

**DESIGN, DEVELOPMENT, PERFORMANCE EVALUATION OF  
FISH DEBONER AND DEVELOPMENT OF FORTIFIED FISH SAUSAGE  
USING DEBONED MEAT FROM LOW VALUE FISH**

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TAMIL NADU, INDIA**

**2013**

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Thesis submitted in part fulfillment of the requirements for the degree of  
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Place: Coimbatore

**(UDAYKUMAR NIDONI)**

March, 2013

## **ABSTRACT**

### **DESIGN, DEVELOPMENT, PERFORMANCE EVALUATION OF FISH DEBONER AND DEVELOPMENT OF FORTIFIED FISH SAUSAGE USING DEBONED MEAT FROM LOW VALUE FISH**

**By**

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**2013**

Fish is a rich source of easily digestible protein that also provides polyunsaturated fatty acids, vitamins and minerals for human nutrition. The demand for fish food is increasing with the increase in population, since fish products are considered as health foods by the consumers. The demand would also be partially met by using the under-utilized fish species through efficient use of the by-catch through separation of meat and development of value added fish products such as surimi, surimi-based products, sausages and fermented products.

Manual methods of meat-bone separation are inefficient, time consuming and expensive. Many mechanical meat-bone separation techniques such as tearing, scraping, flailing with rotating chains, pressing between drum and belt, stamping type and auger type are in commercial use. Of these above mentioned methods, the belt and drum

principle is by far the most effective for deboning of fish since highest meat recovery could be achieved with little preparation of the fish, other than gutting and cleaning.

Most of the commercial fish meat-bone separators are of higher capacity and expensive which are not affordable to small entrepreneurs and small scale fish processors. These machines have lower efficiency (80-90 per cent) leaving behind the valuable meat (protein) with the skin and bones.

Keeping in view of the above facts, an economically feasible belt and drum type fish deboner of 50-75 kg per hour capacity was designed and developed for effective removal of meat from low value and under utilized fishes.

The developed fish deboner consisted of a stainless steel drum of 6 mm thickness with different sizes of perforations through which the flesh portion of the fish is squeezed inside the drum. An endless belt runs over the rollers opposite to the direction of rotation of the drum and fish pieces are pressed between the conveyor belt and the stainless steel drum. The rollers can be adjusted to tighten the conveyor belt for maximum meat recovery.

An electric motor of 1 hp provided the power to perforated drum and conveyor belt through a flexible jaw coupling, speed reduction gear box (30:1), spur gears, chain and sprockets. The developed deboner also consisted of two scraper blades made up of 5 mm thick food grade HDPE sheet one to scrap the outer surface of the drum to keep the perforations clean and another inside the drum to collect the minced meat and stainless steel feeding tray and outlet chute. The components of the fish deboner were mounted on base and supporting frames made up of heavy duty mild steel channels and angles.

The operational parameters of the fish deboner namely, peripheral speed of the drum (7.22, 10.31 and 12.37 m per min.), belt hardness (35 45 and 55 Shore No.) and perforation diameter of the drum (2, 3 and 4 mm) were optimized for maximum meat recovery and minimum bone content in the minced meat using tilapia, a low value fish.

During the optimization process, due to the interaction effect of drum peripheral speed, perforation diameter and belt hardness, the meat recovery ranged from 0.572 to 0.815 kg per kg of dressed fish and the highest (0.815 kg per kg of dressed fish) recovery

obtained at drum speed of  $10.31 \text{ m min}^{-1}$  with the belt hardness of 55 shore and perforation diameter of 4 mm.

Considering the highest meat recovery and lowest bone content in minced meat, among 27 solutions of categorical factor levels obtained by desirability test, the operational parameters namely, peripheral speed of  $10.31 \text{ m min}^{-1}$ , belt hardness of 45 shore and perforation diameter of 3 mm were found to be optimum levels.

Maximum meat recovery of 0.79 kg per kg of dressed fish and minimum bone content of 4.30 mg per 100 g of minced meat were recorded at contact area of 45 per cent of drum surface with optimized process parameters *viz.*,  $10.31 \text{ m min}^{-1}$  drum peripheral speed, 45 shore belt hardness and 3 mm perforation diameter recorded. Higher meat yield and meat extraction efficiency were recorded at 50 to 70 kg per hour feed rate.

The performance of the developed fish deboner was evaluated for meat recovery and bone content in minced meat of three freshwater fish species namely, Tilapia (*Oreochromis mossambicus*), Rohu (*Labeo rohita*) and Mrigal (*Cirrhinus cirrhinus*).

Highest meat recovery of 0.865 kg per kg of dressed fish and minimum bone content of 2.82 mg per 100 g of minced meat were recorded for Rohu followed by Mrigal and Tilapia species when the deboner was operated at optimized conditions. The colour of Mrigal was whiter with higher  $L^*$  value of 62.381, Rohu as reddish with higher  $a^*$  value of 2.15 and Tilapia as bluish with lower  $b^*$  value of 10.459.

Textural properties of the minced meat recovered from tilapia fish were found better with higher values of hardness (231.187 gf), cohesiveness (0.438 g.s), gumminess (100.69 g.s) and chewiness (50.05 g.s) and lowest value of adhesiveness (-8.47 g.s) compared to other two fishes. Tilapia recorded higher values of apparent viscosity and shear stress indicating the meat of higher firmness of the meat compared to Rohu and Mrigal.

Minced meat recovered from Tilapia was used for the development of a ready-to-serve fish sausage fortified with omega-3 fatty acids and iodine through the addition of sardine fish oil (0.25, 0.50 and 0.75 g per 100 g of product) and potassium iodide (150  $\mu\text{g}$  per 100 g of product) in the sausage recipe.

Moisture, crude protein, crude fat, total minerals and total carbohydrate contents of sausages prepared with selected levels of fortification ranged from 68.93 to 68.62 per cent, 14.28 to 15.94 per cent, 7.06 to 7.63 per cent, 2.96 to 3.21 per cent and 5.10 to 5.15 per cent respectively. Total poly-unsaturated fatty acids and n-6 to n-3 ratio of sausages prepared with different treatments ranged from 40.0 to 43.65 g per 100 g of sample and 11.2 to 0.81 respectively.

Biochemical parameters namely, total volatile base nitrogen, peroxide value, free fatty acids, iodine value, pH and water activity in sausages prepared with selected levels of fortification ranged from 6.58 to 6.89 mg N per 100 g of sample, 12.46 to 14.88 mMoles of O<sub>2</sub> per kg of fat, 2.38 to 2.82 per cent of oleic acid, 19.95 to 135.12 µg per 100 g of sausage, 6.6 to 6.8 and 8.72 to 8.98 respectively. The biochemical properties were found in the acceptable range. Total plate count and aerobic spore formers in fortified sausages ranged from  $3.0 \times 10^{-3}$  to  $8.0 \times 10^{-3}$  cfu per g and 31 to 33 cfu per g respectively.

Sausages without fish oil fortification namely T1 (control) and T2 (with KI alone) showed higher apparent viscosity (34.35 to 39.26 Pa.s) values at the selected shear rates compared to fish oil fortified sausage treatments.

Sausage T1 (control) scored highest  $L^*$  (49.62) and  $a^*$  (29.46) values indicating relatively whiter with pink shade whereas sausage T5 (fortified with fish oil @ 0.75 g per 100 g and KI @ 150 µg per 100 g of sausage) recorded highest  $b^*$  value denoting more yellowish among all the treatments. The sensory scores obtained by the sausages with different fortification levels were bound to be above 7.0 indicating the product of highly acceptable quality.

The production cost of the developed fish deboner was found to be Rs. 68,845/-. The cost of operation found as Rs.523/- per day and Rs.65/- per hour. The cost of meat separation observed was Rs.1.31 per kg of dressed fish. Pay back period of the fish deboner was found to be 95 days of operation with benefit-cost ratio of 3.51.

The production cost of 100 kg of fortified fish sausage using tilapia, a low value fish found to be Rs. 10,915.00 with a net profit of Rs. 14,085.00. The B:C ratio was found to be 2.29 indicating a good venture for entrepreneurship.

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## ABBREVIATIONS AND SYMBOLS

<i>a</i> *	red/green colour
AC	alternate current
amp	ampere
AOAC	Association of Official Analytical Chemists
ANOVA	Analysis of variance
<i>b</i> *	yellow/blue colour
BIS	Bureau of Indian Standards
B:C	Benefit: Cost ratio
C	Centigrade
cfu/g	colony forming units per gram
D	diameter
EEZ	Exclusive Economic Zone
<i>et al.</i>	and others
FAO	Food & Agriculture Organisation
FOS	Factor of Safety
GDP	Gross Domestic Product
GI	Galvanised Iron
g	gram
h	Hour
HDPE	High Density Poly Ethylene
hp	Horse Power
HPP	Heavy Duty Platform

HCl	Hydrochloric acid
H <sub>2</sub> SO <sub>4</sub>	Sulphuric acid
IDRC	International Development Research Centre
kg	kilogram
ksc	kg per square centimeter
L*	Lightness or darkness
lb	pound
lbh <sup>-1</sup>	pounds per hour
lit. min <sup>-1</sup>	litre per minute
m	meter
m min <sup>-1</sup>	meter per minute
mg	milligram
ml	milli litre
μg	microgram
min	minute
mPa	milli Pascal
Mpa	Mega Pascal
MS	Mild steel
N	Normality
N-m	Newton meter
N-mm	Newton millimetre
NaOH	Sodium hydroxide
O <sub>2</sub>	Oxygen

psi	pounds per square inch
rpm	revolutions per minute
Rs.	Rupees
S	Peripheral speed
SS	Stainless steel
s	second
s <sup>-1</sup>	per second
TFC	Total Fixed Cost
TPC	Total Plate Count
<i>viz.</i> ,	Namely
W	Watt
Π	Pi
%	per cent
D.cm <sup>-2</sup>	dynes per square centimeter

## **CHAPTER I**

### **INTRODUCTION**

Aquatic food resources are vital sources of nutrients, vitamins and minerals for human beings. Consumption of fish and fishery products has formed an important part of the dietary practice of Indians from time immemorial and is highly relished among people of all classes and ages as the fish is less tough and more easily digestible compared to beef, mutton, chicken and bush meat. These have significantly contributed towards the improvement of nutritional status of Indians.

#### **Fisheries resources of India**

India has been blessed with a coastline of 8,129 km with an exclusive economic zone (EEZ) of 2.02 million square kilometers and a continental shelf of 0.51 million square kilometers. Inland water resources include 1,91,024 km of rivers and canals, 3.15 million ha of reservoirs, 2.25 million ha of ponds and tanks, 1.30 million ha of oxbow lakes and derelict waters and 1.24 million ha of brackish waters. With diverse resources ranging from deep seas to lakes in the mountains and more than 10 per cent of the global diversity in terms of fish and shellfish species, the country has shown continuous and sustained increments in fish production since independence. Constituting about 4.40 per cent of the global fish production, the Indian fisheries contributes to 1.10 per cent of the GDP and 4.70 per cent of the agricultural GDP (Anon, 2011).

#### **Present status of fish production and demand**

The realization of fish as an important source of dietary protein increased the tendency of fish production for direct human consumption rather than for other uses. With the increase in World's food demand, particularly after the Indian independence, the total world fish production has steadily increased from 19.30 million tonnes in 1950 to 100 million tonnes in 1989 and to 143.60 million tonnes in 2006. It has also been reported that, the utilization of fresh fish for human consumption increased from 88 million tonnes in 1996 to 110 million tonnes in 2006. By the year 2012-13, World's demand for fish as human food would reach 120 million tonnes against the total demand of 146 million tonnes (FAO, 2008).

Indian fisheries is an important component of global fisheries with a total fish production of 8.0 million tonnes during 2009-10, of which the marine sector and inland fisheries accounted for 3.07 and 4.93 million tonnes respectively. Possessing 2.40 per cent of the global land area, India sustains 16 per cent of the world population. Increasing per capita fish availability from the present level of only 9.8 kg to 13 kg (as recommended by World Health Organization) is the primary challenge before the country (Anon, 2011).

The price of fish both in domestic and export market has increased over the last few years due to non-availability and inadequate supply of fish at the production point. This is also because of the increased demand due to rise in population and a positive change in the dietary habits of people all over the world as fish products are considered as health foods by the consumers (Sutanuka, 2013).

The increasing demand would be met by enhancing production and productivity through intensive aquaculture, development of reservoir through stocking quality advanced fingerlings, adoption of innovative technologies, mariculture and deep sea fishing. The demand would also be partially met by using the under-utilized fish species through efficient use of the by-catch. Efforts are being made to increase the fish production at an estimated growth rate of 2.50 per cent in the marine and inland sectors. Attention should also be given to proper use of by-catch and under-utilized fish species to meet the future demand (Ayyappan and Diwan, 2006).

### **Need for development of improved fish deboner**

Indian fishery is multi species based and consists of a large number of fish species of varying sizes. However, only a few species of the total catch are commercially important and a major portion (25 to 60 per cent) of it remains unused due to inherent problems related to unattractive colour, flavour, texture, small size and high fat content. Such fish species are categorized as low value or under utilized and are discarded overboard or at landing centers or used for fish meal production (Bhat and Ramachandra, 2006).

These low value fish constitute a sizable part of the country's total marine catch. Discarding of these fishes, which are rich in protein, is therefore a loss to the nation, where such cheap protein food could be better utilized through isolation of meat and development of value added fish products such as surimi, surimi-based products,

sausages and fermented products. Development of such products would provide dual opportunities of diversification of the fish processing industry and utilization of low value fish for human consumption.

Separation of fish meat from skin and bone is the prime process in the development of new products using under-utilized fish species. Manual methods of meat-bone separation are inefficient, time consuming and expensive, and hence the new techniques and improvements to old methods, the efficient recovery and the introduction of novel foods are all becoming increasingly important. Among the various meat-bone separation methods *viz.*, chemical, biochemical, mechanical, thermal, ultrasonic, cryogenic, water jet etc., mechanical method of meat bone separation has been reported as efficient and economical (Newman, 1981).

Mechanical meat bone-separation had begun in Japan in late 1940's and meat-bone separation techniques such as tearing, scraping, flailing with rotating chains, pressing between drum and belt, stamping etc., have been reported. Auger type mechanical deboner has also been used in the fish processing industries to the limited extent. The recovery of meat by mechanical methods was one of the most viable means of utilizing many under-utilized fish species for human consumption (Flick *et al.*, 1990).

Most of the commercial fish meat-bone separators are of one to ten tonne per hour capacity and expensive (Rs. 10 lakh to 200 lakh) which are not affordable to small entrepreneurs and small scale fish processors. These machines have lower efficiency leaving behind the valuable meat (protein) with the skin and bones.

The belt and drum principle has been reported to be the most effective of above mentioned methods for deboning of fish, because of the highest meat recovery with little preparation of the fish required, other than gutting and cleaning. However, improvement in the efficiency of this type of deboner could be achieved by increasing the contact area between drum and belt to provide adequate separation, by adopting more durable belt material to reduce damage upon friction, by providing motor power to drive the belt and by fixing the scraper blades to provide sufficient cleaning of the mass after deboning (Sirilak, 1988).

Development of an economically feasible fish deboner for effective removal of minced meat from low value and under-utilized fishes is the need of the hour and it would not only help in utilizing low value and under utilized fishes of India but also in creating the employment opportunity among the rural fisher-folk, rural youth, small scale entrepreneurs enabling them to utilize low value fishes for commercial production of value added products. The minced meat so obtained could be used for the development of a novel fish based food products for human consumption.

### **Development of value added fish product**

Fish and fish products have presently emerged as the largest group in agricultural exports of India, with 5.2 lakh tonnes in terms of quantity and Rs. 7,200 crores in value. This accounts for around 3 per cent of the total exports of the country and nearly 20 per cent of the agricultural exports. More than 50 different types of fish and shellfish products are exported to more than 75 countries around the world (Anon, 2011).

On the other side, it is reported that, the by-catch available in India is about 56.3 per cent of the total marine production, which is discarded or used for preparation of fish meal (Davies, 2009). In the present scenario of high demand of fish protein for human consumption, it is very much essential to recover the meat from these fishes using suitable meat separators thereby the minced meat can be used for preparation of value added products.

There are various meat based food products popular in Western and Asian countries among which the sausages are widely consumed and India has potential market for sausages (Hassan and Mathew, 1999). Sausage is a product typically made of beef, or beef and pork, or chicken containing 25 to 30 per cent fat. Preparation of sausage requires the meat having high gel forming ability. From the survey carried out along the Indian west coast, it was observed that, there are a few low value fishes having desirable gel forming characteristics for preparation of fish sausage (Sonu, 2002). The main drawback in commercial production of fish sausages is shelf life of the heat processed sausages as these are ideal environments for microbial growth. Efforts were made to enhance the shelf life of sausages using different bio-preservatives (Raju *et al.*, 2003). However, the technologies need to be tested for the sausages prepared from low value or under utilized fishes.

Keeping in view of the above facts, a research study on design, development and evaluation of fish deboner and use of low value fish meat for preparation of value added product was undertaken with the following objectives.

**Objectives:**

- To study the existing meat separation methods for development of a fish deboner
- To design, develop and evaluate the performance of developed fish deboner
- To prepare fortified fish sausage using low value fish meat from the deboner and analyse quality characteristics of the product
- To study the economics of the developed fish deboner and fortified fish sausage

## **CHAPTER II**

### **REVIEW OF LITERATURE**

A comprehensive review is mandatory in any research endeavour. This requires thorough efforts on the part of investigator to select relevant subject matter, to organize and to report it systematically. This chapter deals with a brief account of literature on the existing methods and mechanisms used in meat-bone separation, design, development and performance evaluation of a meat-bone separator including the cost economics of meat-bone separator and small scale fish processing units. The literature on development of value added fish products and its quality characteristics have been reviewed. The recent literature pertaining to the design and development of fish deboners is very meager. Hence, some related references have also been reviewed under the following different sections.

#### **2.1 Study of Existing Methods and Mechanisms used in the Meat-Bone Separation**

The separation of meat from bone by manual methods is inefficient, time consuming and expensive. There are two main approaches to meat recovery, removal of bone from meat and retrieval of meat from bones.

##### **2.1.1 Mechanical methods**

The very earliest form of mechanical recovery, mechanical knives, goes back many decades, whilst the newer technology dates at least from the late 1940's and early 1950's.

Poultry meat has been the subject of a large number of patented machines using alternative techniques. Lapeyre (1963) invented the meat bone separator involving cutting mechanism to reduce the size of the meat and bone then straining the meat by centrifuging against perforated cylinder. However, the mechanism was reported to be effective for poultry meat and the fish meat required another sieve to separate pin bones.

Lindall (1963) developed a meat separator based on the principle of shot blasting the flesh with solid particles (ice crystals or solid CO<sub>2</sub> balls) of 2 mm size with 5 ksc pressure. Draper (1971) developed a machine that used water jets at high pressure for

cutting the flesh. Conrad and Salem (1971) described a system which used high pressure gas jets as the cutting agent. The use of lasers for cutting meat from bone was reported by Herrmann and Nitzsche (1975). However, these methods were found suitable for poultry processing.

Suerbaum (1974) discussed the requirement of a meat bone separator that should provide an ideal product that has been rapidly removed from the bones in an unaltered form by a low cost process in a low temperature environment. Mechanical techniques, by their very nature, tend to be destructive, although mechanical desinewing (as opposed to deboning) was an exception maintaining the majority of the meat in an undenatured state. The belt and drum separation machine was modified by providing drive to the pressure rollers and claimed that this type of system produced relatively large pieces of undenatured deboned meat.

Newman (1981) reviewed the mechanical meat separation methods and mentioned that, during 1960's, Japanese fish processors were alarmed at the relatively large amounts of fish protein that were lost after conventional methods of processing, chiefly in the form of meat protein adhering to and between the fish bones. The mechanism involved in belt and drum type meat separation and the problems associated with basic models of commercial belt and cylinder separators (Baader make) were narrated. There was formation of bulges in the flexible rubber belt especially at the edges and were improved by providing pressure rollers in the newer models. The commercial deboners operate at perforated drum speed of 10 to 25 rpm. The Bibun make separators had an additional straining device sieving out any residual bone.

The methods adopted in meat bone separators manufactured by Paoli, Yieldmaster and Beehive make deboners were also reported by Newman (1981). All these methods used an auger feed and recovered the meat, either through stainless steel screens (Yieldmaster) or via microgrooves (Paoli). The microgroove type of machine could incorporate cooling plant to reduce the temperature rise caused by the processing and could be readily adapted for separating fish, poultry or red meat, usually by a simple change of the screening mesh and readjustment. However, an essential prerequisite was that the bones must be pre-ground in a bone grinder that made the process complex.

An alternative hydraulic-piston type meat separator with British Patent 1 451 128 developed by Unilever was also reported by Newman (1981). This had a hopper to deliver a pre-determined weight of meat/bone into a thick walled steel cylinder. A hydraulic powered piston that compacted the meat and the bone under a pressure of 100-250 atm and the meat flowed off the bones and recovered through a multiplicity of microgrooves. The harder bone was unable to enter in to the grooves and was compacted in to a puck or ejected by a further forward movement of the piston.

### **2.1.2 Cutting techniques**

Cutting and tumbling methods have been suggested by Alford and Salem (1969). A similar method, with additional sieving, has been published by Weiss (1970). Zwiap (1969) described a technique which ploughs tire meat from the bone, using a multiplicity of dull blades, to give a good quality native product. Processing of meat-bone mixtures using impaction techniques has been extensively documented; examples are shown in US Patents 2 734 537, 2 734 540 (Giesler, 1956), 2 858 222 (Harris, 1958) and 3 017 661 (Zartman, 1962). Ziener (1974) suggested a ramming and scraping process.

The compaction and extrusion machine developed by Engelhardt and Rousseau (1974) and the mechanical pressing machine by Suerbaum (1974) are amongst those ideas in use commercially. However, all these techniques were required a bone screening device for fish meat bone separation.

Anonymous (2005) reviewed the process of making minced meat and reported the typical yields of mince from small fish average 22% for capelin, 30% for silver hake and 40- 45% for herring and flounder. Larger species such as cod and hake, filleting generally yielded 23-35% product, whereas belt and drum type mechanical separation could recover 40-55% minced fish. Meat recovery of different aquatic species were analysed and concluded that by recovering mince from frame waste, total product output from filleting operations might be increased by 10 to 20%. Mechanical separation of lobster bodies, crab and undersized shrimp could yield 40% meat. Trimmings (collar and tail sections) from salmon steaking operations could yield 70% deboned salmon meat.

Venugopal (2005) compiled the methods of preparing mince and mince based products and reported that recovery of meat was the ideal means of utilizing many under

utilized fish species, particularly pelagic fish. The principle involved in meat separation was forcing fish pieces against a screen or slotted surface and the most common was belt and drum type in which headed and gutted fish was passed between counter rotating belt and drum. It was mentioned that the dimension of orifice and hardness of belt influence the quality of mince especially with respect to bone content in minced meat.

Peter *et al.* (2008) developed a new concept of processing of fish using water jet. The method involved shooting of fish down a pipe in a stream of water. The target ratio of water to fish was 17 parts water to one part fish wt/wt. High volume and high yield were the potentials of the water evisceration system to economically produce minced fish meat from several species of round fish like walleye pollock, and pacific whiting. The volume throughput reported was 6 tonnes of fish per hour.

Wang and Shanmugam (2009) worked on use of abrasive water jet (AWJ) for cutting of beef, pork and lamb meat with and without bones. Salt particles were used as the abrasives. It was found that an AWJ could significantly increase the depth of cut with much improved cut quality in cutting pure meat as compared to plain (or pure) water jet cutting while a plain water jet was incapable of cutting bone satisfactorily. The study showed that AWJ cutting produced very narrow kerfs of less than 1 mm and hence resulted in much less meat loss than the traditional cutting processes. Using this method, meat could be cut at room temperature to eliminate the freezing or chilling costs. It was shown that a traverse speed of  $20 \text{ mm s}^{-1}$  could be used to cut through 44 mm thick beef rib bones with good cut quality. When slicing pure meat of 150 mm thickness, the traverse speed of  $66.67 \text{ mm s}^{-1}$  yielded very good cut quality. It was suggested that AWJ cutting was a viable technology for meat cutting.

