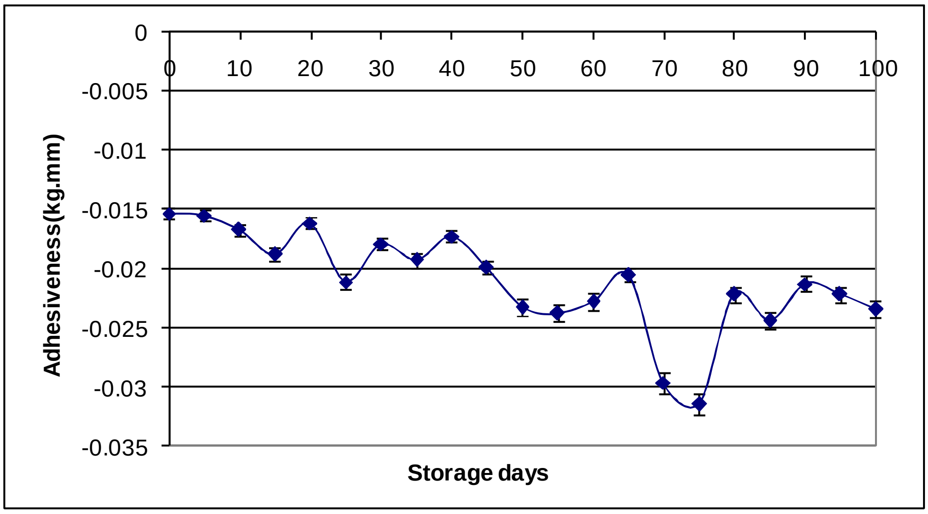

Figure-37. Changes in texture profile (adhesiveness) of thermally processed fish noodles during storage period

6.4.8 Commercial sterility test

The activity of microorganisms is the main factor limiting the shelf life. Sterility test was conducted and showed no growth of microorganisms indicating that the products were commercially sterile throughout the storage period.

6.4.9 Changes in sensory score

Sensory methods are universally applied for the estimation of quality of food in markets, in retail shops and table of the consumer (Nair and Lahiry, 1968). Sensory methods are sensitive, objective and reliable when conducted under standardized conditions by trained personnel (Sims et al. 1992). Sensory evaluation is one of the oldest and most widespread means of evaluating the acceptability and edibility, which can be defined as the scientific discipline used to evoke, measure, analyse and interpret characteristics of food as perceived by the senses of sight, smell, taste and touch. Figure-38 shows the changes in sensory scores of fish noodles during the storage period. Sensory evaluation of noodle eating quality is a direct and ultimate method for evaluating the final product. It was found that during storage, appearance, colour and texture was mostly affected. This could be due to the permeability of see though pouch as well as the Maillard Browning reaction taking place during storage. A score of 8.4 was got for appearance initially. Usually appearance can be evaluated using three parameters: brightness, yellowness and discoloration (Yun et al. 1997). It decreased to 7.5, 5.5 and 4 on 30th, 60th and 90th days of storage. A score of 4 was taken as the acceptable limit for determining the shelf life. Colour values also decreased from a score of 7.9 initially to 7.2, 5.5 and 4.1 for 30th, 60th and 90th days of storage. This is agreement with the values obtained from the instrumental colour values. The instrumental colour values were also found to decrease during storage. The texture of the fish noodles decreased during storage period and low sensory score was obtained at the end of storage. This is agreement with the values obtained by TPA Hardness1 values. Initially good sensory score of 8.2 was obtained for texture. The values decreased to 7.8, 6.8 and 4.1 on 30, 60 and 90 days of storage. Odour, flavour and taste were good till the end of storage period. Initially the score obtained for odour, flavour and taste was 7.1, 8.2 and 8.4, respectively and it reached a value of 5.8, 6.5 and 6.9 on 90th day of storage. The Overall Acceptability Score was obtained by adding all the attributes viz, appearance, colour, odour, flavour, taste and texture (Figure-39). A final score of 5.3 was obtained on 90th day of storage. Kruskal Wallis one way ANOVA was performed and it was observed that there was significant difference in mean ranking of sensory parameters ($p<0.05$) during different storage days. Wilcoxon Scores (Rank Sums) was computed and compared to find out significant difference in the mean scores during storage period in each attributes. Since appearance, colour and texture reached the limit of acceptability, the fish noodles were sensorally accepted for 90th days of storage.