Anonymous (2012) explained the history of making surimi and described the meat separation processes. It was reported that the meat separation machine was made of a thick rubber belt and a perforated drum. As the fish passed through this machine, the belt pressed it against the drum, forcing the soft flesh particles to the interior of the drum while leaving the harder scales and bones on the outside. The drum was constantly rotated and the excess outer material was scraped off and collected in a waste bin.

### **2.1.3 Physical methods**

Watt & Merrill (1963) described a meat and bone separation method using violent agitation of the meat with water followed by concentration by centrifugation. Robertson (1962) published a similar method, but the product was produced in a spray dried form. Meat recovery from the bone was tried by scuffing with brushes (Swett, 1962), flailing with rotating chains (Shanks, 1968), shredding (US Patent 3 142860) or scraping and/or tearing as illustrated in US Patents 3 266 542, 3 266 543 (Paoli, 1966) and 3 256 555 (Paoli, 1965). Stripping of the meat through a hammer-mill-like machine is the basis of US Patent 2 895 162 (Harris, 1958) or by similar means using a retaining bed (Segur, 1970). The grinding and pressing techniques of Paoli (1966, 1976) were reported to be extensively used commercially.

### **2.1.4 Thermal techniques**

Huber (1963) developed an alternative thermal technique, using super heated steam at high pressures in a combined process to reduce the meat to bone adhesion.

Duckworth *et al.* (1969) published a mechanical process for meat-bone separation of cooked meat in which pressure paddles forced the cooked meat in contact with a perforated grid causing the meat to pass through, while the bones were retained. Bacteriologically, this was an improvement and although the material was cooked and lost much of its binding capacity, it still found uses in the processed food industry.

### **2.1.5 Ultrasonic techniques**

Pfeiffer (1975) described a separation system using ultrasonic vibration of a ground meat-bone homogenate in the presence of an extraction solvent such as a solution of sodium citrate and phosphate. The product had the consistency of thin honey and had been successfully incorporated into frankfurter emulsions. Use of centrifugation/flotation technique for meat-bone separation of ground meat and bone mixture was also reported.

### **2.1.6 Cryogenic techniques**

Combined impaction and sieving techniques were described by Ermakov (1974) and Kaukhcheshvili *et al.* (1975). In these, meat was frozen between -70 °C and -110 °C and comminuted under known impact loadings. The different structural and mechanical

properties of the meat and the bone resulted in a differential fragmentation and a selective comminution of the mixture.

The use of electrostatic forces as a method of separation was developed by Kaukhcheshvili *et al.* (1976). Cuts of meat were frozen to -60 °C, ground and then completely separated into tissue and bone fractions on passing through an electrostatic field of 4 to 7 kV cm<sup>-1</sup>. Separation of meat using cryogenic liquids combined with flotation techniques was successfully demonstrated by Ermakov *et al.* (1972) and Kaukhcheshvili *et al.* (1972). The method was essentially same for both processes. Ground meat was frozen with liquid nitrogen and then suspended in an inert, high density liquid. The heavier bone fragments sunk while the lighter meat particles floated and could be skimmed off. Ilyukhin *et al.* (1976) developed this method to the pilot plant stage, although high costs would probably prevented the process becoming a commercial practice.

#### **2.1.7 Chemical methods**

Young (1975) studied the chemical method of meat-bone separation by using dilute acid and alkali and reported that this method was effective in meat-bone separation but led to appreciable breakdown of the proteins as well as dissolving bone, especially with acid treatments. Numerous chemical methods using water, brine or other inorganic salts in solution, alone or together with some mechanical assistance such as centrifugation to separate meat from bone producing protein material have also been reported by Eslinger *et al.* (1972); Linke and Arneth (1974); Miyazaki (1974) and Barbetti (1975). However, the resulting products were found to be suitable only for use in the manufacture of sausages and similar formulated products.

#### **2.1.8 Biochemical methods**

Olekar (1972) worked on the use of various proteolytic, collagenolytic and elastolytic enzymes for meat-bone separation and reported that the control of the separation process was difficult and the enzyme was needed to be inactivated in the final product. The enzymes presently available were not suitable for this purpose.

Chakrabarti (1989) studied the meat separation from small shrimps using different dense media prepared with different proportions of water, saturated salt solution, glycerol, potassium sorbate and polyethylene glycol. The specific gravities of these media ranged between 1.180 to 1.198. The meat was isolated from small shrimps in the dense media and concluded that these media could efficiently be used to separate meat from shell. However, the process was found to be slower due to higher viscosity of the solutions delayed segregation.

Chakrabarti (1993) worked on the use of dense media with specific gravities of 1.217 to 1.220 for efficient meat separation from small crab and small shrimp and reported that the recovered meat from small fish contained considerably less bone than meat obtained using a conventional deboner.

## **2.2 Operational Parameters of Belt and Drum Type Deboners**

Field (1981) reported about the meat-bone separator machine that operated on belt-drum principle, in which the bones were forced against a perforated drum by a rubber belt. Holes in stainless steel drums ranged from 1 to 10 mm in diameter but hole sizes of 4-5 mm were most common. In this machine, meat passed through the holes while bones and skin were retained on the outside of the drum and ejected through a discharge chute. The minced meat obtained after deboning might be refined by passing it through a strainer of 1 to 2 mm in diameter that removed most bone particles and suggested the limit value for perforation diameter of the drum less than 5 mm.

Field (1981a) reported auger type of mechanical deboner which was also used in limited extent in fish industry and was most popular machine for poultry. These machines used rotating augers inside stainless steel cylinder to force meat through orifices approximately 1 mm in diameter. In this system, bones were retained inside and augered out at the end of cylinder to separate it from meat.

Flick *et al.* (1990) worked on the processing of fin-fish in the sea-food industry and reported that recovery of meat by belt and drum type mechanical method was one of the most efficient and more viable means of utilizing many by-catch and under-utilized species for human consumption.

Bykowski and Dutkiewicz (1996) reported that during filleting, considerable amount of meat (30-50%) was usually left along the ribs and backbone. The carcasses were the source of minced meat. Minced meat was also produced from low value fish species after deheading and gutting. Meat was separated from the bones, skin and scales in automated devices called separators. In the separator, meat was squeezed through holes into the cylinder under pressure applied by a conveyor belt partially encircling the cylinder about 25% of the cylinder's perimeter. The openings in the cylinder were 3 to 7 mm in diameter but for processing of freshwater fish 4 and 5 mm hole sizes were most common. It was also reported that the smaller hole sizes resulted in stronger grinding action for better meat separation. Pressure applied by the conveyor to the cylinder was regulated depending upon the type and size of the raw product and on the hole diameter.

Prince *et al.* (1981) designed an auger type deboning apparatus to separate bone and similar hard material from the meat of chicken, fish or other animals. The machine was vertically oriented whereby the ground meat and bone product was introduced above and flown by the auger to the meat exit. The electric drive motor was provided beneath the bottom support plate and there was a bottom radial bearing. Other components of the machine included a regulator for adjusting internal pressure and screen for separation of the bone and meat.

Robertson and Merritt (1985) developed and tested the IDRC (International Development Research Centre, Canada) small-scale fish deboner for fish processors in developing countries. The main features of the apparatus included a stainless steel perforated drum, electrically driven motor and a variable pressure pneumatic tyre. The tyre was in forced contact with the drum and was driven by the drum. The tyre and drum were rotated in opposite directions and caused separation of flesh from bones and skin as the fish were fed to the drum through a hopper and rotating feed roller. The testing procedure involved variation in tyre pressure and drum speed to establish an optimum operating range. With Atlantic smelts, the optimum conditions were found to be higher tyre pressure of 35 psi and lower drum speed of 40 rpm. Under these conditions the input capacity was 148 kg h<sup>-1</sup> and mince yield was 70 per cent. The results indicated that the deboning machine was versatile and reliable. However, he suggested to test for further lower drum speeds for improving the meat recovery.

Ghadi *et al.* (1976) and Sirilak (1987) used a stamp-type deboner, in which the fish was compressed against a perforated steel plate. This was found to be more efficient but the bone content were more than 1 per cent which not acceptable. The minced meat was subjected to straining for removal of excess bones.

Regenstein (1986) conducted experiments on meat separation and tested fish, poultry and red meat. Different perforation/orifice sizes and reported that 3 to 5 mm hole sizes were found efficient for fish and 0.5 to 2.0 mm for poultry and red meat. It was also reported that the larger orifice size of the drum resulted in the higher mince yield with more meaty texture and higher bone content in the mince.

Weyand (1988) invented a tool for the manual deboning of fish. A tool for grasping and manually removing a number of the pin bones from fillets of large fish such as whitefish, lake trout, haddock, scrod etc. was disclosed. A pair of pinching members formed of flat, springy, sheet metal plates arranged in overlapping manner and attached to the ends of a forceps-type body portion. Manual force applied to the body portion moved the adjacent edges of the plates together to grasp pin bones between them. The free edge of one of the pinching members bent inwardly towards the adjacent free edge of the other member to fit around and gripped the curved end portions of the pin bones which were adjacent the surface of the fish fillet.

Petchrat *et al.* (1997) designed the fish deboner composed of a compression force system between tyre roller rotating at speed of 40 rpm and stainless cylinder with hole size 4 mm. The machine was developed for fish having length and thickness not more than 20 cm and 2 cm, respectively. It was reported that the fish deboner could separate the quantity of fish meat about 60 per cent by weight.

Goldstone (1998) designed the deboning machine with slotted chamber which comprised a plurality of elongated slots each formed of a pair of spaced apart side walls presenting interior side edges and an opposing arcuate end walls presenting interior arcuate end edges. The slots were oriented such that side edges lied at an angle relative to the central axis of the separation chamber so as to be tilted in the direction of rotation of co-operating auger. The side and end edges cooperated with the fluted turns of the auger

to shave or peel away the meat from the bone to produce a coarser and highly textured separated product.

Wadsworth (1998) designed the total bone removal system which consisted of a jig, vacuum supports for securing a fish and a traversable blade assembly for cutting the fish. The recovery from round uncut fish to all bones removed was 55 to 60 per cent.

Durst (1999) designed an apparatus for removing pin bones from fish fillets. The apparatus consisted of a rotatable bone pulling cylinder and a puller plate defining a pin bone receiving space between the bone pulling cylinder and puller plate. The bone pulling cylinder had a cylindrical surface which was adapted to snag pin bones extending from a fish fillet disposed adjacent to the bone pulling cylinder and puller plate. The puller plate had a forward portion profiled to have a radius of curvature which was commensurate with the radius of curvature of the cylindrical surface of the bone pulling cylinder. The puller plate was mounted on a body and adapted to slide towards the bone pulling cylinder to bring the leading edge to mate with the bone pulling cylinder.

Grabau *et al.* (1999) reported the method and apparatus for deboning fish of the *Mackerel* family. To allow an accurate filleting of Mackerel fish with their specific bone structure in the ventral cavity region, a slice of fish meat including the ribs was cut free automatically by providing with a cutting edge diverging with respect to the conveying path of the fish and a supporting element. The supporting element in combination with a computer controlled tool including a knife allowed the ribs to be cut away progressively while respecting the anatomical characteristics of the fish.

Henckel *et al.* (2004) conducted experiments on the biochemical composition and histological characteristics of meat recovered mechanically by the auger/sieve and the hollow drum-belt principles from two different chicken carcass parts and the results were compared with meat recovered manually. It was found that the quality of meat recovered mechanically by the hollow drum-belt principle was equal to or higher than the quality of manually recovered meat. The degradation of muscle structure was highest in the meat recovered by the auger/sieve principle and lowest in the manually recovered meat.

Suvanich *et al.* (2000) studied the meat recovery from different commercial deboners and the changes in selected chemical quality characteristics of channel catfish

frame mince during chill and frozen storage. It was reported that meat yields varied due to the different types of deboners, different perforation sizes, belt speed and belt tension on the same type of deboner. The Bibun and Baader deboners were of belt-and-drum-type machines, while the Paoli was a breaker bar and drum-type deboner machine. Lower meat yields were reported using belt-and-drum deboners. Storage studies indicated that mince could be stored for no longer than 3 days at 0 or 5 °C to maintain optimal quality. Frozen mince with cryoprotectant would remain acceptable for at least 3 months at -20 °C.

George (2011) explained the fish mince processing and problems in its storage life. It was reported that the conventional pre-processing was required to recover the meat from mechanical meat separators. Belt and drum type separators required little pre-processing of fish but the meat yield was only 18-36 per cent of the original.

Subhendu (2010) described drum and belt type of deboners as the best tool to use low value fish and using the minced meat different value added products could be prepared such as mince or mince based products and battered and breaded products. The report included the method of meat separation using belt and drum type of fish deboner, ingredients for preparation of various fish products *viz.*, fish sausage, fish sticks, fish fingers and fish balls.

### **2.3 Meat Yield and Bone Content in Mince Meat**

Steinberg (1972) and Miyauchi (1972) conducted experiments on meat yield of selected fish species and reported typical minced yields of 60 per cent on English sole *v/s* 30 per cent for whole fillets, 47 per cent on minced flounder *v/s* 31 per cent for flounder fillets and 43 per cent on minced cod *v/s* 23 per cent cod fillets.

King (1972) reported that Atlantic species generally showed fillet yield of 30 per cent plus an added 20 per cent from mincing operation.

Patashnik *et al.* (1974) worked on bone content of some minced fish muscle product. Three different types of raw fish material were passed through the commercially available meat-bone separators *viz.*, Bibun flesh separator (7 mm perforation), Yanagiya separator (4 mm perforation) and strainers (1 mm and 2 mm). Gravity floatation method and sensory evaluation of the flesh were conducted to detect the bone particles. It was

reported that gravity floatation method was a useful quality control tool to provide reasonably accurate estimate of the bone content. It was also reported that straining/screening of the minced flesh had shown to be as effective means of reducing the bone content to acceptable limits. However, straining reduced the particle size of the flesh and might alter the texture of the cooked product and it also increased product handling and production costs.

Dingle *et al.* (1974) worked on recovery of the bones from minced fish flesh and reported that more bones were found in the mince obtained from a drum with 3 mm holes than from a drum with 5 mm holes. The results were based on headed and gutted fish with back bone partly removed and on cod frames after filleting the headed and gutted fish.

Bone content of the minced flesh could be determined from the residue after the enzyme digestion of one kg of fish flesh. However, calcium determination was generally regarded as the most suitable for routine quality control with an upper limit of 0.5 per cent calcium being recommended by the United State Department of Agriculture (USDA, 1975).

Ghadi *et al.* (1975) carried out study on yield and bone content in minced meat from trash of marine water of India using bone separating machine (imported). They reported that, the per cent meat recovery on dressed weight basis was highest from Ribbon fish (78 per cent) followed by Golden anchovies (69.40 per cent) and the lowest from soles (51.5 per cent) followed by Anchovies (57.2 per cent). The bone content in minced meat was observed highest in Golden anchovies (437 mg/100 g) followed by Anchovies (121 mg/100 g) and lowest in Croaker (18 mg/100 g).

Wong *et al.* (1978) studied the influence of various perforation sizes on bone content and texture of minced fish flesh obtained by using mechanical deboner. They reported that the texture of minced fish flesh after cooking was found to be highest in flesh obtained from drum equipped with larger orifices (5 to 7 mm) though such mince may have a large numbers of long bones. Bone and scale content were considerably lower in minced flesh obtained through the drums with narrower orifices (2 mm) but this brought more disintegration of protein structures which adversely affected the texture of fish flesh. Minced herring flesh obtained through 5 mm and 7 mm orifices had exceedingly

large numbers of long fine bones however, a drum possessing 5 mm perforation offered a suitable compromise in terms of bone content relative to texture.

Young *et al.* (1979) reported that mincing frequently resulted in a product of darker colour than the raw material. This was due to contamination by melanoid pigments of the peritoneum, by blood and head and gut contents. They recommended to bleach the dark muscles with hydrogen peroxide.

According to Indian Standards, for commercial production of minced fish meat, the raw material should be gutted i.e. tail, entrails, bones, tips, scales, skin, head and other non-edible portion should be removed and eviscerated before meat separation. Another important requirement is the bone content in minced meat which should not exceed 1.0 per cent. (IS 10763-1983).

Wood and King (1985) conducted the experiments on the recovery and yields of mince from Silver Belly (*Leiognathus Spp.*), Mackerel (*Scomber scombrus*) and the Sardine (*Centegraulis mysticetus*) using a belt and drum type meat-bone separator and reported that the different orifice sizes (1.2, 3 and 5 mm) did not affect the texture of the mince significantly. They observed that the meat yield was highest in 3 mm orifice size and was less in 1.2 mm and 5 mm. The calcium, bone content and bone length were less in 1.2 mm orifice and higher in 3.0 and 5.0 mm.

Gopakumar (1989) studied the effect of fish size on meat yield and bone content in minced meat. The researcher used four fishes namely, Barracuda (45-55 cm), Threadfin bream (13-15 cm), Tilapia (12-15 cm) and Prawn (10-12 cm) and reported that medium sized fish (Threadfin bream and Tilapia) yielded higher percentage yield of the compared to Barracuda and Prawn. The bone content in prawn was nil followed by Tilapia, Barracuda and highest in Threadfin bream.

Branscheid *et al.* (2009) reported a new morphological method for the detection of both bone and cartilage particles as elevated cartilage contents might be indicative of mechanically separated meat additives also. The method was based on simultaneous staining with Alizarin Red and Alcian Blue. They investigated mechanically separated meat produced from breast of veal for elevated particle contents. In addition, they determined the rate of recovery for minced pork mixed with 0 to 5 per cent bone or

cartilage. The result showed that staining with Alizarin Red and Alcian Blue was suited to the efficient and simultaneous detection of bone and cartilage material in meat mixtures.

## **2.4 Economics of Meat-Bone Separator**

Dilk (1976) conducted physical feasibility of constructing mobile fish processing plants in Canada and reported that unit could be built to accommodate fish deboning, filleting, fish meal and fresh fish packing machines. Fixed (capital) cost, variable (operational) cost, capital reduction options and expected returns were calculated by assuming the existing prices of the raw and finished products.

Butler and Dykstra (1981) proposed discounted cash flow methodologies to evaluate machine replacement decisions and proposed a practical method to estimate maintenance and repairs costs. A simple average of the annual net present values was calculated, which ignored the time value of money.

Robertson and Merritt (1985) developed and tested a small-scale fish deboner for fish processors in developing countries. The input capacity of the machine was found to be 62 to 107 kg h<sup>-1</sup> with 58 to 62 per cent meat recovery. The cost of the machine reported was CAD 6000.

Burgess and Cabbage (1989) proposed a means of evaluating yearly machine costs using cash flows on a before and after tax basis using Lotus spreadsheet templates. It was also provided comparisons with machine rate methods. However, the methodology produced a different cost rate for each year of the machine's life, which was then averaged to come up with a comparison with the machine rate. As with traditional machine rate models, this simple averaging of costs over time also ignored the time value of money, unless the discount rate was 0%.

Reddy *et al.* (2004) described the wholesome method of calculating the economics of the machine by considering fixed cost, variable cost, total cost of production, profit, pay back period based on prevailing prices of the raw materials and final product. The feasibility of operating any machine was explained through estimation of discounted cost, discounted returns, B:C ratio, Net Present Worth considering the probable increase (minimum 2 per cent) in the operational costs.

Bilek (2009) introduced charge-out, an improved model for determining the charge-out rate for a piece of capital equipment based on discounted cash flows. Like the machine rate models, charge-out produced a single rate. Unlike machine rate models, charge-out rate produced a specified rate of return. Charge-out offered many additional advantages over the machine rate methods.

Gunnar (2008) explained a simple financial analysis for a small fish processing plant in Alaska, USA. The analysis involved the assumptions to be made through processing financial basics and methodology for a hypothetical small fish processor. However, in Indian context, the applicability of this analysis looked poor as the capital reserved for sanitation and supply chain considered was more than the cost of machinery.

Robert (2012) worked on technological adoption and economics of small scale fish processing for production of smoked fish in Ghana. Profitability analysis such as profit and profit margin were calculated and market margins and efficiency to assess the market performance of the small scale smoked fish and compared with the salted sun dried fish processor. The results showed positive profits and margins.

Many other reviews were studied and the methodology demonstrated by Reddy *et al.* (2004) found suitable, hence adopted for economic analysis of the developed fish deboner in the present study.

## **2.5 Development of Ready to Serve Fish Sausage**

Fish is a rich source of easily digestible protein that also provides poly-unsaturated fatty acids, vitamins and minerals for human nutrition. The world availability of fish has decreased over the last few years due to a rise in population and a positive change in consumer attitudes toward the consumption of seafood. However, only a few species of the total catch are commercially important and a major portion of it remains unused due to inherent problems related to unattractive color, flavor, texture, small size, and high fat content.

Sausage is a Japanese product made of chopped meat, spices and formed with added fat and starch and packed in to sausage casings. There are different types of sausages produced by the meat industry. These can be classified as fresh, dry and semidry

sausage, cooked sausage, smoked sausage and cooked meat specialties. Many researchers have worked on development of sausages, determination of proximate composition, fatty acid profile and quality aspects of sausages and few of them related to the present study are presented hereunder.

Merill and Watt (1973) explained the procedure for calculation of total carbohydrate content of foods including sausages by difference method. Total carbohydrate would be calculated by subtraction of the sum of the crude protein, total fat, moisture and ash from the total weight of the food.

Delange (1993) critically reviewed the recommendations of dietary iodine given by Natural Research Council, USA. Dietary ratios of 90 µg per day for children of 0-6 years, 120 µg/day to the children of 6 to 12 years and 150µg/day for all persons older than 12 years were suggested. For pregnant and lactating women 200 µg/day was recommended.

Nettleton (1995) reviewed omega-3 fatty acid content of different food products. Linolenic acid (LNA), Eicosapentaenoic acid (EPA) and Docosahexaenoic acid (DHA) were considered for estimation of ratio of n-6 to n-3 of foods. Only EPA and DHA constituted omega-3 fatty acid. Omega-3 fatty acid content in freshwater and marine fishes was compiled and it was reported that marine fishes contained higher level of omega-3 fatty acids than freshwater fish.

Lee *et al*, (1997) developed a chicken breakfast sausage using mechanically deboned chicken meat fortified with pork sausage (2 per cent) and 2.3 per cent fat replacer ingredients. The quality of sausage was analysed in terms of colour, sensory, proximate composition and texture. It was reported that the developed sausage maintained flavour intensity, texture and colour in all treatments and no significant off-flavour was detected.

Hussain (2002) determined the fatty acid composition of muscle lipids of three different farm raised trouts. It was found 1.58, 1.27 and 0.95 omega-3/omega-6 PUFA content in respective fish species and reported that higher ratios indicate the availability of n-3 PUFA that are beneficial to human health. It was concluded that the marine fish in the diet could add n-3 PUFA contents in human nutrition for beneficial effects of health.

Simopoulos (1999) reviewed the importance of n-3 fatty acids in human health and explained by stating that human beings evolved on a diet with a ratio of omega-6 to omega-3 essential fatty acids (EFA) of approximately 1, whereas the normal diets contain 15/1 to 16/1. Excessive amounts of omega-6 PUFA and a very high omega-6 to omega-3 ratio promote diseases like cardiovascular diseases, cancer, inflammatory and autoimmune diseases, whereas increased levels of omega-3 PUFA exert suppressive effects.

Raju *et al.* (2003) conducted experiment on development of sausage using threadfin bream, a marine fish and its shelf life using nisin as preservative. The proximate composition, biochemical and microbial characteristics of developed fish sausage were analysed under ambient and refrigerated storage conditions. The changes in proximate compositions of fish mince, sausage paste and in sausage were observed. It was reported that the changes in PV and FFA values of sausage during storage might be due to hydrolysis and oxidation of proteins and fats. The results revealed that the sausage incorporated with nisin had shelf-life of 150 days against 30 days of control under refrigerated condition.

Devadasan (2005) reviewed the status of value added fishery products and their marketing and reported that the high value species were mostly processed for export, most of the medium and low value species, which formed the bulk of the landings, were marketed fresh or were processed for the domestic market. It was opined that the increasing affluence and the consequent changes reflecting in the eating habits had resulted in the demand for diversely processed value added convenience fish based products and might be met by separation of meat from low value fishes and utilize in preparation of ready to cook or ready to serve value added and diversified products.

Haldimann *et al.* (2005) studied iodine content of different food groups used in daily diet and identified that the bread and milk contained significant amount of iodine in the Swiss diet as these contributed 58 and 29 µg/day. They suggested to include iodine rich foods such as fish and iodized salt in the diet to meet out the daily iodine requirement.

Garg *et al.* (2006) explained the means of delivering recommended levels of long chain n-3 PUFA in human diets. It was stated that n-3 PUFA of marine origin showed positive effect on development and cognitive function. Regular consumption of and/or dietary supplementation with long chain n-3 PUFA gives several health benefits including prevention of cardiovascular diseases, inflammatory diseases, dyslexia and depression. It was observed that majority of the people do not eat sea food on a regular basis because of its cost and non-availability. It was suggested the incorporation of foods in the diet with n-3 PUFA fortification that meets the demands of optimal health of humans.

Kim (2006) conducted experiments on usage of natural and synthetic casings for sausage prepared from ground meat and mixed meat. It was reported that casings could be used for manual or automatic sausage fillers of various concentrations. Synthetic sausages used for sausage protected the contents, reduced loss of moisture and hindered the penetration of microbes in to the product, thereby reducing the hydrolysis and oxidation during storage.

Wijnker *et al.* (2006) studied different aspects of quality assurance in processing of natural sausage casings and suggested NaCl treated natural casings for sausage stuffing that were sufficient to reduce biochemical changes and bacterial contamination below levels at a water activity level of 0.85 or lower for 30 days storage period.

Mohammad *et al.* (2007) conducted sensory evaluation of texture for fish sausage during storage using instruments such as colourimeter and textural analyser. It was found that the instrumental hardness correlated strongly with the sensory hardness and both attributes increased in magnitude with higher starch additions to the preparation. No correlation between fineness, brittleness and adhesiveness. They concluded that the storage stability of the product was acceptable up to 12 weeks at -20°C storage and the spoilage of sausages was due to denaturation of proteins and lipid oxidation.

Amaral *et al.* (2008) studied the fatty acid profiles of 18 commercial *Frankfurt* type sausages by extracting fatty acid methyl esters and determination of fatty acid composition by Gas Chromatography with flame ionization detection (FID). It was reported that poultry meat sausages contained higher polyunsaturated fatty acids and

lower saturated fatty acids compared to pork meat sausages. The quality parameters such as sensory, texture, tenderness and its nutritional value were studied and it was concluded that fat content of the sausage influenced the quality characteristics of sausages.

Maage *et al.* (2008) studied the fortification of foods and reported that 13 per cent of the world population was suffering from iodine deficiency disorder (IDD) and the most severe consequences of IDD was irreversible brain damage which could affect up to 5-15 per cent of a population in severely affected areas. Very less iodine content in foods (<16 per cent) used in the diet and also in drinking water (< 0.8µg per litre) was reported in the study area. It was suggested to add marine fish in the diet that could provide the required iodine to the consumers.

Panpipat and Jirawat (2008) developed fortified fish sausage using African walking catfish (*Clarias gariepinus*) and Rohu (*Labeo rohita*) fish with addition of 2, 4 and 6 per cent tuna oil and potassium iodide (150 µg per 100 g) in the recipe. The stability of potassium iodide and omega-3 fatty acids were studied during storage. The ratio of n-6 to n-3 fatty acids of all samples decreased with an increase of tuna oil addition and was stable throughout 4 weeks of storage. Degradation of linoleic (LA) and linolenic acid (LNA) mainly occurred in the samples added 2% tuna oil whereas samples fortified with higher tuna oil (6–10%) exhibited higher loss of EPA and DHA. Hydroperoxide (HPV) values were increased as addition level of tuna oil increased. Decrease in iodine content (14 per cent) during cooking and remained constant during storage was observed. Textural properties were not affected during storage at 4°C for up to 4 weeks. Two and four per cent fortification with tuna oil and potassium iodide 150 µg per 100 g were recommended for preparation of sausage from both freshwater fishes.

Ugoala *et al.* (2008) studied the fatty acids profiles of freshwater fishes namely *Mormyridae* (*Hyperopisus bebe Occidentalis*), *Cichilidae* (*Oreochromis niloticus*), *Clariidae* (*Clarias gariepinus*) and marine fishes namely *Anchovy*, *Sardine* and *Mackerel*. It was reported that the marine fishes were better sources of omega-3 fatty acids whereas freshwater fishes were good sources of omega-6 fatty acids.

Chakraborty *et al.* (2009) studied fatty acid composition of sardine fish oil. *Bacillus Circulans* enzyme was used to prepare eicosapentaenoic acid (EPA)

concentrates from sardine oil using gas chromatograph. The total saturated fatty acid content, mono-unsaturated fatty acids and poly-unsaturated fatty acids reported were 30, 36.6 and 32.9 g per 100gm of fatty acid methyl esters of sardine oil. It was suggested that the procedure for concentrating n-3 PUFAs by *B.Circulans* lipase would contribute to the commercial application of lipase to obtain concentrated n-3 fatty acids, particularly EPA from sardine oil.

Nowsad and Hoque (2009) standardized the production of fish sausage from unwashed mince blend (UM) of low-cost marine fish (LMF). Colour, texture and sensory characteristics of six different sausages prepared from the individual unwashed minces of five LMF viz., red jewfish, sea catfish, horse mackerel, jeweled shad and skipjack tuna with different levels of ingredients were investigated and compared with commercial sausage. The sausage prepared with autoclave cooking at 115°C for 15 min. had best texture and good mouth feel compared to conventional cooking (90°C for 20-60 min.), broiling (for 20-60 min.), two-step heating (incubation at 50°C for 1 hr and cooking at 90°C for 30 min.) and dip-frying in oil (for 10-30 min). Increase in peroxide and thiobarbituric acid values and aerobic plate count of the sausages were observed after 7 days at 4°C and distinctly lower ( $p < 0.05$ ) than that of commercial fish sausage. It was concluded that good quality stable fish sausage could be prepared from UM blends of LMF.

Venugopal and Shahidi (2009) reviewed the traditional methods to process underutilized fish species for human consumption and reported that some of the low value fish species were industrially used for fish meal manufacture. Need for the conservation and utilization of by-catch and underutilized species for human consumption had become necessary. It was opined that, the possible way to utilize such fish species was through isolation of meat and the development of secondary products such as surimi and surimi-based products, sausages, and fermented products, among others. The report discussed a number of conventional techniques, such as chilling, curing, canning and freezing that are used for fish processing with reference to their application for production of value added products from underutilized species.

Li *et al.* (2010) studied the lipid content and the fatty acid composition in the edible meat of wild and cultured freshwater and marine fish and shrimps from China.

Higher percentages of total PUFA, total n-3 PUFA, and EPA + DHA in cultured freshwater fish were observed than the wild ones. It was reported that, all the marine fish and shrimps had much higher n-3 PUFA than n-6 PUFA, while, most of the freshwater fish and shrimps demonstrated much lower n-3 PUFA than n-6 PUFA which might be due to higher difference in fatty acid composition of marine and freshwater species.

Lorenzo *et al.* (2011) studied the effect of fat level on physico-chemical and sensory properties of dry cured duck sausages. It was reported that fat levels (high - 27.5 per cent, medium - 22.1 per cent and low - 19.3 per cent) affected the lightness, redness and yellowness of sausages. Shear force of sausages increased with decrease in fat content. The sensory properties were significantly different with respect to fat levels and it was concluded that duck sausages with 20 per cent fat content scored higher sensory traits compared to commercial sausages of 30 and 40 per cent fat.

Nowak *et al.* (2006) studied the microbiological and color aspects of cooked sausages made from a porcine blood cell concentrate (BCC) with 15% table salt (NaCl) and 25% protein. The impact of fortification on the color ( $L^*$ ,  $a^*$  and  $b^*$ ) and growth of microbes in sausages in comparison with commercial sausages was determined. Increase in microbial load in the sausages was observed because of the spice ingredients and found comparable to those found in commercial blood sausages. It was reported that the bacterial loads of the sausages produced with BCC and spice extracts were significantly lower (APC and bacilli, 2.0 log CFU/g) than those of the other blood sausages.

Huda *et al.* (2012) studied quality characteristics of 5 brands of Malaysian commercial fish sausages by analyzing proximate composition and physico-chemical properties. The study showed that proximate contents namely protein and fat ranged from 8.18 -10.77 per cent and 0.93 – 6.53 per cent respectively. No significant difference among the fish sausages on lightness value was observed. The sausages showed significant difference in hardness and shear force. It was concluded that the fish sausages of different brands varied in their physico chemical properties due to difference in raw materials used, formulation and processing method adopted.

Karolyi and Curic (2012) studied total fatty acids composition of raw and ripe *Slavonian Kulen* in relation to raw material used. The proximate composition and fatty

acid profiles of sausages were analysed and reported that proximate composition significantly changed during drying/ripening and ripening had little effect on initial fatty acid composition of raw materials used. It was opined that the finding would be useful for developing healthier pork and pork products by modification of fatty acid composition.

Tamas *et al.* (2012) determined the fatty acid profile of fillet, liver and mesenteric fat in tilapia fed with vegetable oil supplementation in the finishing period of fattening. It was observed that tilapia fed with basal diet had highest (7.8) n-6/n-3 PUFA ratio indicating poor source of n-3 PUFA whereas the fish fed with soybean oil, flax seed oil and fish oil had lesser n-6/n-3 ratios *viz.*, 1.3, 1.1 and 1.1 respectively.

Many researchers have reported that sausage was a healthy food and its quality during storage degrades due to protein denaturation and lipid oxidation. The reviews sufficiently supported the fact that marine fishes are rich sources of n-3 PUFA, which helps in human health. Looking at the areas away from coastal line and the people depend on freshwater fishes, it is required to introduce fortified fish products that provide required nutrition and better health.

## CHAPTER III

### MATERIALS AND METHODS

This Chapter deals with the design procedure followed to develop a small capacity fish deboner, materials used for fabrication and the methodology adopted to evaluate the performance of the developed fish processing equipment. The meat extracted by the fish deboner was used for the development of a value added fish product. The materials used and methods followed for development of fortified fish sausage are also included in this chapter.

#### 3.1 Assessment of Existing Deboning Methods

Methods of mechanically separating flesh from bones and skin of fish, chicken or red meat could be classified in to four major categories from the literatures reviewed.

**3.1.1 Belt and perforated drum apparatus**, in which the belt and drum move relative to each other in opposite directions. The belt (usually of nylon or reinforced rubber) is slightly wrapped and tightened on the perforated drum, leaving a gap or mouth on one side. The cleaned and dressed fish pieces are forced between the belt and drum, thus extruding the edible flesh inward so as to move inside the drum.

**3.1.2 Piston and screen apparatus**, in which cleaned and dressed fish pieces are imposed on the piston and in turn, the flesh is pressed on the screen, where the edible flesh passes through and the bones and skin remain on the screen.

**3.1.3 Pair of concentric cylinder with a pressure bar** consisting of an inside cylinder with a continuous sharp helical groove, which allows flesh to pass through its surface as it rotates relative to the outside stationary cylinder. The pressure bar between the rotating and stationary cylinder provides the needed clearance and aids in the separation process. As the flesh passes through the grooved cylinder, a screw conveyor moves the edible flesh to an open part at one end of the machine, while the hard pieces of bone and skin are transferred on the exterior of the helical shaped cylinder to another open part at the opposite end of the machine.

**3.1.4 Stamp and beater type**, in which a beater taps against a perforated base plate holding the dressed and cleaned fish pieces. Due to the stamping action, the flesh comes out through the perforations of the base plate and the waste (skin and bone) remain on the base plate.

Of these four methods mentioned, the belt and drum principle is by far the most effective for deboning of fish because of its higher meat recovery with little preparation of the fish, other than gutting and cleaning. However, the efficiency of this type of deboner could be achieved by increasing the contact area between drum and belt to provide adequate separation, by adopting more durable belt material to reduce damage upon friction, by providing motor power to drive the belt and by fixing the scraper blades to provide sufficient cleaning of the mass after deboning (Sirilak, 1988). On the other hand, chopping or grinding of the fish is required prior to using the concentric cylinder type of machines and possibly even in the smaller piston type and stamping type machine.

The concentric cylinder machine extrudes a fish paste or slurry and the mince tends to be darker pink or reddish in colour because of the deboning process. This together with the finer texture makes it less attractive as an edible product. In the light of above discussions, the present study is undertaken primarily to design and develop a small-scale prototype fish deboner, with a capacity 50-75 kg per hour for use in small scale and or family owned business, especially along the Indian coastal region and other production centres of freshwater fishes.

### **3.2 Conceptual Design of Proposed Fish Deboner**

Most of the technical papers reviewed, dealt with deboning of chicken and red meat or just deboning in general with little technical data of the type, required to design a deboner for fish. The information on existing deboning methods, construction, drive mechanisms, physical size, capacity, horse power requirement, electrical power requirement, ease in operation and cleaning etc., was sought to design appropriate fish deboner of suitable capacity for the use of small and marginal fishermen and entrepreneurs.

Considering all the above facts, it was decided to design and develop a belt and drum type fish deboner, taking in to consideration the suggestions given by the previous researchers to improve the efficiency of the deboner.

It consists of a perforated drum, a conveyor belt, rollers, a drive system and an electric motor as power source. A feed tray to hold the cleaned and dressed fish, a waste collection outlet and a scraper blade are also provided at their respective places. The base table acts as a supporting frame to all these components. The major components of the belt and drum type fish deboner to be designed and developed are discussed hereunder.

### **3.2.1 Perforated drum**

This is the main part of the fish deboner, which has perforations of definite size through which the flesh portion of the fish is squeezed inside the drum. The size of the perforation has a greater role to play in achieving the quality and quantity of the minced flesh. The drum is mounted at one end of the drive shaft with locking arrangement.

### **3.2.2 Conveyor belt or endless belt**

Conveyor belt runs over the rollers on which cleaned or dressed fishes are fed for separation of meat. The belt tension and the hardness of belt material have greater influence on the extent of meat recovery by offering maximum squeezing of the meat through the perforated drum. The rotation of the belt is provided in counter direction with that of the perforated drum.

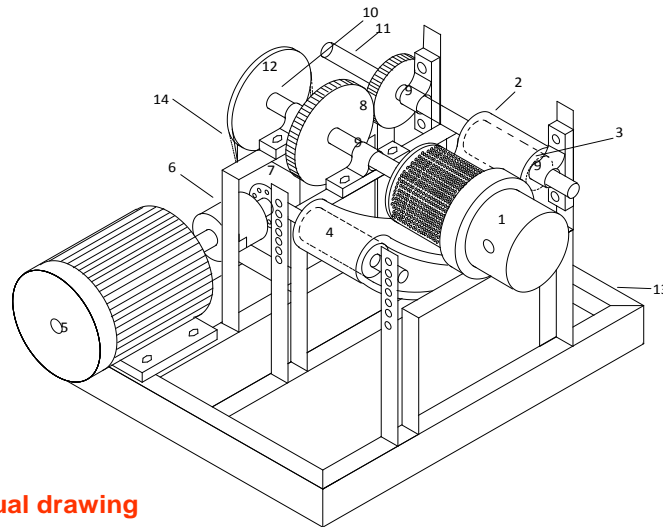
### **3.2.3 Rollers and bearings**

Three rollers are provided to the conveyor belt, two of them (driving and driven) are to provide the drive from power source and the third one to adjust the clearance for providing the necessary pressure between conveyor belt and perforated drum. The positions of these rollers can be adjusted to tighten the conveyor belt for maximum meat recovery. Bearings and bushes provide necessary support to the shafts and ensure smooth running of the perforated drum and conveyor belt.

### **3.2.4 Drive system**

The drive system includes one single phase AC motor, a coupling, speed reduction gear box, chain and sprocket, a pair of spur gears mounted on main and

secondary shafts. The speed reduction gear box reduces the output speed of the motor from 1440 rpm to 30-50 rpm in order to increase the torque availability on the drum. Chain and sprocket mechanism transmits the drive from output shaft of gear box to the main shaft on which the perforated drum is mounted. A pair of spur gears provides change in the direction of rotation and transmits the drive from main shaft to the secondary shaft on which driving roller for conveyor belt is mounted. The conceptual drawing of proposed fish deboner is given in Fig. 3.1.



**Conceptual drawing**

- |                              |                             |                                   |
|------------------------------|-----------------------------|-----------------------------------|
| 1. Perforated drum           | 6. Coupling                 | 11. Secondary / Belt drum shaft   |
| 2. Conveyor belt             | 7. Speed reduction gear box | 12. Main shaft sprocket           |
| 3. Belt drum                 | 8. Pair of spur gear        | 13. Base table / Supporting frame |
| 4. Adjustable tension roller | 9. Bearing                  | 14. Chain                         |
| 5. Motor                     | 10. Main shaft / Drum shaft |                                   |

**Fig. 3.1 Conceptual drawing of proposed fish deboner**

**3.3 Design and Development of Fish Deboner**

Design of fish deboner involve the computation of the power requirement and the design of different machine elements namely, shafts (motor, main and secondary), coupling, keys, speed reduction gear-box, sprockets, chain drive, spur gears, conveyor belt, perforated drum, bearings and supporting rollers. The procedure followed for the design of proposed fish deboner is discussed hereunder.

**3.3.1 Power requirement**

The force required to compress the fish to 98 per cent of its thickness for extraction of meat through the perforated cylinder was measured by conducting a

compression test on Texture Analyser (Model: TA.HD Plus; Make: Stable Micro System, Surrey, United Kingdom). Before starting the compression test, the probe (75 mm Compression Platen, P/75 using 500 kg load cell) was calibrated to acknowledge the base of the machine as zero. Heavy duty platform (HDP/90) was secured and the following parameters were set for the test (Lepetit and Culioli, 1994).

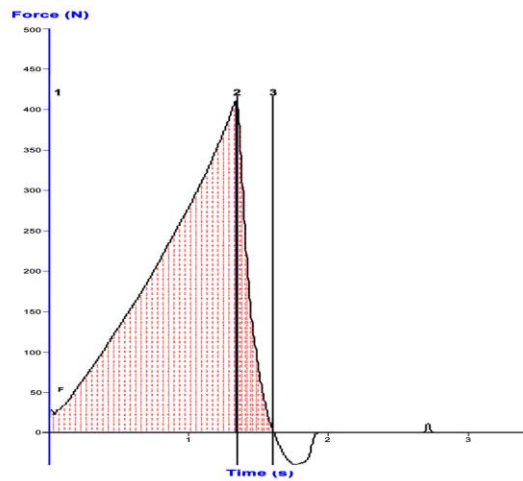
Mode	: Measure Force in Compression
Option	: Return to start
Pre-test speed	: 1.0 mm per s
Test speed	: 10.0 mm per s
Post-test speed	: 5.0 mm per s
Compression	: 98 per cent
Trigger type	: 100 g (Auto)
Data acquisition rate	: 25 pps

The fishes (*Tilapia* sp.) were procured from the Raichur fish market (Karnataka, India) and were gutted and washed to obtain cleaned fillets. One piece of fish fillet was positioned centrally over the platform and static compression test was commenced. Once a trigger force of 100 g was achieved, the compression platen proceeded to move down on to the fillet and a rapid rise in force was observed. During this stage, the fillet started deforming under the applied force and the meat squeezed out of the fillet till the platen compressed 98 per cent of the thickness of the fillet (Plate 3.1). The cycle completed in less than 3 seconds. The force profile was obtained in the form of a graph and is depicted in Figure 3.2.

The test was carried out for ten samples and an average value of the force 411.12 N was considered for calculating the power requirement of the proposed fish deboner.



**Plate 3.1. Compression test of fish fillet using Texture analyser**



**Fig. 3.2 Texture profile analysis of fish fillet at 98 per cent compression**

Selecting the diameter of the perforated cylinder as 155 mm (Standard stainless steel pipe size), the radius ( $r$ ) of 77.5 mm was considered as the distance of application of force from the centre of the shaft. The torque ( $T$ ) to be made available at the centre of the shaft for extraction of meat from the fish fillets was calculated by multiplying the force ( $F$ ) required to squeeze the meat and the radius ( $r$ ) of the perforated cylinder.

$$\begin{aligned}
 \text{Torque (T)} &= \text{Force (F)} \times \text{radius (r)} && \dots\dots (3.1) \\
 &= 411.12 \times 77.5 \text{ N-mm} \\
 &= 31.86 \text{ N-m}
 \end{aligned}$$

Substituting the values of torque (31.86 N-m) and the revolutions of the perforated cylinder as 40 rpm reported optimum in case of belt and drum type deboners by Robertson and Merrit (1985) in the following equation to obtain the power requirement of the fish deboner (Khurmi and Gupta, 2005).

$$P = \frac{2 \times \pi \times n \times T}{60} \quad \dots\dots (3.2)$$

Where,

P – Power required, Watt

n – Speed of drum shaft, rpm

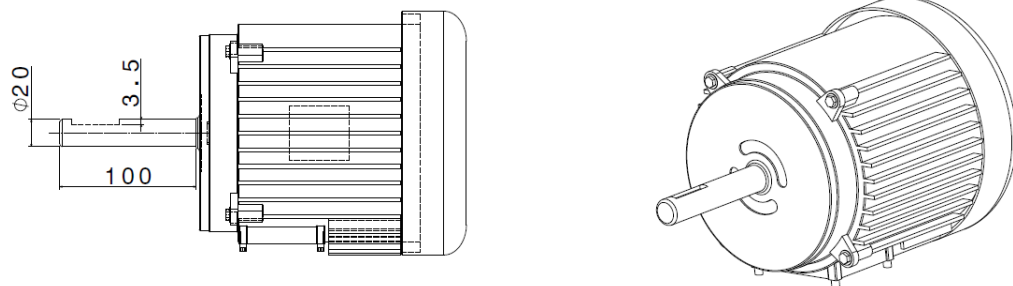
$\tau$  – Torque input at the drum shaft, N-m

$$P = \frac{2 \times \pi \times 20 \times 31.86}{60} \therefore$$

$$P = 133.51 \text{ W}$$

Considering, Factor of Safety as 4.0 to overcome frictional resistance offered by the gears, couplings, bearings and the pulleys, the power required;

$$P = 133.51 \times 4 = 534.04 \text{ W}$$



**(dimensions in mm)**

**Fig. 3.3 Schematic view of electric motor as power source**

Hence, commercially available power source of 1 hp (746 W) electric motor (Fig. 3.3) was selected for further designing of the fish deboner.

### 3.3.2 Motor shaft ( $d_m$ )

The diameter ( $d_m$ ) of the motor shaft was designed by considering the torque on the motor shaft and allowable shear stress for MS shaft using the following equation (Khurmi and Gupta, 2005). For power source (P) of 1 hp (746 W), the torque (T) available on motor shaft was computed as below;

$$T = \frac{P \times 60}{2 \times \pi \times n}$$

$$T = \frac{746 \times 60}{2 \times \pi \times 1440}$$

$$T = 4.95 \text{ N-m} = 4950 \text{ N-mm}$$

Mild steel shaft of 20 mm standard diameter ( $d_m$ ) was selected for the motor shaft and checked against its maximum allowable shear stress ( $\tau_s$ ) of 40 N-mm<sup>-2</sup> (Khurmi and Gupta, 2005).

$$\text{Allowable shear stress, } \tau_s = \frac{16 \times T}{\pi \times d_m^3} = \frac{16 \times 4950}{\pi \times 20^3} = 3.15 \text{ N-mm}^{-2} < 40 \text{ N-mm}^{-2}$$

Hence, the design of motor shaft is safe.