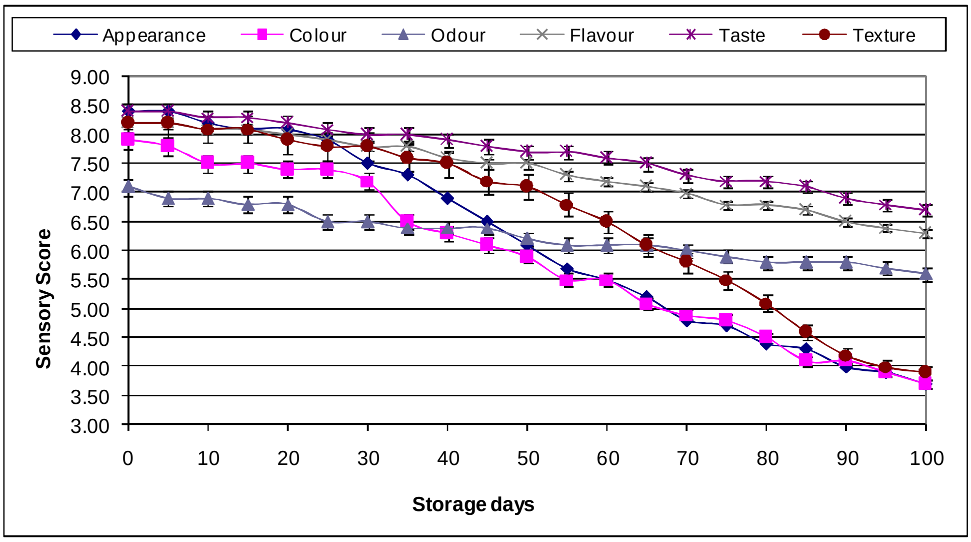

Figure-38. Changes in Sensory characteristics of thermally processed fish noodles during storage period

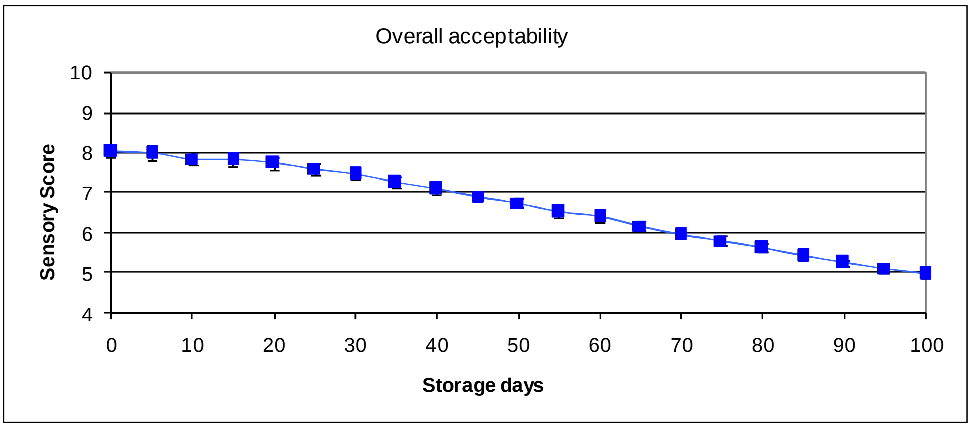

Figure-39. Changes in Overall Acceptability Score of thermally processed fish noodles during storage period

6.4.10 Correlation

6.4.10.1 Relationship between the overall sensory acceptability and color parameters at the end of storage period at ambient temperature

The correlation coefficient between sensory parameters and colour parameters (L*, a* and b*) during 90 days of storage period at ambient temperature is given in the Table-17. The L* found to have highly significant positive correlation with all the sensory parameters; whereas, a* and b* produced significant negative correlation with all the sensory parameters.

Table-17. Spearman correlation coefficient on sensory parameters and CIE Lab colour values. Correlation is significant at the 0.05 level

Parameters	L* value	a* value	b* value
Appearance	0.97893<.0001	-0.93942<.0001	-0.84058<.0001
Colour	0.98155<.0001	-0.94200<.0001	-0.84308<.0001
Odour	0.98280<.0001	-0.94042<.0001	-0.82775<.0001
Flavour	0.97846<.0001	-0.93890<.0001	-0.84169<.0001
Taste	0.97319<.0001	-0.93275<.0001	-0.83905<.0001
Texture	0.98287<.0001	-0.93896<.0001	-0.83480<.0001
Overall Acceptability	0.98070<.0001	-0.93860<.0001	-0.84335<.0001

6.4.10.2 Relationship between the overall sensory acceptability and textural parameters at the end of storage period at ambient temperature

The correlation among sensory acceptability and texture profile analysis at the end of storage period of 90 days stored at ambient temperature is given in the Table-18. The textural parameters like hardness, cohesiveness, springiness, gumminess, chewiness found to have highly significant positive correlation with all the sensory parameters; whereas, adhesiveness produced significant negative correlation with all the sensory parameters.