### 3.3.3 Coupling

A flexible jaw coupling was used to transmit the power from motor shaft to gear reduction unit by means of a sleeve and key. The following procedure was adopted to design a cast iron (CI) sleeve coupling. The outer diameter (D) and length (L) of the sleeve were calculated by using following formulae recommended for the design of cast iron sleeve coupling. The diameter ( $d_m$ ) of the motor shaft was considered as 20 mm for the calculation.

$$D = 2d_m + 13 = 2 \times 20 + 13 = 53 \text{ mm} \quad \dots\dots\dots (3.3)$$

$$L = 3.5 d_m = 3.5 \times 20 = 70 \text{ mm} \quad \dots\dots\dots (3.4)$$

The sleeve was designed by considering it as hollow for which the permissible shear stress is 15 N/mm<sup>2</sup> (Khurmi and Gupta, 2005).

The torque transmitted by flexible jaw coupling was calculated by the following equation

$$T = \frac{\pi}{16} \times \tau_c \times \left( \frac{D^4 - d_m^4}{D} \right) \quad \dots\dots\dots (3.5)$$

Where, T - Torque to be transmitted by the coupling,  $4.95 \times 10^3$  N-mm

$\tau_c$  - Permissible shear stress of the sleeve (for cast iron,  $\tau_c = 15$  N/mm<sup>2</sup>)

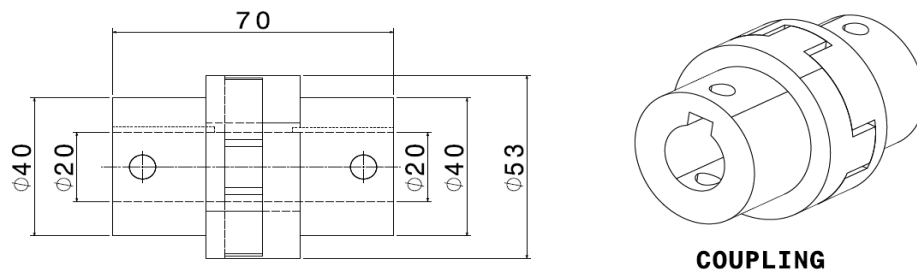
D – Outer shaft diameter of the coupling, 53 mm

$d_m$  – Motor shaft diameter, 20 mm

Permissible shear stress  $\tau_c = 16 \times T \times \frac{1}{\pi} \times \left( \frac{D}{D^4 - d_m^4} \right)$

$$\tau_c = 16 \times 4.95 \times 10^3 \times \frac{1}{\pi} \times \left( \frac{53}{(53)^4 - (20)^4} \right) = 0.17 \text{ N/mm}^2 < 15 \text{ N/mm}^2$$

Hence, the design of flexible jaw coupling is safe and the schematic view of the coupling is shown in Fig. 3.4.



**Fig. 3.4 Schematic view of flexible jaw type coupling (dimensions in mm)**

### 3.3.4 Keys

Plain carbon steel was selected for making keys for which, the allowable shear stress and crushing stress are 40 MPa and 80 MPa respectively. The width (w) and thickness (t) of the keys were chosen from the standard table for motor shaft diameter of 20 mm (Khurmi and Gupta, 2005).

Width of key (w) = 8 mm

Thickness of key (t) = 7 mm

The length of the coupling key ( $l$ ) is required to be at least equal to the length of the sleeve (i.e.  $3.5d_m$ ). The coupling key is usually made into two parts so that length of the key in each shaft was half of the sleeve length.

$$l = \frac{L}{2} = \frac{3.5d_m}{2} = \frac{3.5 \times 20}{2} = 35\text{mm} \quad \dots\dots (3.6)$$

After fixing the length of the key in each shaft, checked for the induced shearing ( $\tau_{ks}$ ) and crushing ( $\tau_{kc}$ ) stresses in the key for safe key design using following equations (Khurmi and Gupta, 2005).

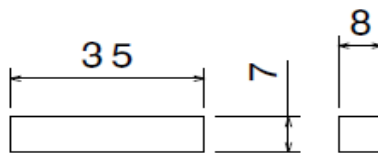
$$\text{Shearing stress, } T = l \times w \times \tau_{ks} \times \left(\frac{d_m}{2}\right) \quad \dots\dots (3.7)$$

$$\tau_{ks} = \frac{2 \times T}{l \times w \times d_m} = \frac{2 \times 4.95 \times 10^3}{35 \times 8 \times 20} = 1.76\text{MPa} < 40 \text{ M Pa and}$$

$$\text{Crushing stress, } T = l \times \frac{t}{2} \times \sigma_{kc} \times \left(\frac{d_m}{2}\right) \quad \dots\dots (3.8)$$

$$\sigma_{kc} = \frac{2 \times T}{l \times t \times d_m} = \frac{2 \times 4.95 \times 10^3}{35 \times 7 \times 20} = 2.02\text{MPa} < 80 \text{ M Pa}$$

The induced stresses were less than the permissible induced stresses of the key. Hence, the design of key (Fig. 3.5) is safe.

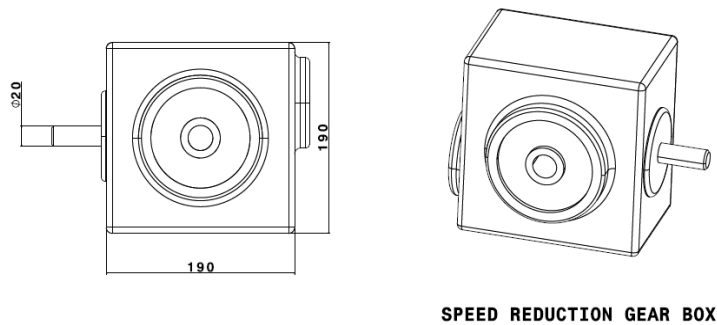


**Fig. 3.5 Schematic view of key (dimensions in mm)**

### 3.3.5 Speed reduction gear box

The objective of providing gear box in the proposed equipment was to reduce the speed of motor shaft that increases the torque on main shaft. A speed reduction gear box of 30:1 was selected for the purpose and procured from the local market of Raichur city.

Hence, the speed on the output shaft of the gear box =  $1440/30 = 48$  revolutions per minute. A schematic view of the speed reduction gear box is depicted in Figure 3.6.



**Fig. 3.6 Schematic view of speed reduction gear box (30:1) (dimensions in mm)**

### 3.3.6 Chain and sprockets

The sprockets and chain drive were selected for providing positive drive and designed according to the design of the experiment. Based on the drum speeds used in commercial deboners (10 to 25 rpm) reported by Newman (1981) and considering the findings of Robertson and Meritt (1985), lower drum speeds *viz.*, 14, 20, and 24 rpm were selected for improving the meat yield of proposed deboner. Different drum speeds could be obtained by changing the numbers of teeth on the sprocket mounted on the main shaft. The sprockets were designed by considering the velocity ratio of the chain drive. Velocity ratio of the chain drive was calculated by using the following standard formula (Khurmi and Gupta, 2005).

$$\text{Velocity ratio} = \frac{N_1}{N_2} = \frac{T_2}{T_1} \quad (3.9)$$

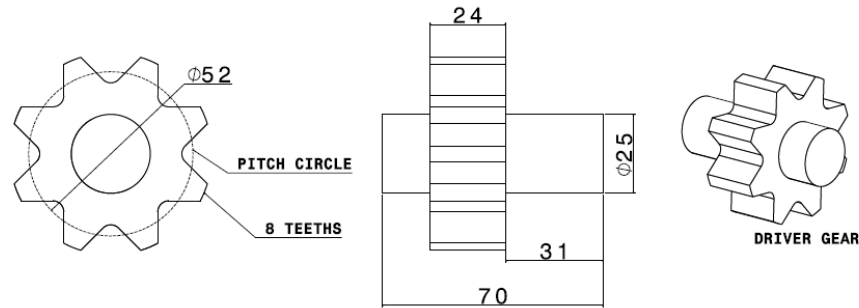
Where,  $N_1$  and  $N_2$  - Speed of rotation of smaller and larger sprocket respectively, rpm

$T_1$  and  $T_2$  - Number of teeth on smaller and larger sprocket respectively, No.

The number of teeth required on the main shaft sprocket was calculated for three different drum speeds *viz.*, 14, 20 and 24 rpm.

### 3.3.6.1 Drum speed of 14 rpm

A pinion sprocket having 8 No. of teeth was selected for mounting on the gear box output shaft, i.e.,  $T_1 = 8$  teeth and was kept constant for all the speed variables.



**Fig. 3.7 Schematic view of pinion sprocket (dimensions in mm)**

Considering, the output speed of gear-box ( $N_1$ ) as 49 rpm and the required speed of the perforated drum ( $N_2$ ) as 14 rpm and no slip during the chain movement, the number of teeth required on the main shaft sprocket ( $T_2$ ) was calculated as hereunder.

$$49 \times 8 = 14 \times T_2$$

Number of teeth required ( $T_2$ ) = 28 teeth

Therefore, a sprocket having 28 teeth was required to mount on the main shaft to obtain 14 rpm.

### 3.3.6.2 Drum speed of 20 rpm

Required speed of the drum ( $N_2$ ) = 20 rpm

$$49 \times 8 = 20 \times T_2$$

Number of teeth required ( $T_2$ ) =  $19.6 \approx 20$  teeth

Therefore, sprocket having 20 teeth was used for obtaining drum speed of 20 rpm.

### 3.3.6.3 Drum speed of 24 rpm

Required speed of the drum ( $N_2$ ) = 24 rpm

$$49 \times 8 = 24 \times T_2$$

Number of teeth required ( $T_2$ ) =  $16.33 \approx 16$  teeth

Therefore, sprocket having 16 teeth was used for obtaining drum speed of 24 rpm

Accordingly, the pitch angles for the respective sprockets were calculated using the following equation.

$$\text{Pitch angle} = \frac{360}{T_s} \quad \dots\dots (3.10)$$

Where,  $T_s$  is the number of teeth on the sprocket

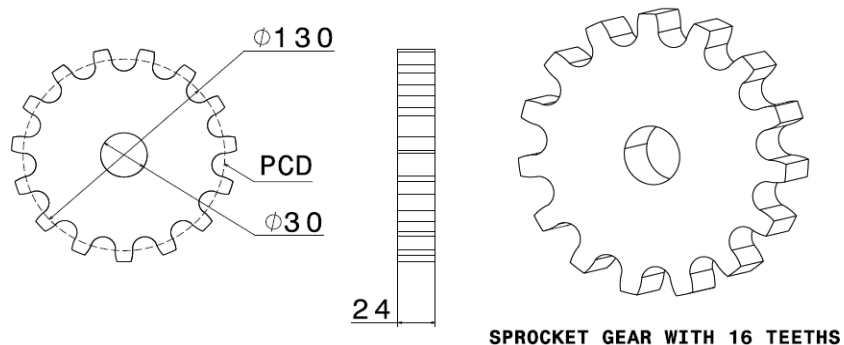
$$\text{For driver sprocket, } \alpha_1 = \frac{360}{8} = 45^\circ$$

$$\text{For driven sprocket, } \alpha_2 = \frac{360}{20} = 18^\circ$$

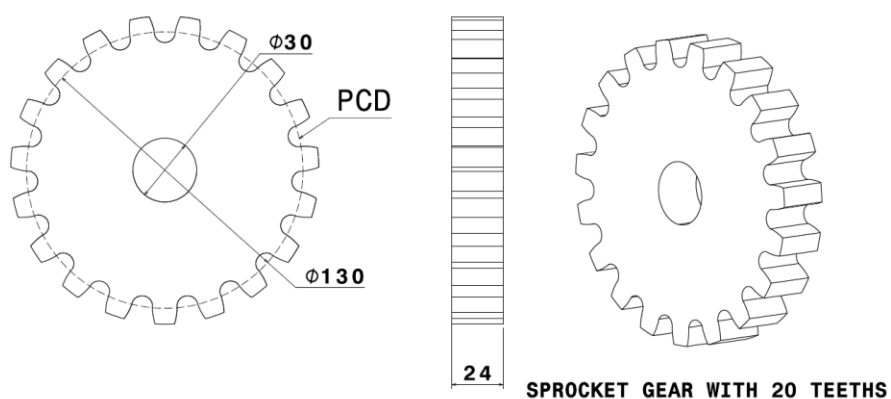
Pitch circle diameter of driver sprocket ( $D_1$ ) and driven sprocket ( $D_2$ ) were calculated by using following equations

$$\text{For driver sprocket } D_1 = \frac{20}{\sin \frac{180}{8}} = 52.26 \text{ mm} \approx 52 \text{ mm}$$

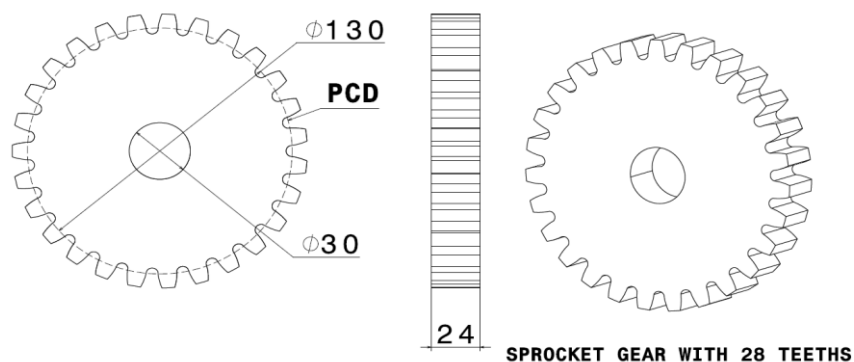
$$\text{For driven sprocket } D_2 = \frac{20}{\sin \frac{180}{20}} = 127.84 \text{ mm} \approx 130 \text{ mm}$$



**Fig. 3.8 Schematic view of sprocket gear (for 14 rpm) (dimensions in mm)**



**Fig. 3.9 Schematic view of sprocket gear with 20 teeth (for 20 rpm) (dimensions in mm)**



**Fig. 3.10 Schematic view of sprocket gear with 28 teeth (for 24 rpm) (dimensions in mm)**

A suitable chain drive (heavy duty single row roller chain of rating 12 B) was selected to transmit the power from gear box output shaft to main shaft (drum mounted shaft). The number of links and length of the chain were computed by following standard design procedure (Bhandari, 1997).

Roller chain was selected as per IS: 2403-1991 and the specification of the chain are;

Rating – 12 B

Pitch (P) – 19.05 ≈ 20.00 mm

Roller diameter (d<sub>1</sub>) – 12.07 mm

Width between inner plates (b<sub>1</sub>) = 11.68 mm

Transverse pitch (P<sub>1</sub>) = 19.46 mm

Minimum breaking load = 28.9 kN

Average velocity of the chain (V) was calculated by using the following formula (Khurmi and Gupta, 2005).

$$V = \frac{\pi D_1 N_1}{60 \times 10^3} \text{ms}^{-1} \quad \dots\dots (3.11)$$

Where, D<sub>1</sub> is the diameter of the sprocket mounted on gear box in mm and N<sub>1</sub> is the output speed of the gear box in rpm.

$$\therefore V = \frac{\pi \times 52 \times 49}{60 \times 10^3} = 0.135 \text{ms}^{-1}$$

A centre to centre distance between the gear box output shaft and main shaft of 215 mm was assumed to accommodate drum and belt in desired position. Considering this distance, the number of links (L<sub>n</sub>) and total length of the chain (L) were calculated by using the following formulae.

$$L_n = 2 \left( \frac{a}{P} \right) + \left( \frac{T_1 + T_2}{2} \right) + \left( \frac{T_2 - T_1}{2\pi} \right)^2 \times \frac{P}{a} \quad \dots\dots (3.12)$$

Where,

a = Centre to centre distance between the shaft, 215 mm

P = Pitch of the chain, 20 mm

T<sub>1</sub> = No. of teeth of sprocket mounted on gear box shaft

T<sub>2</sub> = No. of teeth of sprocket mounted on main shaft

$$\text{Number of links, } L_n = 2\left(\frac{215}{20}\right) + \left(\frac{8+20}{2}\right) + \left(\frac{20-8}{2\pi}\right)^2 \times \frac{20}{215}$$

$$L_n = 36$$

$$\text{Length of the chain (L)} = L_n \times \text{Pitch of the chain}$$

$$= 36 \times 20 = 720 \text{ mm}$$

Factor of safety (FOS) of the designed chain drive was determined by the following equations.

$$\text{FOS} = \frac{\text{Breaking strength}}{\text{Load on chain}} = \frac{W_B}{W} \quad \dots\dots (3.13)$$

Where,

$$W_B = \text{Breaking strength} = 106 \times P^2$$

$$= 106 \times 20^2$$

$$= 42400 \text{ N}$$

$$= 42.4 \text{ kN}$$

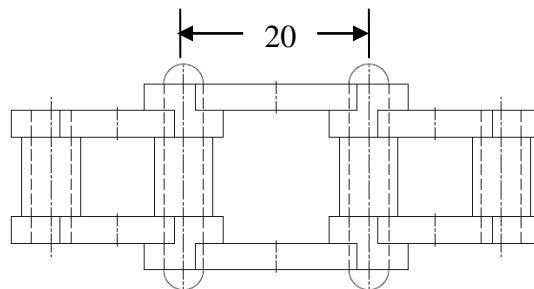
$$W = \text{Load on chain, kN}$$

$$W = \frac{\text{Rated power (kW)}}{\text{Pitch line velocity (m/s)}} = \frac{0.746}{0.135} = 5.49 \text{ kN} \quad \dots\dots (3.14)$$

Substituting the values of  $W_B$  and  $W$  in the above equation,

$$FOS = \frac{42.4}{5.49} = 7.72$$

Since the FOS is greater than 7.0, the design of chain and sprocket drive is safe.



**Fig. 3.11 Schematic view of standard roller chain with 20 mm pitch (IS: 2403-1991)**

### 3.3.7 Main shaft and secondary shaft

Main shaft and secondary shaft are the important parts of the fish deboner as these shafts provide required power transmission to the perforated drum and the belt mounted on the respective shafts. These shafts were designed by considering the torque (T) coming on to the respective shaft and by assuming the maximum permissible stress ( $\tau_m$ ) in tension or compression for Mild Steel shaft with allowance for key ways as 84 MPa or 84 N-mm<sup>-2</sup> (Khurmi and Gupta, 2005)

The design of the diameter of main shaft ( $d_{\text{main}}$ ) and secondary shaft ( $d_{\text{secondary}}$ ) are given below.

$$\text{Maximum torque on main shaft } (T_{\text{main}}) = \frac{P \times 60}{2 \times \pi \times n_{\text{main}}} \quad \dots\dots (3.15)$$

Where,

P = Power input, 746 W

$n_{\text{main}} = 20$  rpm

$$T_{\text{main}} = \frac{746 \times 60}{2 \times \pi \times 20} = 356.14 Nm$$

The diameter of the main shaft ( $d_{\text{main}}$ ) was calculated by substituting the value of  $T_{\text{main}}$  and the maximum permissible stress for MS shaft in the following equation.

$$d_{\text{main}} = \sqrt[3]{\frac{T_{\text{main}} \times 16 \times 1000}{\pi \times \tau_m}} \quad \dots\dots (3.16)$$

Where,

$T_{\text{main}} =$  Torque coming on main shaft,  $356.14 \times 10^3$  N-mm

$\tau_m =$  Maximum permissible stress, 84 M Pa or N-mm<sup>-2</sup>

$$\begin{aligned} \text{Diameter of the main shaft, } d_{\text{main}} &= \sqrt[3]{\frac{356.14 \times 16 \times 1000}{\pi \times 84}} \\ &= 27.85 \text{ mm} \end{aligned}$$

To determine the diameter of the secondary shaft, a speed ratio of 1.55:1 (secondary shaft speed: main shaft speed) was considered. The speed ratio has been recommended by International Development Research Centre, Canada for better movement of the meat through the perforations in case of belt and drum type meat separators (IDRC Report, 1986).

$$\text{Hence, maximum torque on secondary shaft } (T_{\text{secondary}}) = \frac{P \times 60}{2 \times \pi \times n_{\text{secondary}}} \dots\dots (3.17)$$

Where,

$$P = \text{Power input, } 746 \text{ W}$$

$$n_{\text{secondary}} = 1.55 \text{ times } n_{\text{main}} = 1.55 \times 20 = 31.0 \text{ rpm}$$

$$\text{Therefore, maximum torque, } T_{\text{secondary}} = \frac{746 \times 60}{2 \times \pi \times 31} = 229.77 \text{ Nm}$$

Similarly, the diameter of the secondary shaft ( $d_{\text{secondary}}$ ) was computed by substituting the value of  $T_{\text{secondary}}$  and the maximum permissible stress for MS shaft in the following equation.

$$d_{\text{secondary}} = \sqrt[3]{\frac{T_{\text{secondary}} \times 16 \times 1000}{\pi \times \tau_m}} \dots\dots (3.18)$$

Where,

$$T_{\text{secondary}} = \text{Torque coming on main shaft, } 229.77 \times 10^3 \text{ N-mm}$$

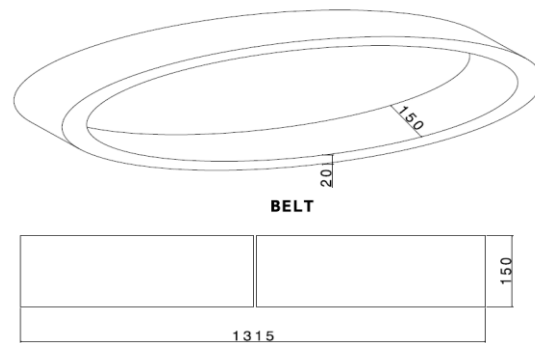
$$\tau_m = \text{Maximum permissible stress, } 84 \text{ M Pa or N-mm}^{-2}$$

$$\begin{aligned} \text{Diameter of the secondary shaft, } d_{\text{secondary}} &= \sqrt[3]{\frac{229.77 \times 16 \times 1000}{\pi \times 84}} \\ &= 24.06 \text{ mm} \end{aligned}$$

Hence, commercially available Mild Steel shafts (40 C 8 – Indian Standard designation) of diameter 30 mm and 25 mm were used in fabrication of main and secondary shaft respectively.

### 3.3.8 Conveyor belt or endless belt

Conveyer belts made of food grade perfluoroelastomer rubber with 35, 45 and 55 shore hardness were selected for the study as Robertson and Meritt (1985) reported that belt hardness or pressure had direct influence on meat recovery. The dimensions of conveyer belt (Fig. 3.12) were selected based on the positions of driving and driven rollers assumed in the conceptual drawing. The driving roller was made of galvanized iron pipe of 65 mm diameter and 150 mm length. Its two ends were closed with 5 mm thick mild steel plates. The roller was mounted on secondary shaft with the help of bushes welded on either side of the roller with quarter pins. This arrangement helped in holding the driving roller in position and restricting its lateral movement on the shaft. The belt was tightened between the rollers for maximum tension of 50 kg or 490 N with the help of a standard spring dynamometer (0-200 kg).



**Fig. 3.12 Schematic view of conveyor belt or endless belt (dimensions in mm)**

Thickness of the belt was calculated by using the following equation.

$$T_{\max} = \sigma_b \times b \times t \quad \dots\dots (3.19)$$

Where,

$T_{\max}$  = Maximum belt tension, 490 N

$\sigma_b$  = Permissible working stress of the belt,  $1.25 \text{ N mm}^{-2}$

$b$  = Width of belt, 150 mm

$t$  = Thickness of the belt, mm

$$\begin{aligned} \text{Therefore, } t &= T_{\max} / (\sigma_b \times b) = 490 / (1.25 \times 150) \\ &= 2.61 \text{ mm} \end{aligned}$$

Belt thickness of 20 mm was considered for better durability and easy handling of the belt. The density of the belt varied with its hardness and the selected belts of 35, 50 and 65 shore had density of 1040, 1140 and 1267 kg-m<sup>3</sup> respectively. The belt with said specifications was procured from M/s. Royal Rubber manufacturing company, Hyderabad for the present experimentation.

### 3.3.9 Spur gears

Spur gears were selected as positive drive to provide the power from main shaft to the secondary shaft that facilitates the driving of conveyor or endless belt. Spur gears were designed by the standard design procedure described by Khurmi and Gupta (2005).

Spur gear ratio (Gs) of 1.55 and centre to centre distance (Ls) between the main and secondary shaft of 153 mm were considered for design of spur gears using following equations.

$$\text{Spur gear ration, } G_s = \frac{D_g}{D_p} = \frac{T_g}{T_p} \quad \dots\dots (3.20)$$

Where,`

Dg = Diameter of gear, mm

Dp = Diameter of pinion, mm

Tg = No. of teeth on gear, No.

Tp = No. of teeth on pinion, No.

$$\therefore 1.55 = \frac{D_g}{D_p} = \frac{T_g}{T_p}$$

$$1.55 \times D_p = D_g$$

$$\text{Centre to centre distance, } L_s = \frac{D_g}{2} + \frac{D_p}{2} = 153 \quad \dots\dots (3.21)$$

Substituting for Dg in the equation 3.21

$$\frac{1.55 \times D_p}{2} + \frac{D_p}{2} = 153$$

$$153 \times 2 = 2.55 \times D_p$$

$$D_p = 120 \text{ mm}$$

$$\text{Therefore, } D_g = 1.55 \times D_p = 1.55 \times 120 = 186 \text{ mm}$$

Diameter of spur gear ( $D_g$ ) = 186 mm = 0.186 m

Diameter of spur pinion ( $D_p$ ) = 120 mm = 0.120 m

Minimum number of teeth required on the spur pinion ( $T_p$ ) to avoid the interference was calculated by using following standard formula.

$$T_p = \frac{2A_w}{G_s \left[ \sqrt{\left( 1 + \frac{1}{G_s} \left( \frac{1}{G_s} + 2 \right) \sin^2 \phi \right)} - 1 \right]} \quad \dots\dots (3.22)$$

Where,

$A_w$  - Fraction by which the standard addendum for wheel should be multiplied, 1.0

$\phi$  - Pressure angle,  $20^\circ$

$$\text{Number of teeth, } T_p = \frac{2 \times 1}{1.55 \left[ \sqrt{\left( 1 + \frac{1}{1.55} \left( \frac{1}{1.55} + 2 \right) \sin^2 20 \right)} - 1 \right]} = 13.54$$

$\approx 14$  No. of teeth

Minimum number of teeth required on the spur pinion ( $T_p$ ) = 14 No.

Therefore, number of teeth on spur gear ( $T_g$ ) =  $1.55 \times 14 = 21.7 \approx 22$

The width of pinion was calculated by considering the tangential ( $W_T$ ) and normal load ( $W_N$ ) coming on the pinion. The tangential load and normal load on the pinion were calculated by using the following standard formulae (Khurmi and Gupta, 2005).

$$\text{Tangential load, } W_T = \frac{\text{Torque acting on pinion}}{\left( \frac{D_p}{2} \right)} \quad \dots\dots (3.23)$$

Speed of spur gear ( $N_g$ ) mounted on main shaft = 20 rpm

Speed of spur pinion ( $N_p$ ) mounted on secondary shaft = 31 rpm,

Torque acting on pinion = Torque acting on secondary shaft = 229.77 N-m

Diameter of spur pinion ( $D_p$ ) = 0.12 m

$$\text{Therefore, } W_T = \frac{229.77}{\left(\frac{0.12}{2}\right)} = 3829.50N$$

$$\text{Now, normal load, } W_N = \frac{W_T}{\cos\phi} = \frac{3829.50}{\cos 20} = 4073.94N \quad \dots\dots (3.24)$$

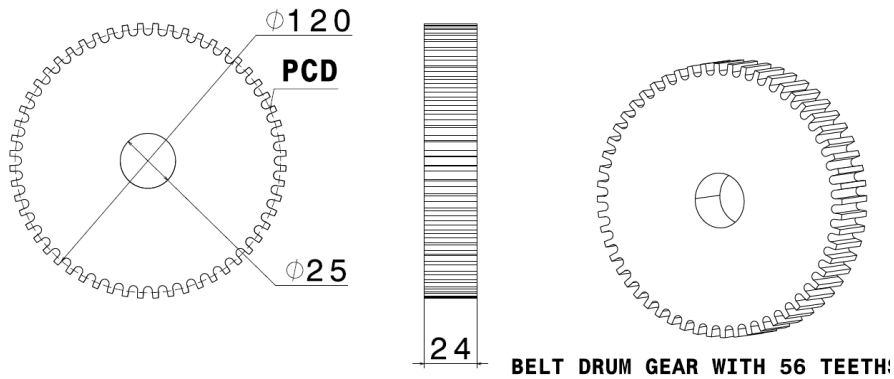
Considering maximum normal pressure between teeth ( $P_N$ ) as  $175 \text{ N mm}^{-1}$  (Khurmi and Gupta, 2005)

The necessary face width of the pinion (b) was calculated by using following relation

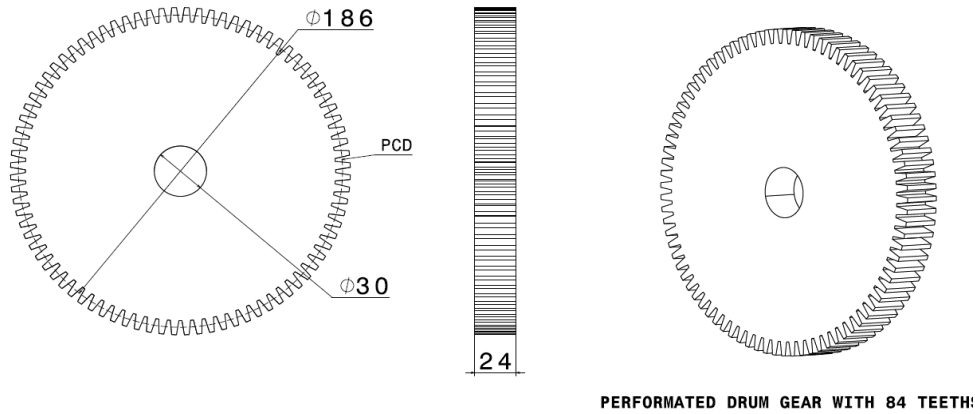
$$\text{Face width of pinion (b)} = \frac{W_T}{P_N} = \frac{4073.94}{175} = 23.28 = 24\text{mm} \quad \dots\dots (3.25)$$

The minimum numbers of teeth required on the pinion and gear to avoid interference were 14 and 22, respectively. The minimum face width of the pinion or gear was 24 mm.

Therefore, commercially available cast iron spur gear of 84 teeth and pinion of 56 teeth with 24.00 mm face width were procured from Raichur local market (Fig. 3.13 and Fig. 3.14).



**Fig. 3.13 Schematic view of spur pinion (dimensions in mm)**



**Fig. 3.14 Schematic view of spur gear (dimensions in mm)**

### 3.3.10 Perforated drum

Perforated drum made of stainless steel (SS-306L) cylinder of 6 mm wall thickness with internal diameter of 152 mm and 305 mm length was selected for the fabrication of the drum. The perforations *viz.*, 2, 3, and 4 mm were selected to assess the effect of perforation size on meat recovery and texture of the recovered meat (Regenstein, 1986 and Petchrat *et al.*, 1997). The effective length of perforated drum was taken as 150 mm equal to the selected width of the endless belt. The drum was mounted and locked at one end of the main shaft with the help of bearings.

The following equation was used to test the drum for safe transmission of the torque coming on the main shaft ( $T_{\text{main}}$ ) by considering the maximum allowable shear stress ( $\tau_c$ ) of stainless steel cylinder (SS-306L) as  $600 \text{ N/mm}^2$ .

$$\tau_c = \frac{T_{\text{main}} \times 16 \times d_o}{\pi(d_o^4 - d_i^4)} \quad \dots\dots (3.26)$$

Where,  $\tau_c$  = Permissible shear stress,  $\text{N-mm}^{-2}$

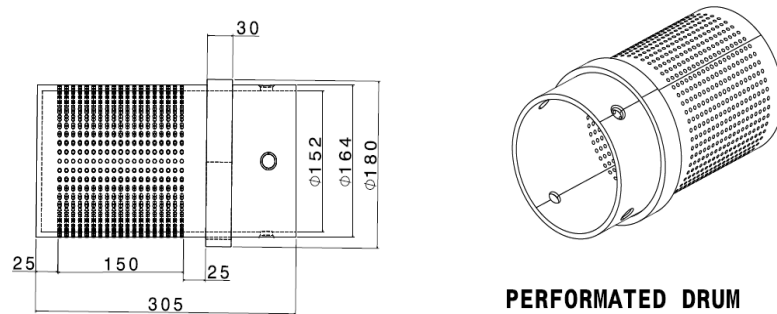
$d_o$  = Outer diameter of cylinder, 164 mm

$d_i$  = Inner diameter of cylinder, 152 mm

$T_{\text{main}}$  = Torque coming on main shaft / on perforated cylinder,  $356.14 \times 10^3 \text{ N-mm}$

$$\text{Therefore, } \tau_c = \frac{356.14 \times 1000 \times 16 \times 164}{\pi(164^4 - 152^4)} = 1.58 \text{ N-mm}^{-2} < 600 \text{ N-mm}^{-2}$$

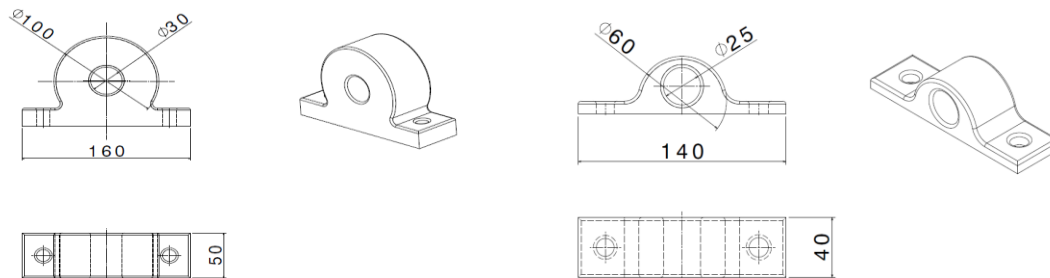
Since, the induced shear stress in the cylinder was meager compared to its maximum allowable shear stress, the design of selected perforated drum (Fig. 3.15) is safe.



**Fig. 3.15 Schematic view of perforated drum (dimensions in mm)**

### 3.3.11 Bearing

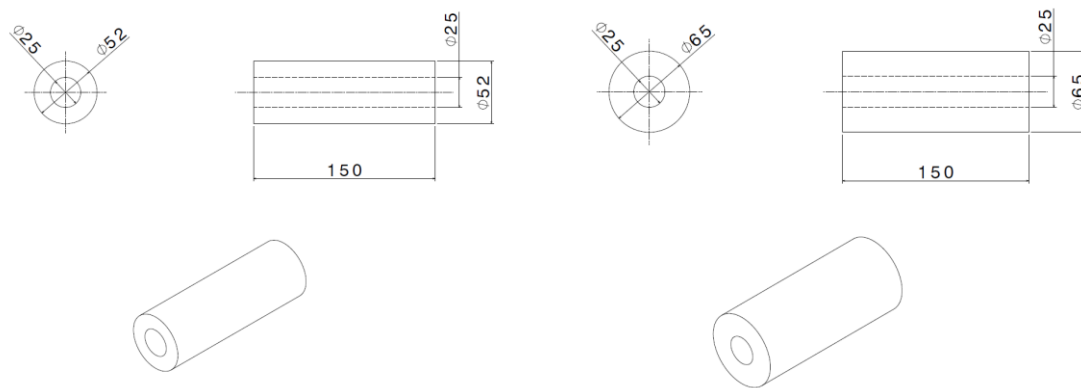
Radial ball bearings (4 No.) (Model No. FKD UC 27080) were selected and procured from the local market. Two bearings (Fig. 3.16) were used to support main shaft (30 mm diameter) and another two were used for secondary shaft (25 mm diameter).



**Fig. 3.16 Schematic view of roller bearings (dimensions in mm)**

### 3.3.12 Rollers

Rollers made of nylon were selected to provide belt tension (65 mm $\varnothing$ ) and to support the belt on underside of the conveyor belt (52 mm  $\varnothing$ ). Length of these rollers was kept equal to the width of the belt (150mm) as shown in Fig. 3.17. Nylon rods were procured from the local market of Raichur city for fabrication of these rollers.

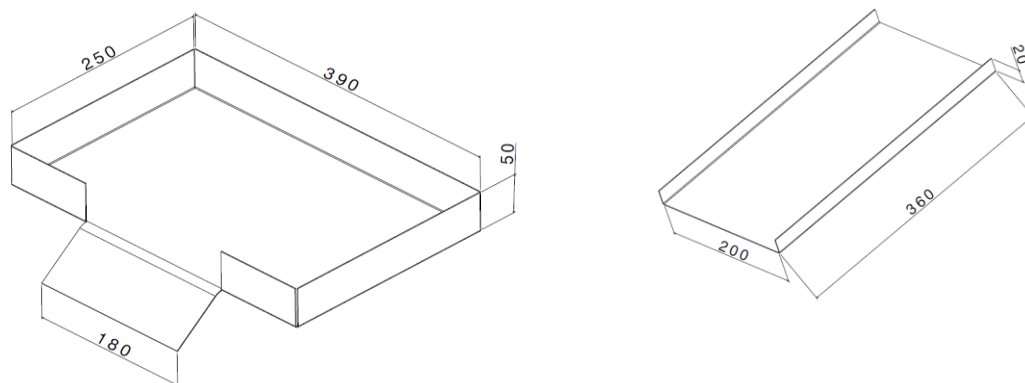


**Fig. 3.17 Schematic view of tension and belt supporting rollers (dimensions in mm)**

### 3.3.13 Feed tray and outlet chute

A feed tray was designed to accommodate 5 kg of fish pieces and the dimensions selected were  $390 \times 250 \times 50$  mm with feeding chute size of  $180 \times 10$  mm. Stainless steel metal sheet (SS-304) of 24 gauge was used for the fabrication of the feed tray (Fig. 3.18) and was fixed at an appropriate position on the base frame for easy feeding of the fish pieces.

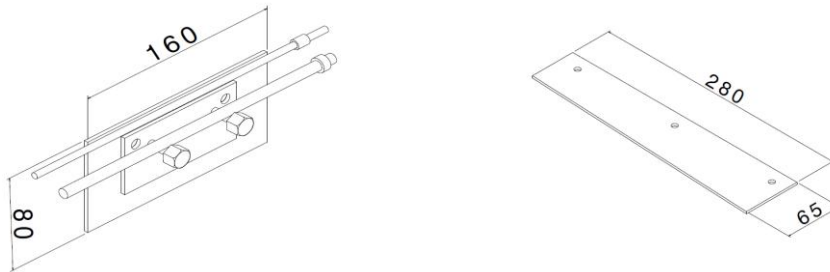
A suitable outlet chute of  $360 \times 200 \times 20$  mm size was designed to collect the bones and the skin after meat separation (Fig. 3.18). It was also fabricated with stainless steel metal sheet (SS-304) and fixed to the base frame.



**Fig. 3.18 Schematic view of feed tray and outlet chute (dimensions in mm)**

### 3.3.14 Scraper blades

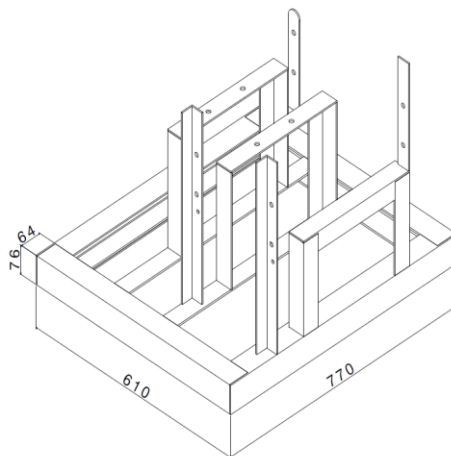
Two scraper blades were provided on the fish deboner, one (160 × 80 mm) to scrap the outer surface of the perforated drum for keeping the perforations clear and another (280 × 65 mm) to collect the minced meat inside the perforated drum. These blades were made of 5 mm thick food grade wear resistant HDPE sheets. The blades were mounted on the base frame at the respective positions. The sketches of scraper blades with dimensions are shown in Fig. 3.19.



**Fig. 3.19 Schematic view of scraper blades (dimensions in mm)**

### 3.3.15 Base and supporting frames

A frame of 770 mm length and 610 mm width was fabricated with heavy duty mild steel C channel of size 76× 64 × 6 mm to provide strong base to the designed fish deboner. To this, mild steel angles of 51× 51 × 4 mm and 38 × 38 × 4 mm sizes were welded at the appropriate positions to provide vertical support and to accommodate different machine elements of fish deboner (Fig. 3.20).



**Fig. 3.20 Schematic view of base frame (dimensions in mm)**

### 3.3.16 Development of designed fish deboner

The development of fish deboner was carried out as per the designed data for the different machine elements. The fabrication and the assembly of the deboner was done at the main workshop of College of Agricultural Engineering, Raichur.

### 3.4 Optimization of Operational Parameters of Developed Fish Deboner

Three levels of peripheral speeds of the drum *viz.*, 7.22, 10.31 and 12.37 m min<sup>-1</sup>, drum perforation sizes (2, 3 and 4 mm Ø) and belt hardnesses (350, 450 and 550 MPa or 35, 45 and 55 Shore No.) were considered for optimization experiment. The details of the dependent and independent variables are given in Table 3.1.

**Table 3.1. Dependent and independent variables for optimization experiments**

<b>Independent variables</b>	<b>Levels of variables</b>	<b>Dependent variables</b>
Drum peripheral speed	3 levels (7.22, 10.31 and 12.37 m min <sup>-1</sup> )	Meat recovery (kg/kg of dressed fish)
Drum perforation size	3 levels (2, 3, and 4 mm Ø holes)	
Belt hardness	3 levels (35, 45 and 55 Shore No.) or (350, 450 and 550 MPa)	Bone content (mg per 100 g of minced meat)

Three perforated drums having 2, 3, and 4 mm Ø holes and three conveyor belts having hardness of 35, 45 and 55 shore No. used in the experiments are shown in Plate 3.2 and Plate 3.3 respectively. The maximum belt tension of 50 kg (490 N) was set by adjusting the positions of the driving and driven rollers. The peripheral speed of the drum and speed of conveyor belt were measured with the help of a contact type tachometer (Make: Lutron, USA, Model: LT-2236).



**Plate 3.2 Perforated cylinders  
(2, 3 and 4 mm  $\emptyset$  holes)**



**Plate 3.3 Conveyor belts  
(35, 45 and 55 Shore No.)**

### **3.4.1 Raw material**

Tilapia (*Oreochromis mossambicus*), a low value and under utilized fresh water fish was selected for the optimization of the operational parameters of developed fish deboner and the fishes were procured from local fish market of Raichur city. Fishes were washed in tap water to remove the debris and other foreign material. Washed fishes were subjected to be-heading and gutting on a stainless steel gutting tray. The cleaned and dressed fish pieces or fillets (Plate 3.4) were stored at  $-20^{\circ}\text{C}$  in the deep freezer for further usage during the experimentation.



**Plate 3.4 Tilapia (*Oreochromis mossambicus*) fish and dressed fish  
for testing fish deboner**

### 3.4.2 Meat separation in the developed fish deboner

The cleaned and dressed fishes from the deep freezer were taken out and kept for thawing in tap water prior to deboning. Fish pieces weighing 1.0 kg were fed manually in the feeding section in such a way that the meat portion faced the perforated drum.



**Plate 3.5 Separation of meat and bone using developed fish deboner**

The meat was squeezed through the perforations due to the compression of fish pieces between the conveyor belt and the perforated drum. The minced meat was then packed in polythene pouches and stored for further analysis of quality of the minced meat. After each experiment, the perforated drum and the conveyor belt were washed thoroughly with clean water. Outer scraping blade continuously cleared the perforations from sticky meat and inner scraping blade scraped off the meat entered inside the perforated drum. The fish pieces with skin, bone and residual meat were collected at the outlet section of the deboner. These fish pieces were re-fed twice to the feeding section for extraction of residual meat. Three passes were carried out during each experiment for total meat recovery and each experiment was replicated thrice. At the end of each pass meat and skin along with bones (waste) collected separately and weights were recorded (Plate 3.5).

### **3.4.3 Meat recovery**

The meat recovery was calculated as the total quantity of meat extracted from unit kg of dressed fish. It is the total of meat recovered during Pass I, Pass II and Pass III and is expressed as kg per kg of dressed fish. This is the total meat recovered during and bone content in the minced meat were computed for selecting the optimum operational parameters for performance evaluation of the developed fish deboner using selected fresh water fishes.

### **3.4.4 Bone content in minced meat**

The bone content in the minced meat was determined by using gravity – floatation method as described by Patashnik (1974). The method involves shredding of minced meat in water with a low speed stirring device and gravity separation of bones from low density floatable muscle fibers.

A sample of 100 g minced meat was placed in the blender jar with 100 ml of tap water for shredding of meat sample. The blender was put on to run for about two minutes. Then the dilute mass was transferred to a 500 ml glass beaker. The beaker was placed under the tap allowing water to flow at a rate of 4 to 5 lit / min. until the water was essentially free of floating muscle fibers present in the meat. The residue was transferred to a paper towel and separated into different components namely, bone, fin and cartilage. The weight of the bones was recorded. The procedure was followed for all the samples collected during three passes of meat separation and the total weight of the bones was computed and expressed as mg of bone content per 100 gram of minced meat.

### **3.4.5 Statistical analysis**

The results obtained from the experiment were analysed statistically three factors Completely Randomized Block Design. The optimized solution of operational parameters for maximum meat recovery (kg per kg of dressed fish) and minimum bone content (mg per 100 g of minced meat) was obtained from the desirability analysis using Design Expert – Version 7.0 software.

### 3.4.6 Effect of contact area of belt and drum on meat recovery and bone content

The effect of contact area of belt and drum on meat recovery and bone content in minced meat was studied. Four different contact areas viz., 25, 35, 45 and 55 per cent of the outer surface of the drum in contact with the belt were selected for the study keeping other optimized variables (drum peripheral speed, belt hardness and perforation size of the drum) constant for this experiment. This experiment was also carried out three times. The maximum meat recovery and minimum bone content were considered for selecting the optimum contact area.

### 3.4.7 Efficiency of the developed deboner

The fish deboner was assembled and set for the optimized operational parameters. Five levels of feed rates viz., 50, 60, 70, 80 and 90 kg of dressed fishes per hour were selected for the experiment. Fixed time of one minute was considered for deboning process and accordingly, fish pieces weighing 0.83, 1.00, 1.17, 1.33 and 1.50 kg were fed in to the fish deboner for three passes in one minute for maximum recovery of minced meat.