Table-18. Spearman correlation on sensory parameters and texture profile analysis values. Correlation is significant at the 0.05 level

Parameters	Hardness1	Hardness2	Cohesiveness	Springiness	Gumminess	Chewiness	Adhesiveness
Appearance	-0.94950 <.0001	-0.91484 <.0001	-0.92000 <.0001	-0.11352 0.6436	-0.93942 <.0001	-0.94857 <.0001	0.81242 <.0001
Colour	-0.94901 <.0001	-0.91740 <.0001	-0.92521 <.0001	-0.09019 0.7135	-0.94025 <.0001	-0.94897 <.0001	0.80520 <.0001
Odour	-0.94083 <.0001	-0.90157 <.0001	-0.90850 <.0001	-0.10262 0.6759	-0.92806 <.0001	-0.93901 <.0001	0.83083 <.0001
Flavour	-0.95339 <.0001	-0.91605 <.0001	-0.92122 <.0001	-0.09819 0.6892	-0.93978 <.0001	-0.94982 <.0001	0.80644 <.0001
Taste	-0.95339 <.0001	-0.91253 <.0001	-0.91901 <.0001	-0.09376 0.7026	-0.93978 <.0001	-0.94718 <.0001	0.80908 <.0001
Texture	-0.95167 <.0001	-0.91524 <.0001	-0.92084 <.0001	-0.09943 0.6855	-0.93983 <.0001	-0.94943 <.0001	0.81101 <.0001
Overall Acceptability	-0.95129 <.0001	-0.91754 <.0001	-0.92227 <.0001	-0.09444 0.7006	-0.94035 <.0001	-0.94774 <.0001	0.80775 <.0001

6.5 Conclusions

Present study found better shelf life of thermally processed fish noodles and also its biochemical parameters were well within the limit of acceptability. Changes in CIE L*a*b*values of fish noodles during storage revealed that the lightness decreased and yellowness increased during the storage period. The instrumental texture analysis showed an increasing trend for hardness 1 and hardness II, cohesiveness. The product remained in elastic behaviour throughout the storage period. TPA indicated that mechanical texture characteristics were in agreement with the same attributes analyzed by sensory panel. There was no significant difference in springiness during storage. Gumminess and chewiness increased during storage. The product was found to be sticky when the storage days increased. Sensory analysis revealed that during storage, appearance, colour and texture was mostly affected. Appearance of the sample decreased during storage period. Odour, flavour and taste were well accepted even at the end of storage period. Based on the overall acceptability, thermally processed fish noodle was revealed to have shelf life of 90 days at ambient temperature.

Chapter 7

SUMMARY AND CONCLUSIONS

The changing market demands is one of the aspects in developing value added products to basic agricultural commodities. Modern consumer prefers processed foods which is convenient to use. Preferences for ready to eat products are in increasing trends. Among different types of value added products, thermally processed products are gaining importance. Noodles are popularly consumed in many Asian countries because of their simple cooking process and low price. Cereal flours are low in protein content and are limited in some essential amino acid. Fish is a good source of high quality proteins, polyunsaturated fatty acids, many vitamins and minerals. In order to increase the nutritive value of extruded products, incorporation of protein-rich fish mince is a good alternative. Nowadays extrusion technology is used to produce noodles and other wide variety of food products. Thermal processing, one of the most widely used methods for fish preservation facilitates long-term stability for a wide range of seafood products. In case of thermal processing, packing materials are most important. Thermoformed trays and retortable pouch are commonly used packaging materials for thermal processing in most parts of the world.