The quantity of minced meat recovered ( $M_1$ ) and the waste containing skin and bone were weighed and recorded for each feed rate. The residual meat (un-recovered meat) ( $M_2$ ) present in the waste was manually separated and noted for calculating the efficiency of the fish deboner. The experiments were carried out thrice and the average values were computed. Meat recovery in terms of percentage meat yield and meat recovered in kg per hour and the efficiency of the fish deboner for meat recovery were calculated using the following expressions (Robertson and Meritt, 1985).

$$\text{Percentage meat yield, \%} = \frac{M_1}{F} \times 100 \quad \dots\dots\dots (3.27)$$

$$\text{Meat recovery, kg per hour} = M_1 \times 60 \quad \dots\dots\dots (3.28)$$

$$\text{Meat extraction efficiency, \%} = \frac{M_1}{M_1 + M_2} \times 100 \quad \dots\dots\dots (3.29)$$

Where,

$M_1$  – Weight of meat recovered per minute, kg per min<sup>-1</sup>

F – Weight of fish pieces fed per minute, kg per min<sup>-1</sup>

$M_2$  - Weight of residual meat present in waste, kg

### 3.5 Performance Evaluation of the Developed Fish Deboner

Performance of the developed fish deboner was evaluated at optimized processed parameters in terms of meat recovery, bone content, colour of minced meat, textural and rheological properties of the minced meat. Three freshwater fish species namely, Tilapia, Rohu and Mrigal fishes (Plate 3.6) were used for the experiment. The fishes were procured from Raichur fish market and brought to the fish processing laboratory in the iced condition. Fishes were washed in tap water and subjected to be-heading and gutting on a stainless steel gutting tray. The cleaned and dressed fish pieces or fillets were stored at -20°C in the deep freezer for further usage during the experimentation.



**Plate 3.6 Tilapia, Rohu and Mrigal fresh water fishes selected for performance evaluation of the fish deboner**

The fish deboner was assembled and set for the optimized operational parameters. The meat separation process (as explained in Section 3.3.2) was carried out for three fish species. The quantity of meat recovered from respective fish species was collected separately and stored at -20°C for further analyses of minced meat. The details of the independent and dependent variables considered for the study are as given below (Table 3.2).

**Table 3.2. Dependent and independent variables for performance evaluation of developed fish deboner**

<b>Independent variables</b>	<b>Dependent variables</b>
Three fish species F1 – Tilapia ( <i>Oreochromis mossambicus</i> ) F2 – Rohu ( <i>Labeo rohita</i> ) F3 – Mrigal ( <i>Cirrhinus cirrhinus</i> )	Meat recovery (kg/kg of dressed fish) Bone content (g per 100 g of minced meat) Colour value ( $L^*$ , $a^*$ and $b^*$ ) Textural properties Rheological properties

### 3.5.1 Meat recovery

The developed fish deboner was tested for meat recovery from three different fish species. The procedure explained in Section 3.3.3 was followed for computing the meat recovery from respective samples.

### 3.5.2 Bone content in minced meat

Bone content in the minced meat of three fish species was determined by following the procedure described in Section 3.3.4.

### 3.5.3 Colour of minced meat

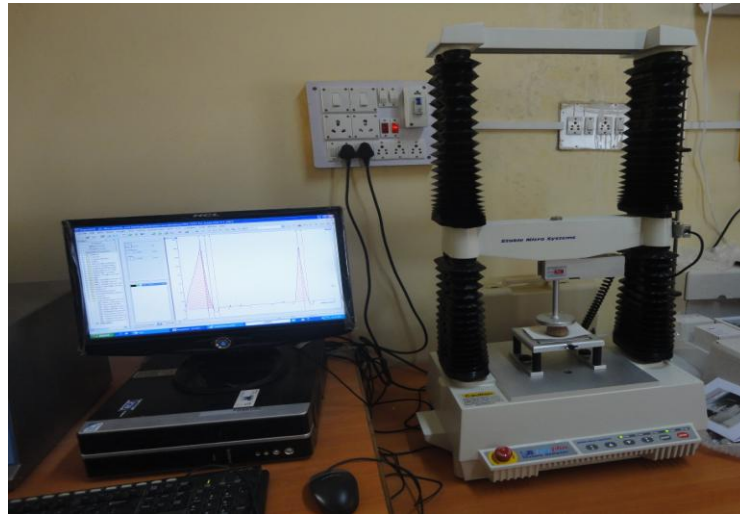
Colour is one of the most important qualities of minced meat as it indicates the freshness of the meat. Hunter lab colourmeter (Plate 3.7) was used to measure the colour of minced meat recovered during each pass. The colour was measured at 10° observer scale with illumination of D<sub>65</sub>. The instrument was initially calibrated with standard white ceramic plates. The 3-dimensional scale  $L^*$ ,  $a^*$  and  $b^*$  was used for the measurement (Oliveira *et al.*, 2010). The  $L^*$  is the lightness coefficient, ranging from 0 (black) to 100 (white),  $a^*$  represents greenness and redness (+100 for red and -80 for green) while  $b^*$  represents yellowness and blueness (+70 for yellow and -80 for blue). Three random spots on each sample were measured and the average data were recorded.



**Plate 3.7 Color of the mined meat measured by using Hunter lab Colorimeter**

### 3.5.4 Texture profile analysis of minced meat

Texture Analyzer (Stable Micro System, Surrey, UK) (Plate 3.8) was used to assess the textural properties of minced meat of three fish species (Uresti *et al.*, 2002). Textural profile analysis (TPA) was performed using a cylinder probe (P50) having 50 mm Ø. Samples were compressed to 50% of initial height using a compression speed of 2 mm s<sup>-1</sup>. Hardness, springiness, cohesiveness, chewiness and resilience were recorded. The analysis was replicated thrice.



**Plate 3.8 Texture profile analysis of minced meat using Texture analyser**

### 3.5.5 Rheological properties

The rheological properties of the minced meat samples were determined by using a rotational rheometer (Brookfield Engineering Laboratories, Inc., USA, Model PVS Rheometer) equipped with torque measuring head and rotating outer cylinder (Plate 3.9). A 'B1' geometry stator/bob was used as geometry set. The speed of the rotor was selected within the range of 10 to 50 rpm (10, 20, 30 40 and 50). A temperature controlled water bath was used to maintain the temperature of the sample constant at 25°C. Before conducting the experiment the rheometer was calibrated to 0% torque. The BEAVIS (Brookfield Engineering Advanced Viscometer Instruction manual) test was used to set the different speeds in a cycle at a constant time interval of 30 seconds. After checking all the parameters, the instrument was made to run by rheovision software. For

each test, 25 g of sample was taken in the sample cup. The sample cup was carefully installed in the rheometer by pushing it up squarely followed by tightening the knurled locking ring. The rheological properties of the minced meat, such as viscosity (Pa.s), shear rate ( $s^{-1}$ ) and shear stress (Pa) were recorded. Each experiment was replicated thrice for each measurement, the sample cup and bob were carefully cleaned to avoid error in data.



**Plate 3.9 Rheometer used for determining rheological properties of minced meat samples**

### **3.6 Economics of Developed Fish Deboner**

The economics of the developed fish deboner was studied through the computation of the production cost of the fish deboner, cost of operation, payback period, benefit-cost ratio and net present worth.

#### **3.6.1 Cost of fish deboner**

The cost of the developed machine was calculated by considering the actual quantity of the raw material used in the fabrication of the designed fish deboner and their present cost including transportation charges and labour charges.

### 3.6.2 Cost of operation

The cost of operation of the developed fish deboner was conducted by straight line method described by Micheal and Ojha (2003). The following assumptions were made before calculating the cost of operation.

- i. No. of working days per year = 150
- ii. No. of working hours per day = 8 h
- iii. No. of labours required per day = 2 No.
- iv. Life of developed machine = 10 years
- v. Junk value of the machine = 10% of initial cost
- vi. Insurance = 1% on initial cost
- vii. Rate of interest = 15% of initial cost
- viii. Tax = 2% on initial cost
- ix. Housing = 5% of initial cost
- x. Repair and maintenance = 10% of initial cost

The expected returns for the machine were estimated based on the deboning charges (Rs. 2.00) per kg weight of raw material. In the fixed cost, annual depreciation, annual interest on investment and taxes were computed by using the following equations.

$$\text{Annual depreciation (Rs.)} = \frac{\text{Initial investment} - \text{Junk value}}{\text{Life in years}} \quad \dots\dots (3.30)$$

$$\text{Interest} = \frac{\text{Initial investment} + \text{Junk value}}{2} \times \frac{\text{Interest rate}}{100} \quad \dots\dots (3.31)$$

$$\text{Total cost} = \text{Fixed cost} + \text{Operating cost} \quad \dots\dots (3.32)$$

### 3.6.3 Pay back period:

Pay back period of the developed fish deboner in terms of number of years was computed by using the following equation (Reddy *et al.*, 2004)

$$\text{Payback period} = \frac{\text{Investment}}{\text{Net annual return}} = \frac{I}{E} \quad \dots\dots (3.33)$$

Where, P- Payback period, years

I- Investment, Rs.

E- Annual net return, Rs.

### 3.6.4 Benefit cost ratio

Benefit cost ratio was estimated by using the equation suggested by Reddy *et al.* (2004).

$$\text{Benefit-Cost ratio} = \frac{\text{Discounted return}}{\text{Discounted cost}} \quad \dots\dots (3.34)$$

The discounted cost and discounted return were calculated by using the following equations. Assuming, an increase in annual operational cost of the machine as 2% due to the probable hike in the repair and maintenance cost.

$$\text{Discounted return} = \sum_{t=1}^n \frac{B_t}{(1+r)^t} \quad \dots\dots (3.35)$$

$$\text{Discounted cost} = \sum_{t=1}^n \frac{C_t}{(1+r)^t} \quad \dots\dots (3.36)$$

Where,  $B_t$  - Returns for year  $t$ , Rs.

$C_t$  - Cost of production for year  $t$ , Rs.

$t$  - Economical life, years

$r$  - Discount rate, fraction

### 3.6.5 Net present worth (NPW)

Net present worth is the present worth of cash flow stream of the operation. It was calculated by using the following formula (Reddy *et.al.*, 2004)

$$NPW = \frac{P_1}{(1+i)^{t_1}} + \frac{P_2}{(1+i)^{t_2}} + \dots + \frac{P_n}{(1+i)^{t_n}} - C \quad \dots\dots(3.37)$$

Where, P- Net cash flow, Rs.

i - Discount rate, fraction

t - Time period, years

C - Investment, Rs.

### 3.6.6 Statistical Analysis

The results of the performance evaluation of the developed fish deboner were analysed through single factor ANOVA using Microsoft Excel-2007 software. The effect of different fish species on meat recovery, bone content in minced meat and quality parameters of minced meat were studied for Pass I, Pass II and Pass III respectively.

## 3.7 Development of Fortified Fish Sausage from Mince Meat

Experiments were conducted to prepare fortified fish sausage enriched with fish oil and Iodine) from Tilapia, low value and under-utilized freshwater fish at the Department of Processing and Food Engineering, College of Agricultural Engineering, Raichur. The materials used and methodology followed for the preparations of fish sausage are discussed under the following Sections.

### 3.7.1. Raw material

Medium sized fresh tilapia, an under-utilized freshwater fish was used for the preparation of fortified fish sausage. The fresh fishes were procured from local fish market of Raichur city and were transported in iced condition to the fish processing laboratory. After washing in chilled water, fishes were preserved in cold water (8±2°C) until used for the experiment. Omega-3 rich sardine fish oil was procured from Coastal Exports Corporation, Mangalore, Karnataka and Food grade potassium iodide (KI) and

other chemicals were purchased from SD Fine laboratory, Bangalore, Karnataka. The necessary ingredients were procured from super market, Raichur, Karnataka.

### **3.7.2 Treatment details**

The recipe described by Raju *et al.*, (2003) was followed for the preparation of fortified fish sausage with 70% fish meat and 5% vegetable oil. Sardine fish oil rich in omega – 3 fatty acids (Ugoala, 2008) was added at 5, 10 and 15 per cent % of the vegetable oil proportion along with other ingredients of the sausage recipe (Panpipat and Jirawat, 2008). The sausage was also fortified with potassium iodide (KI) at 150 µg/100g of sausage except in control sample to improve iodine content in the diet (Magee *et al.*, 2008).

The treatment details are as given below;

T1 - Sausage without addition of KI (control)

T2 - Sausage with KI @ 150 µg/100g of sausage

T3 - Sausage with fish oil @ 0.25 g + KI @ 150 µg/100g of sausage

T4 - Sausage with fish oil @ 0.50 g + KI @ 150 µg/100g of sausage

T5 - Sausage with fish oil @ 0.75 g + KI @ 150 µg/100g of sausage

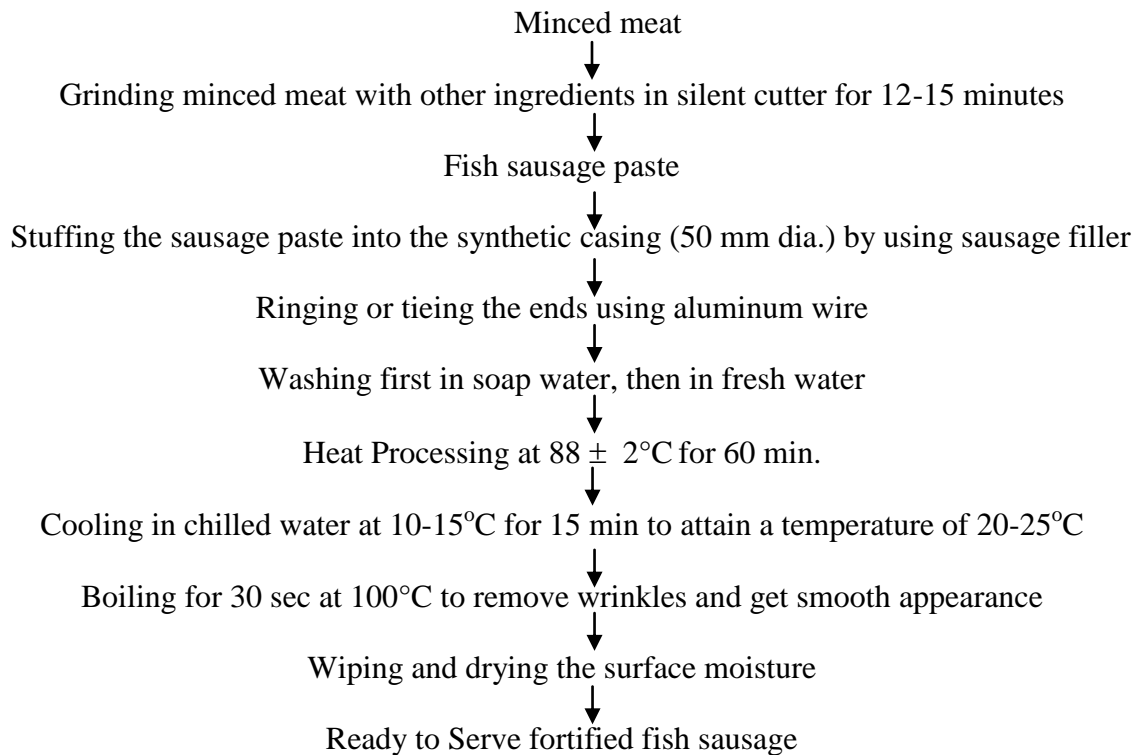
T6 – Commercial sausage

### **3.7.3 Preparation of fish sausage**

The process flow chart followed for the preparation of fish sausage (Raju, *et al.*, 2003) is presented in Fig.3.21. The fishes were dressed to remove scales, head and viscera and washed in chilled water and excess water was drained. The cleaned fish pieces were fed into the developed deboner to separate the meat from skin and bones.

The separated meat was minced in a mincer to prepare homogenous meat mass. The ingredients used for the preparation of fish sausage are listed in Table 3.3. The minced meat was thoroughly mixed with other ingredients in a silent cutter to make fine paste. The paste mixture was stuffed into the synthetic casing with the help of the sausage filler and both the ends of casing were tied off using the aluminum wire.

The sausages were heat processed at  $88 \pm 2^\circ\text{C}$  for 60 minutes and cooled to room temperature ( $28 \pm 2^\circ\text{C}$ ). The cooled sausages were re-heated in boiling water (for 30 sec at  $100^\circ\text{C}$ ) to remove wrinkles and get smooth appearance. Then, the sausages were taken out of boiling water, wiped the surface moisture and cooled to room temperature. The sausages prepared with different levels of treatments are shown in Plate 3.10. Commercial sausage (20 days old) was purchased from super market; Hyderabad for comparative study of sausages is also depicted.



**Fig. 3.21 Process flow chart for preparation of fish sausage**

#### **3.7.4 Proximate composition of fresh fish mince, sausage paste and sausage**

The proximate compositions of fresh fish mince, sausage paste and sausages were determined by following standard procedures described hereunder.

**Table 3.3 Ingredients used in the preparation of fish sausage**

<b>Ingredients</b>	<b>% (by weight)</b>
Minced fish meat	70.00
Salt	02.50
Sugar	01.50
Poly phosphate	00.20
Monosodium glutamate	00.20
Potassium sorbate	00.20
Colour solution*	00.10
Chilli powder	00.60
Pepper powder	00.20
Coriander	00.30
Ginger paste	00.10
Garlic paste	00.10
Corn starch	10.00
Fats**	05.00
Crushed ice	9.00
<b>Total</b>	<b>100.00</b>

\* (Ponceau 4R-60% and Carmosine-40%)

\*\* vegetable oil or vegetable oil + fish oil as per the treatments



**Plate 3.10 Fish sausages prepared with different levels of treatments**

### 3.7.4.1 Moisture content

The moisture contents of the fresh fish mince, sausage paste and sausages were determined by following hot air oven method (AOAC, 1995). About 10 g of the sample was weighed in a moisture box and dried in an oven at  $100 \pm 1^\circ\text{C}$  for 16 hours and cooled in a desiccator. The weight of the dried sample was recorded. The moisture content (per cent) of the sample was calculated by using the following formula.

$$\text{Moisture content (\%)} = \frac{W_1 - W_2}{W_1} \times 100 \quad (3.38)$$

Where,

$W_1$  = Initial weight of the sample, g

$W_2$  = Bone dried weight of the sample, g

### 3.7.4.2 Crude protein

The crude protein contents in fresh fish, sausage paste and sausage were determined using micro Kjeldahl method (AOAC, 1995). One gram of sample was transferred to a digestion tube, to this 0.5 gram of digestion mixture and 10 ml of

concentrated H<sub>2</sub>SO<sub>4</sub> were added. The sample was digested in a digester till it became colourless. Then the tubes were cooled and transferred to the distillation unit. Forty ml of 40% NaOH solution was allowed into the tube. Liberated ammonium was absorbed in 2% boric acid solution containing mixed indicator. The pink colour of the boric acid solution turned to green then the solution was titrated against 0.01N HCl until the pink colour was obtained. Per cent crude protein of the sample was calculated by using the following formula.

$$\text{Protein (\%)} = \frac{TV \times 0.014 \times 100 \text{ (ml)} \times 0.01 \times 100 \times 6.25}{\text{Weight of the sample (g)} \times \text{Aliquot used for distillation (ml)}} \dots\dots (3.39)$$

Where,

TV = Titre value of the sample

### 3.7.4.3 Crude fat

The crude fat contents in fresh fish mince, sausage paste and sausages were determined by following soxhlet apparatus method (AOAC, 1995). Five grams of sample was weighed into a thimble and plugged with cotton. The thimble was then placed in a soxhlet apparatus (Make: Pelican Model: Socs plus SCS -8) and the fat content was extracted with anhydrous ether for about 6 hours. The ether was then removed by evaporation and the flask with the residue was dried in an oven at 100°C for 10-15 minutes, cooled in a desiccator and weighed. Per cent crude fat of the sample was calculated by using the following formula.

$$\text{Crude fat (\%)} = \frac{W_4 - W_3}{W_2 - W_1} \times 100 \dots\dots\dots (3.40)$$

Where,

W<sub>1</sub> = Weight of empty thimble, g

W<sub>2</sub> = Weight of thimble + sample, g

W<sub>3</sub> = Weight of empty flask, g

W<sub>4</sub> = Weight of flask + fat, g

#### **3.7.4.4 Total ash**

The total ash content of the fresh fish, fish sausage paste and fish sausage was determined by muffle furnace method (AOAC, 1995). Five grams of sample was weighed into a crucible (which was previously heated to about 600°C and then cooled). The crucible was placed on a clay pipe triangle and heated first over a low flame till all the material was completely charred, followed by heating in a muffle furnace for about 3-5 hours at 600°C. It was then cooled in a desiccator and weighed. Ash content in percentage was calculated by using the following expression.

$$Total\ ash\ (\%) = \frac{Weight\ of\ ash\ (g)}{Weight\ of\ sample\ (g)} \times 100 \quad \dots\dots (3.41)$$

#### **3.7.4.5 Total carbohydrates**

The total carbohydrates of the fish mince, sausage paste and sausages were calculated by using difference method suggested by Merrill and Watt (1973). The equation followed for the calculation is as given below.

$$Total\ Carbohydrates = 100 - Total\ (Moisture + Protein + Fat + Ash) \quad \dots(3.42)$$

### **3.7.5 Bio-chemical characteristics of fresh fish, fish sausage paste and fish sausage**

#### **3.7.5.1 Total volatile base nitrogen (TVB-N)**

The TVB-N of fresh fish mince, sausage paste and sausages were analyzed. Ten grams of sample was ground with 50 ml of distilled water and proteins were precipitated by the addition of 15 ml of 20% trichloro acetic acid (TCA) and filtered through Whatman No. 4 filter paper. The filtrate was made up to a known volume. Total volatile base nitrogen from the trichloro acetic acid extract thus prepared for fresh fish and final products were determined by the procedure of Beatty and Gibbons (1937) using Conway's micro diffusion units. The results were expressed as mg nitrogen percent of samples.

#### **3.7.5.2 Free fatty acid (FFA)**

The free fatty acid (FFA) contents of fresh fish, fish sausage paste and fish sausages were determined by the improved titrimetric method (Ke *et al.*, 1976). Eight milliliters of chloroform extract of the sample was added to a conical flask of 250 ml

followed by 4 ml of methanol and 8 ml of isopropanol in the ratio of 2:1:1. To this solution 3 drops of 0.5 % metacresol purple was added as an indicator. The solution was titrated to purple end point with 0.05 N sodium hydroxide. The percentage of free fatty acid (as oleic acid percentage) was calculated by using the following equation.

$$\text{Free Fatty Acid content (FFA, \%)} = \frac{(TV_s - TV_b) \times N_{NaOH} \times 28.2}{\text{Weight of the sample (g)}} \quad \dots\dots (3.43)$$

Where,

TV<sub>s</sub> - Titre value of sample, ml

TV<sub>b</sub> - Titre value of blank, ml

N<sub>NaOH</sub> – Normality of NaOH

### 3.7.5.3 Peroxide Value (PV)

Peroxide value (PV) of fresh fish, fish sausage paste and fish sausage was determined by titrimetric method (Ke *et al.*, 1976). Ten grams of sample was taken and ground well with 15 grams each of anhydrous sodium sulphate and chloroform. Then the obtained extract was transferred to a 100 ml volumetric flask and made the volume upto 100 ml using chloroform. Ten milliliters of chloroform extract was put into 250 ml conical flask followed by adding 25 ml of solvent mixture (two volume of glacial acetic acid and one volume of chloroform), one milliliter of potassium iodide solution and 35ml of water and placed in dark for 15 minutes. The liberated iodine was titrated against standard sodium thiosulphate solution and the PV expressed as millimoles of oxygen/kg of lipid was calculated using the following expression.

$$\text{Peroxide Value (PV)} = \frac{(TV_s - TV_b) \times N_{Na_2SO_4}}{\text{Weight of the sample (g)}} \times 1000 \quad \dots\dots (3.45)$$

Where,

TV<sub>s</sub> - Titre value of sample, ml

TV<sub>b</sub> - Titre value of blank, ml

N<sub>Na<sub>2</sub>SO<sub>4</sub></sub> – Normality of Na<sub>2</sub>SO<sub>4</sub>

#### 3.7.5.4 Iodine value

Iodine value of fish meat, sausage paste and sausage was determined by titration method (AOAC, 1995). The sample (0.2 g) was taken in a 500 ml conical flask fitted with a round glass stopper. Chloroform (20 ml) was added the sample and shaken to dissolve the sample completely. To this solution 25 ml of Hanus iodine solution was added, mixed well and kept in dark for 30 min. KI solution (20 ml) was added and titrated with shaking continuously against 0.1N sodium thiosulphate. Three to four drops of starch solution as an indicator was added and the shaking was continued until the solution discoloured. A blank test sample was carried out under the same condition. Iodine value of the sample was computed using the following expression and converted the values to  $\mu\text{g}/100\text{g}$  of sample.

$$\text{Iodine value} = \frac{A \times N_{\text{Na}_2\text{S}_2\text{O}_3} \times 0.1269 \times 100}{W_s} \text{ g per 100 g of sample} \quad \dots\dots\dots (3.46)$$

Where,

A= ml of  $\text{Na}_2\text{S}_2\text{O}_3$  (test- blank)

$N_{\text{Na}_2\text{S}_2\text{O}_3}$  = Normality of  $\text{Na}_2\text{S}_2\text{O}_3$  solution

$W_s$  = Weight of the sample, g

#### 3.7.5.4 Fatty acid profile analysis

Fatty acid profiles of fish tissue and sausage samples during storage were determined using gas chromatography (GC) (Plate 3.11) according to the AOAC method (1995).

Total lipids were extracted according to the modified Folch's method (Folch *et al.*, 1957). The fatty acid methyl esters (FAME) were prepared by the addition of 1.5 ml of 0.5M sodium hydroxide in methanol to 25 mg of lipid. The mixture was heated in boiling water bath ( $100^\circ\text{C}$ ) for 2 min. After cooling, 2 ml of 14 per cent boron trifluoride in methanol was added in the mixture and reheated in a boiling water bath for 30 min. Subsequently, 1ml of isooctane was added. Five millilitres of saturated NaCl was added to the mixture to separate isooctane phase (containing FAME) from

methanol/water phase. Isooctane fraction was collected and the isooctane extraction was repeated once more. Two millilitres of isooctane (containing FAME) was dried under nitrogen gas at room temperature.

Subsequently, 1ml of isooctane was added to solubilize the dried FAME. The FAME was analysed using Gas Chromatograph (GC-2010, Shimadzu make) equipped with a flame ionization detector. Fused silica capillary column was used for the experiment. Temperature was programmed from 140 to 240°C at a rate of 4.0°C per min. Temperature of both injector and detector was set at 260°C. Helium was used as carrier gas and a flow rate of 0.9 ml/min was maintained throughout the experiment. Identification of fatty acid methyl esters (FAME) was based on comparison of retention time of tested samples to methyl ester standards procured from SD Fine laboratory, Bangalore. Absolute response factors were calculated for each identified fatty acid. Fatty acid composition was expressed as g per 100 g of sample and was determined in triplicate. The ratio of n-6 to n-3 of sausage samples was calculated. The n-6 fatty acids used in the calculation were linoleic (LA), eicosatrienoic, and arachidonic acid. Linolenic (LNA), eicosapentaenoic (EPA), and docosahexaenoic (DHA) were used for calculation of n-3 fatty acids.



**Plate 3.11 Gas chromatograph used for fatty acid profile of samples**

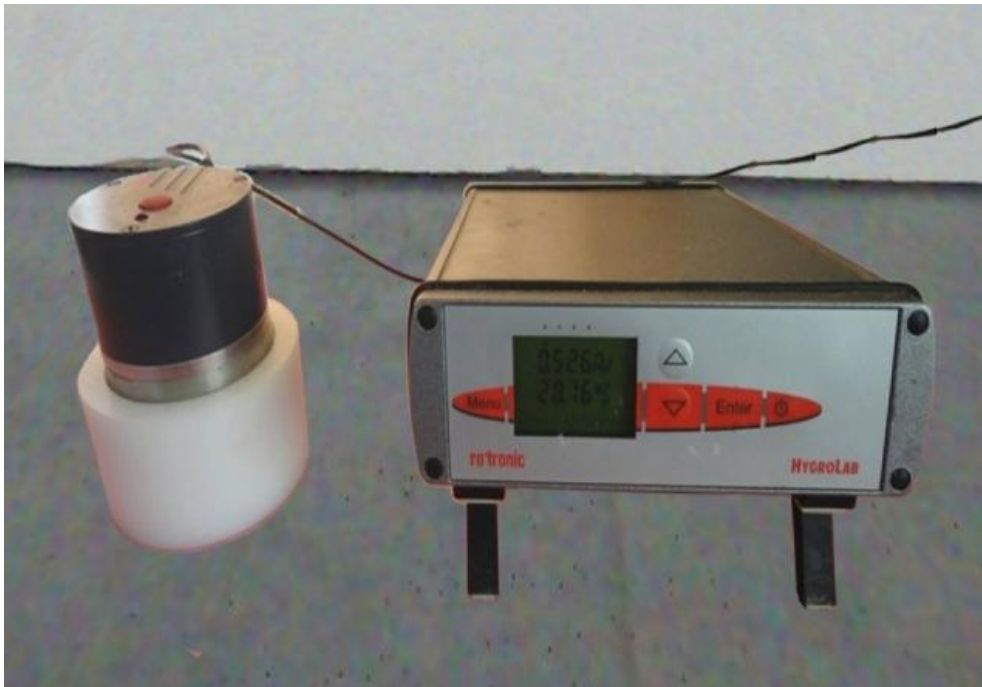
### **3.7.6 Quality parameters of fresh fish, fish sausage paste and fish sausage**

#### **3.7.6.1 Colour**

The Hunter lab colorimeter was used to determine the colour of fresh meat, sausage paste and sausage in the present investigation. The colour of fresh meat, sausage paste and sausage was measured at 10° observer scale and at illuminate of D<sub>65</sub>. The procedure described under the Section 3.3.6.

#### **3.7.6.2 Water activity**

The water activity of fresh meat, sausage paste and sausage was measured by water activity analyzer (Make: Rotronic and Model: Hygrolab 3) (Plate 3.12). The instrument was calibrated for its accuracy by measuring the water activity of distilled water. The sample under test was kept in sample cup of 50 ml size provided with water activity meter. The sensor was placed on the sample cup firmly and the reading displayed on LCD screen of water activity meter was recorded. Measurements for each treatment were replicated thrice.



**Plate 3.12 Water activity meter (Hygrolab-3) used for determination of water activity of the samples**

### **3.7.6.3 pH**

pH of fresh meat, sausage paste and sausage was measured by the method described by Suzuki (1981). Five grams of homogenized sample mixed with 45 ml of distilled water and stirred well in a beaker. The pH of this suspension was measured using combined electrode pH meter (Systronics pH meter - 324). The calibration of pH meter was done using potassium hydrogen phthalate and borate.

### **3.7.7 Microbiological characteristics of fresh fish, fish sausage paste and fish sausage**

Total plate count (TPC) and Aerobic spore formers (ASF) from fresh fish, sausage paste and prepared fish sausages including commercial sausage were enumerated according to the procedures described in APHA (1992). The TPC and aerobic spore formers were expressed as cfu g<sup>-1</sup> of meat or sausage.

Ten grams of sample was weighed and transferred to 100 ml water blank to obtain 1:10 dilution. The suspension was thoroughly shaken for 5 min. and the coarse particles were allowed to settle down. One milliliter of the suspension was transferred to 10 ml water blank to get 1:100 (10<sup>-2</sup>) dilution to each of two plates to enumerate bacteria. To all the plates, melted nutrient agar medium was poured (10-15 ml/plate). The plates were rotated carefully to ensure uniform distribution of diluted sample in the medium and the media was allowed to solidify. The plates were incubated at room temperature in the inverted position for a week. The number of colonies were counted per plate and recorded.

### **3.7.8 Sensory evaluation**

The procedure for sensory evaluation of fish sausages was followed using a panel of 12 judges (Siddaiah *et al.* 2001). All the judges were experienced in assessing the quality of fishery products including fish sausages. The assessors were trained to detect small differences especially in texture and flavour of fish sausages. Fortified (with fish oil and Iodine), control and commercial sausage fish sausages were heated in a hot water bath (80°C) for 10 min. The casings were peeled and sausages were cut into slices of 3–5 mm before evaluation. Assessors evaluated five sensory attributes namely, appearance, colour, taste, texture and flavour. The assessors were also asked to indicate

the overall acceptability score based on the five sensory attributes. Each sensory attribute was evaluated using 9 point hedonic scale (1 for disliked very much to 9 for liked very much). The scores of 12 judges were averaged and recorded.

### **3.7.9 Economics of production of fortified fish sausage**

The cost of production of 100 kg fortified fish sausage was computed by considering the actual costs of raw materials used in the preparation of the product. Net returns and B:C ratio were also calculated to study the economic feasibility of the process.

### **3.7.10 Statistical Analysis**

Experiments were conducted in three replications. Mean values and standard deviations were presented. The effects of iodine and sardine fish oil fortification on biochemical, microbiological and quality characteristics were analyzed by performing ANOVA using Microsoft Excel 2007 software.

## CHAPTER IV

### RESULTS AND DISCUSSION

This chapter deals with the results obtained and discussion made on design and development of the fish deboner, optimization of the operational parameters, performance evaluation and economics of the fish deboner. The results of the experiments conducted on standardization of recipe for preparation of the fortified fish sausage and changes in physico-chemical and quality characteristics during storage are also discussed in this chapter.

#### 4.1 Assessment of Existing Deboning Methods

Methods of mechanically separating flesh from bones and skin of fish, chicken or red meat were reviewed. Belt and perforated drum type principle was found to be most effective method of deboning of fish as higher meat recovery could be achieved with little preparation of fish, other than cleaning and gutting. Commercial belt and drum type deboners are of larger capacity and have lower efficiency (80-90 per cent) leaving behind the valuable meat (protein) with the skin and bones. The efficiency of belt and drum type deboners could be improved by proper designing of different machine components for adequate separation of meat, by selection of appropriate belt hardness to reduce damage upon friction, by providing motor power to drive both belt and drum, by increasing the contact area of drum with the belt and by fixing the scraper blades to provide sufficient cleaning of the mass after deboning.

#### 4.2 Design and Development of Fish Deboner

A belt and perforated drum type meat bone separation mechanism was considered for the design and development of a small-capacity (50-75 kg/h) fish deboner suitable for small scale fish processing business, especially along the Indian coastal region and other fish production centres of fresh water-fishes.

Design of fish deboner involved the computation of the power requirement and the design of different machine elements namely, shafts (motor, main and secondary), coupling, keys, speed reduction gear-box, sprockets, chain drive, spur gears, conveyor belt, perforated drum, bearings and supporting rollers. The results

obtained from the design procedure followed for the development of fish deboner are discussed below.

#### **4.2.1 Power requirement**

The average value of compressive force obtained from compression test in Texture analyzer for compressing fish (98 per cent) to extract meat through perforated cylinder was 411.12 N. The torque on the perforated drum shaft required for meat extraction was found to be 31.86 N-m and the calculated power requirement was 133.51 W. Considering factor of safety of 4 to overcome frictional resistance offered by different machine elements, an electric motor of 746 W (1 hp) with shaft diameter of 20 mm was procured from local market (Plate 4.1).

#### **4.2.2 Coupling**

In the design of coupling, outer diameter of 53 mm, inner diameter of 20 mm and length of 70 mm were obtained. Accordingly a flexible jaw coupling made of cast iron with the above mentioned specifications was procured from local market (Plate 4.2).

#### **4.2.3 Keys**

The keys having standard width of 8 mm and thickness of 7 mm with 35 mm length were fabricated using plain carbon steel. The keys were used for mounting different machine elements on the designed shafts (Khurmi and Guptha, 2005).

#### **4.2.4 Speed reduction gear box**

A speed reduction gear box of 30:1 was selected for reducing the speed of the motor thereby increasing the torque availability on the main shaft for better extraction of meat. The gear box was procured from Raichur local market (Plate 4.3).

#### **4.2.5 Chain and sprockets**

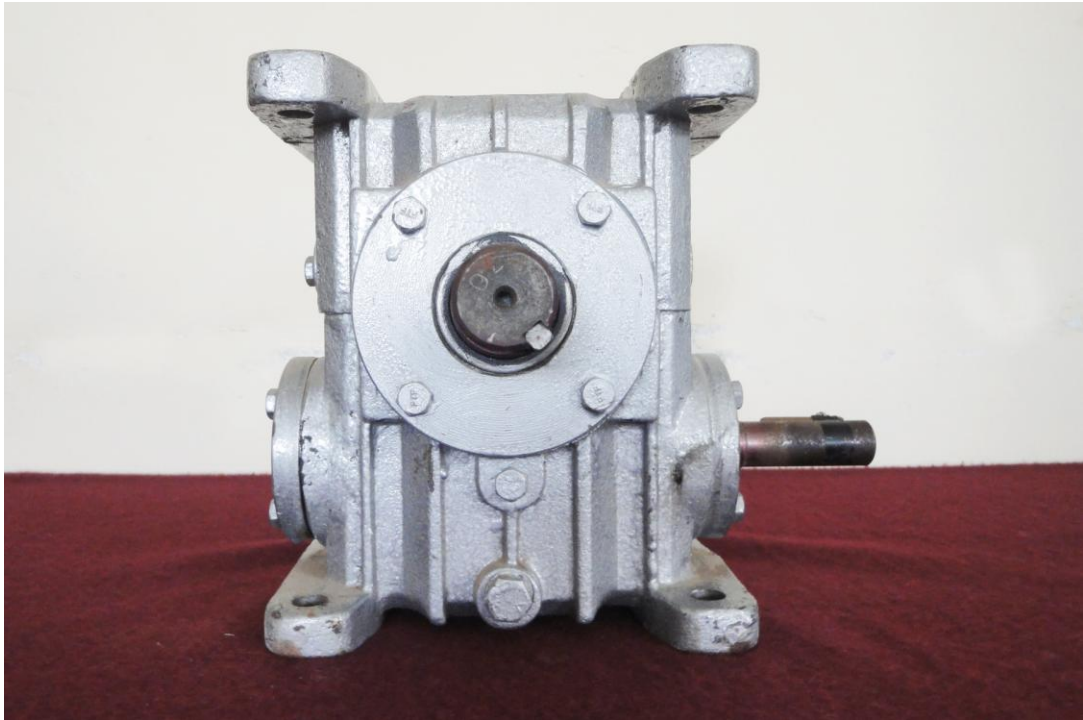
The sprockets and chain drive were designed to transfer the power from power source to the main shaft. Standard pinion sprocket having 8 teeth, three sprocket gears (16, 20 and 28 teeth) and one heavy duty single row roller chain of rating 12 B (IS: 2403-1991) were procured from local market for obtaining perforated drum speeds of 14, 20 and 24 rpm (Plate 4.4).



**Plate 4.1 Single phase electric motor (one hp)**



**Plate 4.2 Flexible jaw coupling**



**Plate 4.3 Speed reduction gear box (30:1)**



**Plate 4.4 Chain and sprockets**

#### **4.2.6 Spur gears**

Spur gears were selected as positive drive to provide the power from main shaft to the secondary shaft that facilitates the driving of conveyor or endless belt. The minimum numbers of teeth on the pinion and gear (to avoid interference) obtained were 14 and 22, respectively. The minimum face width of the pinion or gear was 24 mm. Therefore, commercially available cast iron spur gear of 84 teeth and pinion of 56 teeth with 24 mm face width were procured from Raichur local market (Plate 4.5).

#### **4.2.7 Main shaft and secondary shaft**

Main shaft and secondary shaft are the important parts of the fish deboner as these shafts provide required power transmission to the perforated drum and the belt mounted on the respective shafts. Commercially available Mild Steel shafts (40 C 8 – Indian Standard designation) of diameter 30 mm (Equation 3.16) and 25 mm were procured and used in fabrication of main and secondary shaft respectively (Plate 4.6).

#### **4.2.8 Conveyor belt or endless belt**

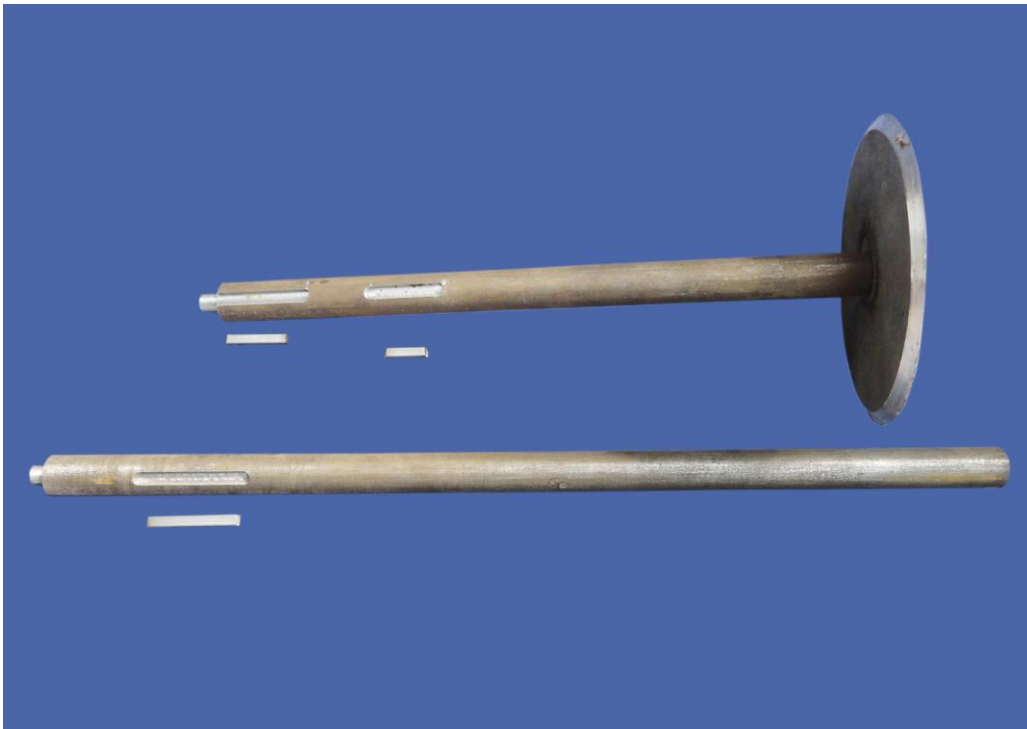
Conveyer belts made of food grade perfluoroelastomer rubber with 35, 45 and 65 Shore hardness were selected for the study. The dimensions of conveyer belt designed are length of 1135 mm, width of 150 mm and thickness of 20 mm. The conveyer belt with above specifications were procured from Royal rubber manufacturing company, Hyderabad and used for the experimentation (Plate 4.7).

#### **4.2.9 Perforated drum**

Stainless steel (SS-306L) cylinder of 6 mm wall thickness with internal diameter of 152 mm and 305 mm length was used for fabrication of perforated drums. These cylinders were drilled for perforation size of 2, 3, and 4 mm  $\varnothing$  (Plate 4.8) for effective length of 150 mm equal to the width of the endless belt. The drum was mounted at one end of the main shaft with the help of bearings.



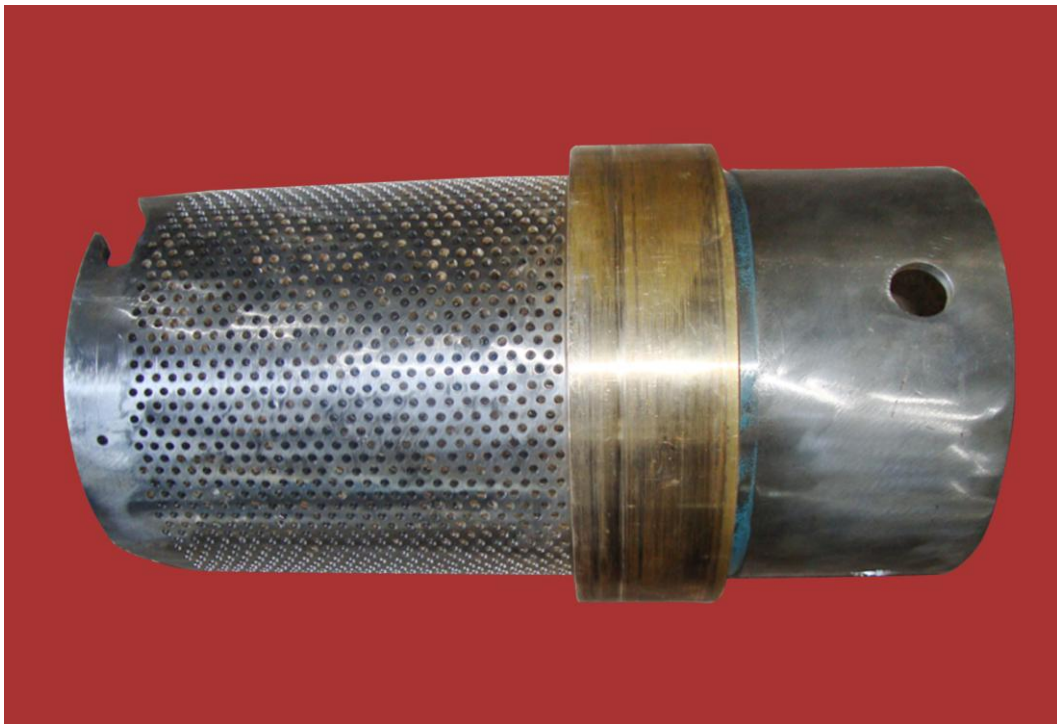
**Plate 4.5 Spur pinion and gear**



**Plate 4.6 Main and secondary shafts**



**Plate 4.7 Conveyor or endless belt**



**Plate 4.8 Perforated drum**

#### **4.2.10 Bearing**

Radial ball bearings (Model No. FKD UC 27080) were procured from the local market. A set of two bearings each were used to support main and secondary shafts respectively. Third set was used for supporting driven pulley of conveyor belt.

#### **4.2.11 Rollers**

Nylon rods having outer diameter of 65 and 52 mm  $\varnothing$  were cut into 150 mm lengths. These rods were drilled on a lathe for 20 mm inner diameter so as to fix on the base frame for providing support to the conveyor belt.

#### **4.2.12 Feed tray and outlet chute**

One feed tray (390 × 250 × 50 mm) with feeding chute (180 × 10 mm) and one outlet chute (360 × 200 × 20 mm) were fabricated using stainless steel metal sheet (SS-304) of 24 gauge (Plate 4.9 and Plate 4.10).