The present study was to develop fish incorporated noodles by extrusion technology and to preserve in ready to eat form by thermal processing in semi rigid containers. Fish mince, pink perch (*Nemipterus japonicus*) of varying concentration from 5%, 10%, 15% and 20% were incorporated with maida in the ratio of 95%, 90%, 85% and 80%. It was then extruded with single screw extruder with noodle die at 90°C and dried in electrical dryer for 6 hours. Analysis of proximate composition of the fish noodles revealed that there was increase in protein content by the addition of fish mince. Experimental design using response surface methodology and D-optimal mixture experimental design with 9 runs was formulated to optimize the different levels of fish mince. The physical and sensory properties of the noodles were studied and result obtained in the present study revealed the combination of fish mince and refined wheat flour significantly altered the physical properties of fish noodles. Water Absorption Index reduced when the fish mince concentration increased. Noodle cooking quality was affected by the difference in protein content in fish noodles. Significant colour changes were found to affect the appearance of the noodles. An increasing trend in cooking time and decreasing trend in cooking loss of the noodles were observed as a function of different levels of fish mince and refined wheat flour. Quadratic model was found suitable to explain the effect of percentage of fish mince on rehydration capacity and on colour L* value. Whereas cubic model was fitted for bulk density, colour b* value, a* value, shearing strength and sensory property. From the physical properties and sensory evaluation point of view, 15% fish incorporated noodle was found to be superior among the samples. Desirability function score was computed by simultaneous evaluation of multiple responses to optimize the combination of different concentrations of fish-flour incorporated noodles. The maximum desirability function score at 15 % of fish mince and 85% of refined wheat flour was identified. Sorption characteristic revealed that the 15% fish incorporated noodles had a water activity of 0.48.

The standardised fish noodles was thermal processed in containers, which should withstand thermal process temperature and suitable for consumption. The packaging materials used were High Impact polypropylene tray. The size of the tray was 12.5 x 9.2 x 2.5 cm (length x breadth x height) having 220 ml capacity was prepared using 1.2 mm HIPP sheet. The trays were thermoformed in the laboratory.

The top of the tray was sealed with PEST/CPP film and the packed product was further repacked in see-through silicon dioxide incorporated retort pouch. The packaging material was tested for its food contact application. The overall migration residue levels of water extractives and n-heptane extractives for PEST/CPP film were 4.97 and 2.13 mg L-1, respectively. See through pouches had a level of 4.5 and 1.3 mg L-1. In case of HIPP trays the values were 5.4 and 3.6 mg L-1. The values obtained for the packaging materials were below the limits. It was observed from the results that the packaging materials can withstand thermal processing temperature of 121.1°C. The result also revealed that it can withstand a working pressure of 28 psig. The HIPP trays were ideal for thermal processing and do not change the shape during retorting.

The developed ready to cook fish noodles was thermally processed so as to be kept at ambient temperature for consumption. Thermal processing parameters have to be standardised for developing ready to eat fish noodles. Total process time taken for fish noodles in thermoformed containers to reach Fo value of 5, 7 and 9 were 29.37, 36.04 and 41.89 minutes, respectively. The commercial sterility test revealed that Fo values (ie., Fo 5, 7 and 9) were sufficient to get the product sterile. Cook value is measures of heat treatment were 41.03, 74.78 and 93.99 min for Fo 5, Fo 7, Fo 9 respectively. Effect of heat penetration parameters (Fo value of 5, 7 and 9) on sensory parameters revealed that appearance and colour of fish noodles diminished with increase of Fo-values; whereas, flavour was enhanced. There was no significant difference for odour of fish noodles processed at Fo 5 and Fo 7. Better taste and texture score was obtained for the fish noodles processed at Fo 7. Among the processed samples, fish noodles of Fo 7 value was found better overall acceptability score. Statistical comparison on the effect of Sensory properties on Fo values for thermal processing of fish noodles revealed that overall acceptability score was found to be good for Fo 7 and had a maximum value of 12.80. Effect of heat penetration parameters (Fo value of 5, 7 and 9) on colour values indicated that Lightness (L* value) of thermally processed fish noodle was significantly reduced with increasing Fo values; whereas, yellowness (b*) and redness (a*) were increased (p <0.05). Based on sensory property and Hunter lab colour measurement, it was found that thermally processed noodles at Fo 7 min was rated better compared to other two samples.

Storage study was conducted to evaluate the shelf life of thermally processed (Fo 7) fish noodles packed in high impact polypropylene containers during ambient storage (28±1 °C). The result revealed that there was a slight decrease in pH and moisture content was noticed during storage period. There was significant increase in the TBA and FFA values during the storage period. TBA value reached to 0.392 mg/kg sample on 90th day of storage indicating that the values were well below the limit of acceptability. FFA attained a value of 14.36 %, 17.79% and 19.85 % of oleic acid on 30th, 60th and 90th day of storage. On the analysis of amino acid content, it was found that there was not much change in the amino acid content in thermally processed fish noodles and also during storage period. However the higher content of glutamic acid and lysine compared to other amino acids is due to addition of fish mince in noodle preparation. Analysis of colour values in terms of L*, a*and b* values showed a decrease in the lightness during storage. The initial L*values for fish noodles stored at ambient temperature were 60.73. During storage it reduced to a value of 59.87 and 57.66 on 30^{th} and 60^{th} day of storage, respectively. Finally on 90^{th} day of storage the L* value was 55.59. There was an increase in a* and b* values during storage period. Initial value of 17.35 was recorded for thermally processed fish noodles. It increased to 17.45, 18.49 and 18.89 on 30^{th}, 60^{th} and 90^{th} days of storage. One way ANOVA was performed and there was significant difference in colour values during storage. Changes in the texture profile analysis also revealed that there was increase in the Hardness of fish noodles as the period of storage increased. The noodles had an initial hardness of 5.55 N. The hardness-1 increased to 6.24 N after 30^{th} days of storage. It further increased to 8.06 N and 8.71 N on 60^{th} and 90^{th} day of storage ($p<0.05$). Cohesiveness refers to the visco-elasticity of the product also increased during storage period. The elastic behaviour of the product retained throughout the storage period. Gumminess refers to the quantity to stimulate the energy required to disintegrate the semisolid product increased during storage. Chewiness is the quantity to stimulate the energy required to masticate a sample also increased on storage. There was a slight decrease in adhesiveness of the sample during storage. Sterility test was conducted and showed no growth of microorganisms indicating that the products were commercially sterile throughout the storage period.

Sensory evaluation of noodle eating quality is a direct and ultimate method for evaluating the final product. It was found that during storage, appearance, colour and texture was mostly affected. There was a decrease in the appearance of the sample during storage. A score of 8.4 was obtained for appearance initially. It decreased to 7.5, 5.5 and 4 on 30^{th}, 60^{th} and 90^{th} days of storage. Colour values also decreased from a score of 7.9 initially to

7.2, 5.5 and 4.1 on 30^{th}, 60^{th} and 90^{th} days of storage. The texture of the fish noodles decreased during storage period and low sensory score was obtained at the end of storage. Odour, flavour and taste were good till the end of storage period. The Overall Acceptability Score was obtained by adding all the attributes viz, appearance, colour, odour, flavour, taste and texture. A final score of 5.3 was obtained on 90th day of storage. Kruskal Wallis one way ANOVA was performed and it was observed that there was significant difference in mean ranking of sensory parameters ($p<0.05$) during different storage days. Since appearance, colour and texture reached the limit of acceptability, the fish noodles were sensorally accepted for 90 days of storage.

In conclusion, fish mince, pink perch (*Nemipterus japonicus*) of 15% fish mince and 85% refined wheat flour was used for the production of noodles. The physical and sensory properties of the noodles were studied and result obtained in the present study revealed the combination of fish mince and refined wheat flour significantly altered the physical properties of fish noodles. HIPP trays were ideal for thermal processing and do not change the shape during retorting. PEST/CPP film for top sealing for trays and see through retort pouch (PEST silicon dioxide/ Nylon/ CPP) can be used for food contact application. Fo value of 7 min, cook value of 74.78 min and total process time of 36.04 min were found to be optimum for processing fish noodles in HIPP trays. Storage studies of the fish noodles at ambient temperature revealed that lightness decreased. Yellowness and redness increased during the storage period. The instrumental texture analysis showed an increasing trend for hardness. Sensory analysis revealed that during storage, appearance, colour and texture was mostly affected. Appearance of the sample decreased during storage period. Odour, flavour and taste were well accepted even at the end of storage period. Biochemical parameters were well within the limit of acceptability. Based on the overall acceptability, thermally processed fish noodle had a shelf life of 90 days at ambient temperature (28±1°C).

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Appendix 1

THERMAL RESISTANCE OF DIFFERENT FOOD COMPONENTS. (Source: Lund, D.B. 1977)

Component	Z (^{0} F)	E_a (kcal/mole)	D_{121} minutes
Vitamins	45-55	20-30	100-1000
Color, texture, flavour	45-80	10-30	5-500
Enzymes	12-100	12-100	1-10
Vegetative cells	8-12	100-120	0.002-0.02
Spores	12-22	53-83	0.1-5