#### **4.2.13 Scraper blades**

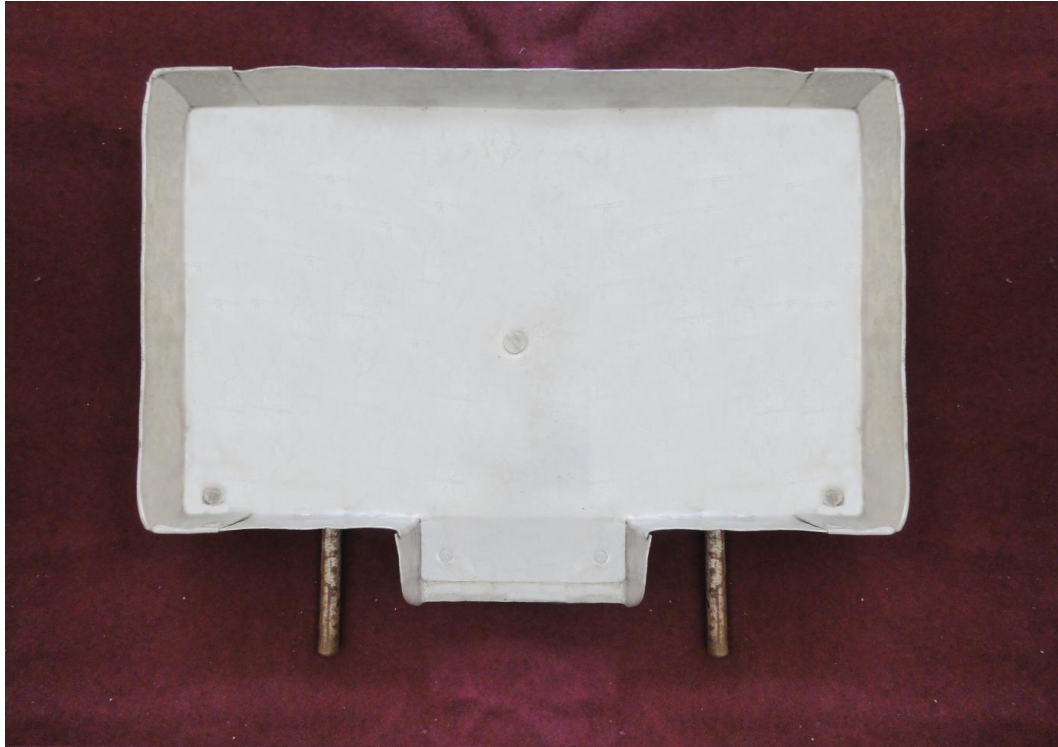
Two scraper blades one (160 × 80 mm) to scrape the outer surface of the perforated drum for keeping the perforations clear and another (280 × 65 mm) to collect the minced meat inside the perforated drum were made using 5 mm thick food grade wear resistant HDPE sheets (Plate 4.11 and Plate 4.12).

#### **4.2.14 Base and supporting frames**

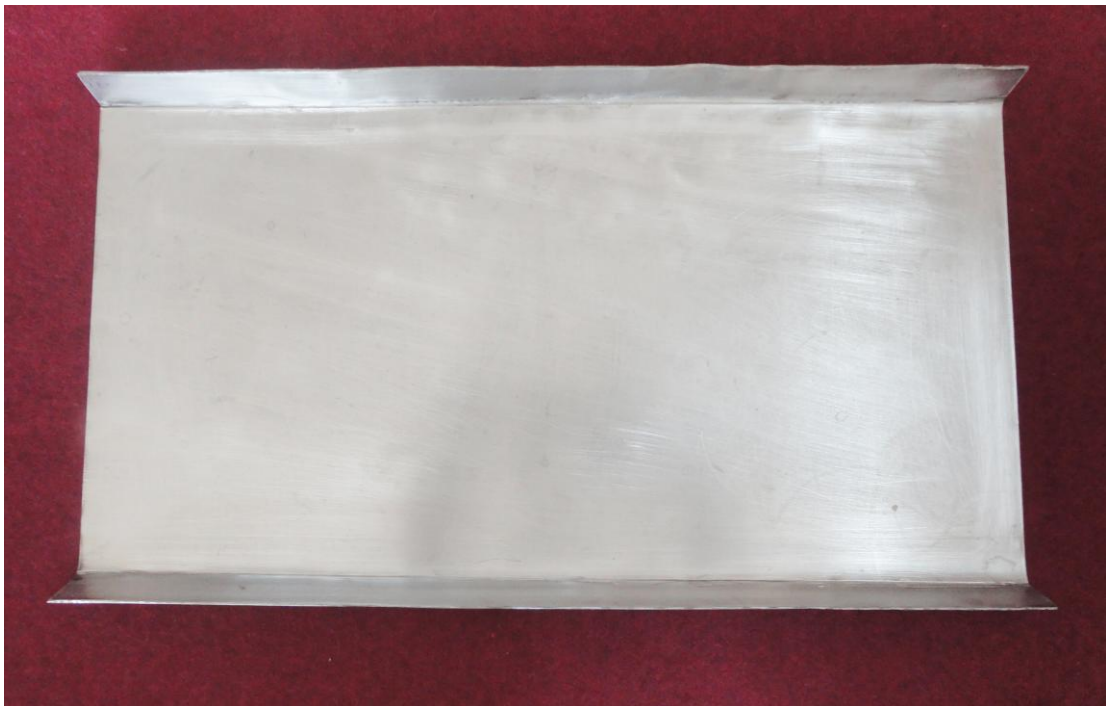
A base frame of 770 × 610 mm with supporting frames were fabricated with heavy duty mild steel C channel of 76 × 64 × 6 mm and mild steel angles (51 × 51 × 4 mm and 38 × 38 × 4 mm). A view of base and supporting frames is depicted in Plate 4.13.

#### **4.2.15 Assembly drawings of designed fish deboner**

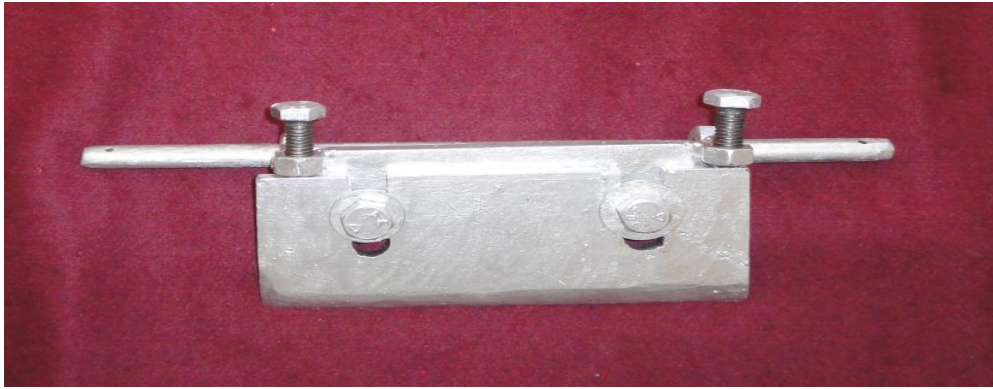
The assembly drawings *viz.*, plan, elevations in three planes and isometric views of the designed fish deboner were prepared for fabrication and presented hereunder (Fig. 4.1 to Fig 4.5).



**Plate 4.9 Feed tray for holding fish pieces**



**Plate 4.10 Outlet chute for collection of skin and bone**



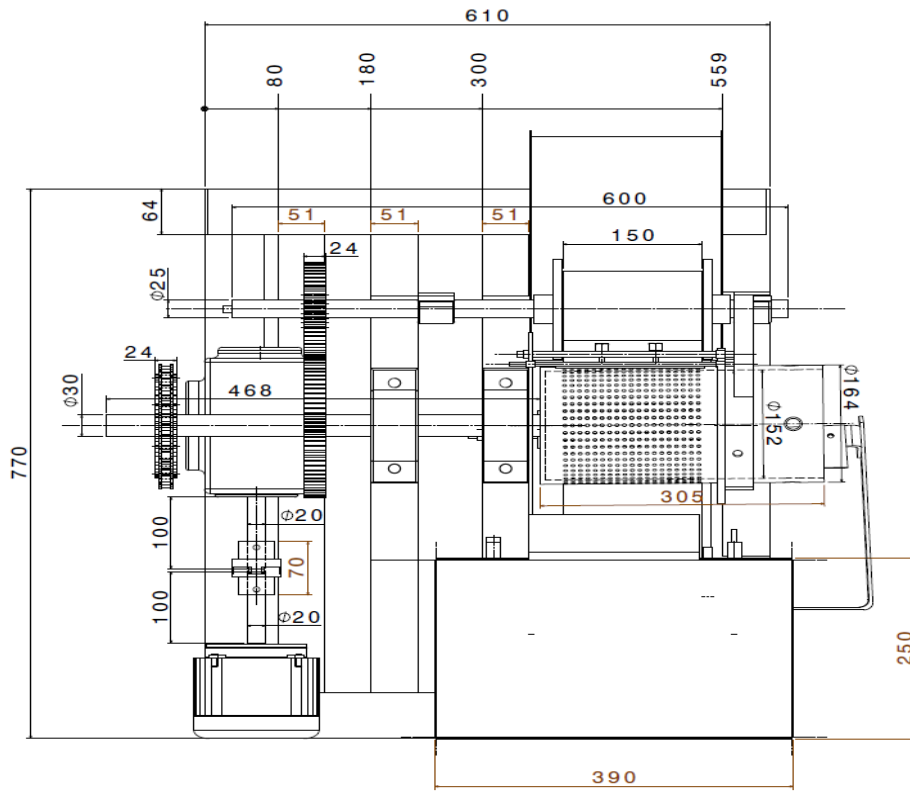
**Plate 4.11 Scraper blade for cleaning outer surface of perforated drum**



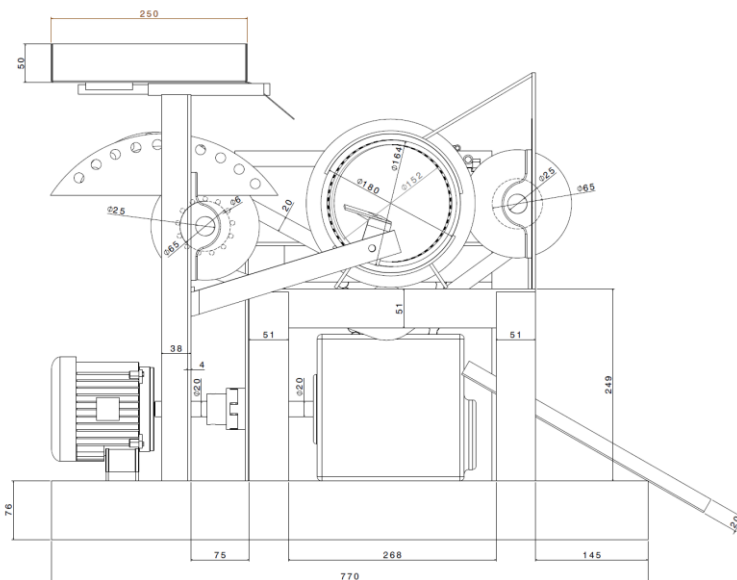
**Plate 4.12 Blade for scraping meat inside perforated drum**



**Plate 4.13 Base frame with supporting frames**

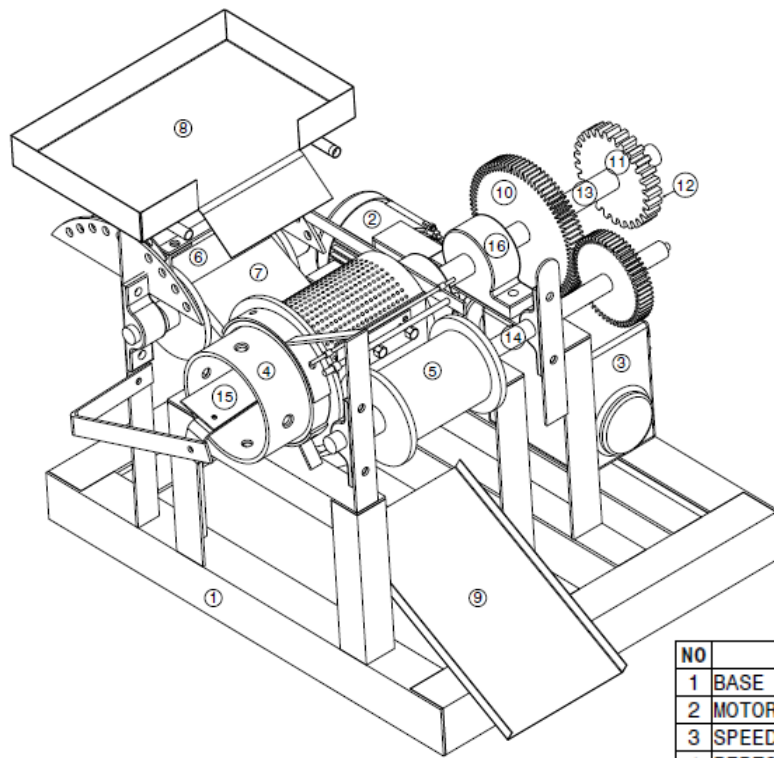


**Fig. 4.1 Schematic view showing plan of fish deboner (dimensions in mm)**

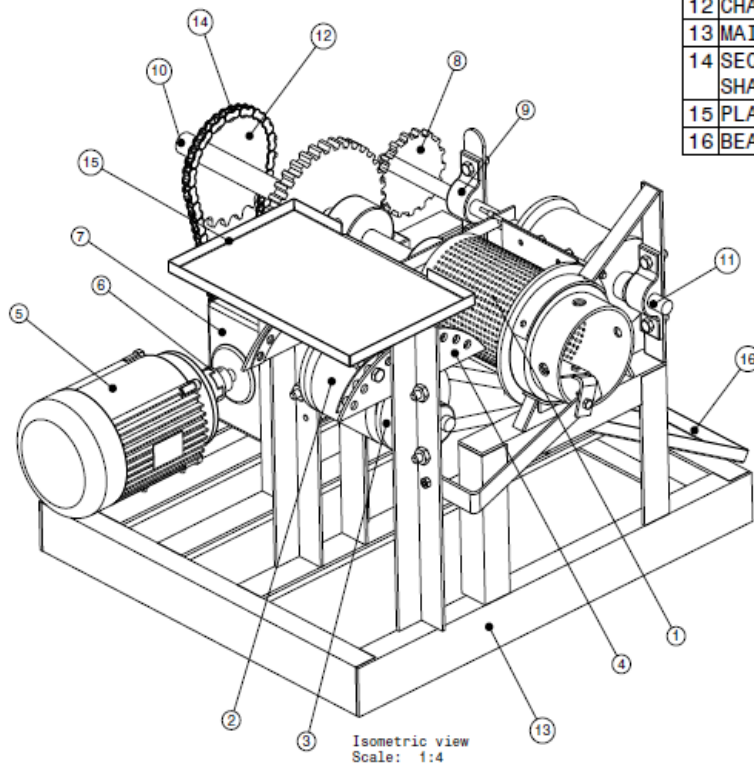


**Fig. 4.2 Schematic view showing right side elevation of fish deboner (dimensions in mm)**





NO	DESCRIPTION
1	BASE FRAME (STRUCTURE)
2	MOTOR
3	SPEED REDUCTION GEAR BOX
4	PERFORATED DRUM
5	BELT DRUM
6	ADJUSTABLE TENSION ROLLER
7	CONVEYOR BELT
8	FEED TRAY
9	COLLECTING TRAY
10	SPUR GEAR
11	SPROCKET ON MAIN SHAFT
12	CHAIN
13	MAIN SHAFT/DRUM SHAFT
14	SECONDARY SHAFT / BELT DRUM SHAFT
15	PLATE
16	BEARING



**Fig. 4.5 Schematic isometric views of fish deboner**

#### 4.2.16: Fabrication of designed fish deboner

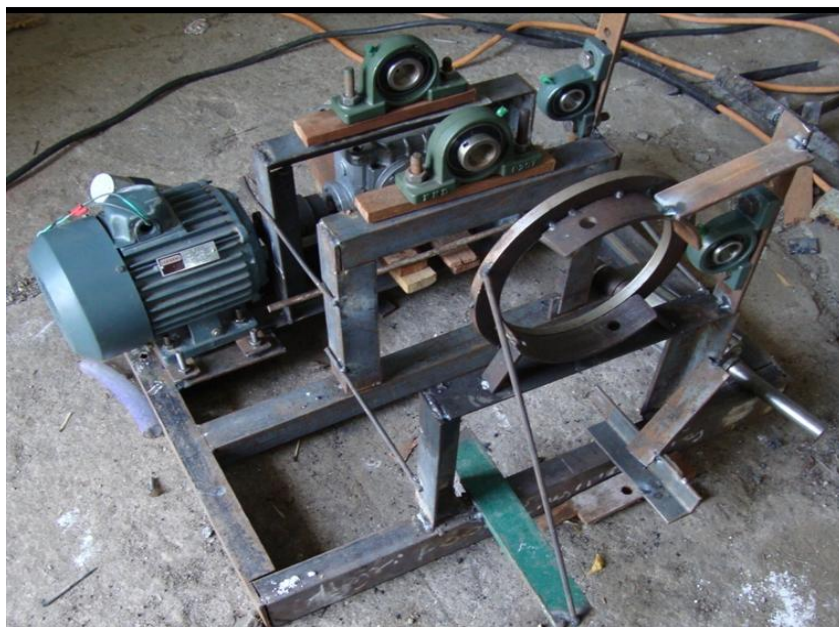
The dimensions and specifications of the machine elements obtained from the design procedure are listed in Table 4.1.

**Table 4.1 Specifications of the developed fish deboner**

Particulars	Material of construction/make	Specifications	Quantity (No.)
Power source	Kirloskar make	One hp, single phase, 1440 rpm	1
Motor shaft (d <sub>m</sub> )	Mild steel (40 C 8)	20 mm Ø	1
Flexible jaw coupling	Cast iron hub with nitrile rubber cushioning	OD – 53 mm ID – 20 mm Length - 70 mm	1
Keys	Plain carbon steel	Width – 8 mm Length – 35 mm Thickness – 7 mm	4
Speed reduction gear box	SMS Gears, Hyderabad (Bevel gears)	30:1	1
Sprocket	Transmax Mumbai make, A3 Steel	Pinion teeth – 8 No. Gear -16, 20 and 28	1 3
Chain (single row roller)	Transmax Mumbai make, SAE – 1045	Heavy duty – 12 B Pitch – 20 mm Ø	3
Main and secondary shaft	Mild steel (40 C 8)	30 mm Ø 630 mm 25 mm Ø 430 mm	1 1
Conveyor or endless belt	Food grade rubber (perfluoroelastomer)	Perimeter–1315mm Width – 150 mm Thickness – 20 mm	3
Spur gears	Cast iron with 20° Pressure angle	Pinion teeth – 56 Gear teeth – 84 Face width – 24 mm	1 1
Perforated drum	Stainless steel (SS-306L)	ID – 152 mm OD – 164 mm Thickness – 6 mm	3

Pedestal bearings (Radial ball type)	SKF make, chrome steel with cast iron	Model No. FKD UC 27080	4
Belt tension rollers	Nylon - local make	OD-52 and 65 mm Ø Length – 150 mm	1 1
Feed tray	Aluminum sheet	387 × 253 mm Depth – 20 mm	1
Outlet tray	Aluminum sheet	362 × 200 mm Depth - 20 mm	1
Scraper blades on outer surface and inside of perforated drum	Food grade wear resistant HDPE sheet	160 × 80 mm 280 × 60 mm Thickness – 5 mm	1

The designed components were assembled over a base frame fabricated using C channel (76 × 64 × 6 mm) and angle iron of 51 × 51 × 4 mm and 38 × 38 × 4 mm size. Motor shaft (20 mm Ø) of one hp single phase motor (1440 rpm) was fitted to the flexible jaw coupling to transfer the power to the speed reduction gear box. The motor speed of 1440 rpm was reduced to 48 rpm at the output shaft of speed reduction gear box. Electric motor, speed reduction gear box and bearings mounted on base frame are depicted in Plate 4.14.



**Plate 4.14 Electric motor, gear box and bearings on base frame**

A sprocket having 8 No. of teeth was fitted on the output shaft of the gear box to transmit the power to the main shaft (30 mm  $\varnothing$  and 630 mm long) on which another sprocket of 28 No. of teeth was mounted. Both the sprockets were fixed with the help of designed keys. At the other end of the main shaft a perforated drum (152 mm  $\varnothing$  and 305 mm long) was welded. The main shaft was firmly fitted on the base frame with the help of two pedestal bearings (radial ball type). A pair of spur gears having 24 mm face width was used for parallel transmission of power to the secondary shaft. Spur gear (84 teeth) mounted on main shaft was meshed with the spur pinion (56 teeth) fixed on secondary shaft.

At the other end of the secondary shaft, a driving roller was fixed to provide drive to the conveyor belt. The position of the secondary shaft was made adjustable by providing 13 mm  $\varnothing$  holes drilled at 120 mm (centre to centre) apart on the base frame to obtain different contact areas (25, 35 and 45 per cent of the perforated drum). The assembly of the secondary shaft was supported with pedestal roller bearings (2 No.) mounted vertically on the base frame. A belt tension roller of 65 mm  $\varnothing$  and 150 mm in length was fitted on an offset shaft mounted on base frame with bushes on either side. A curved (175 mm radial curvature) mild steel plate of 5 mm thickness with holes (13 mm  $\varnothing$  and  $10^\circ$  apart) drilled on 161 mm curvature was welded to the base frame to obtain desired belt tension of 50 kg with respect to the selected contact area.

The conveyor belt made of food grade perfluoroelastomer rubber was driven between the rollers. A feed tray  $390 \times 250 \times 50$  mm size to hold 5 kg of fish pieces was provided at an appropriate position on the base frame. An outlet chute ( $360 \times 200 \times 20$  mm) was also fixed at the desired position to collect the wastes (fish skin and bone). Two scraper blades were provided, one to keep the outer surface of the perforated drum clean and other to collect the minced meat from the inside wall of the perforated drum. The drive system consisting of chain and sprockets and spur gears mounted on shafts was covered by providing a protective enclosure made of mild steel sheet of 24 gauge.

#### **4.2.17 Assembly of developed fish deboner**

The perforated drum was mounted on main shaft and conveyor belt was fitted between the driving pulley and driven pulley mounted on secondary shaft and supporting frame respectively. Feed tray, outlet chute, scraper blades were fixed on the supporting

frame at their respective positions. The complete views of assembled fish deboner are presented in Plate 4.15 and 4.16. The specifications of the developed fish deboner are presented in Appendix IV.



**Plate 4.15 Assembled view of designed fish deboner**



**Plate 4.16 Assembled view of designed fish deboner with enclosure**

### **4.3 Optimization of Operational Parameters of Developed Fish Deboner**

Experiments were conducted to optimize the operational parameters namely, peripheral speed of the drum (7.22, 10.31 and 12.37 m per min.), belt hardness (35, 45 and 55 Shore No.) and perforation diameter of the drum (2, 3 and 4 mm) of the developed deboner. Tilapia, an under-utilized freshwater fish was selected for the experiment. Fishes were procured from the local fish market and brought to the fish processing laboratory in iced condition. The fishes were cleaned, dressed and cut in to fillets/pieces. One kg of fish pieces were fed in the developed fish deboner for three passes in each experiment. The quantity of meat recovered and time taken for each pass were recorded. Pin bone content in each sample of minced meat was determined. Three Factor Completely Randomized Block Design was applied for the analysis of the data and the effects of dependent variables on the responses are discussed hereunder.

#### **4.3.1 Meat recovery**

The data obtained from the experiments to study the effects of peripheral speeds of drum, belt hardness and perforation size on meat recovery are presented in Appendix-I. The data were analysed statistically and reported in Table 4.2. It was observed from the table that, the effects of peripheral speeds of drum (S), belt hardness (B) and perforation size (P) on meat recovery were significant at 1 per cent level. Two factor interactions namely, peripheral speeds of drum (S) × belt hardness (B); peripheral speeds of drum (S) × perforation size (P) and belt hardness (B) × perforation size (P) were also found to be significant at 1 per cent level. The interaction effects of all the three variables (S × B × P) on meat recovery were found to be significant at 1 per cent level.

##### **4.3.1.1 Effect of drum peripheral speed and belt hardness on meat recovery**

The data depicting effect of drum peripheral speeds *viz.*, 7.22, 10.31 and 12.37 m min<sup>-1</sup> and belt hardness *viz.*, 35, 45 and 55 Shore No. were considered for optimization of the factors and are presented in Fig 4.6. It was observed that, peripheral drum speed of 7.22 m min<sup>-1</sup> recorded highest meat recovery of 0.555, 0.597 and 0.699 kg per kg of dressed fish for belt hardness of 35, 45 and 55 Shore, respectively. Similarly, the meat recovery at 10.31 and 12.37 m min<sup>-1</sup> peripheral drum speeds observed were 0.613, 0.687, 0.742 and 0.534, 0.569, 0.639 kg per kg dressed fish for belt hardness of

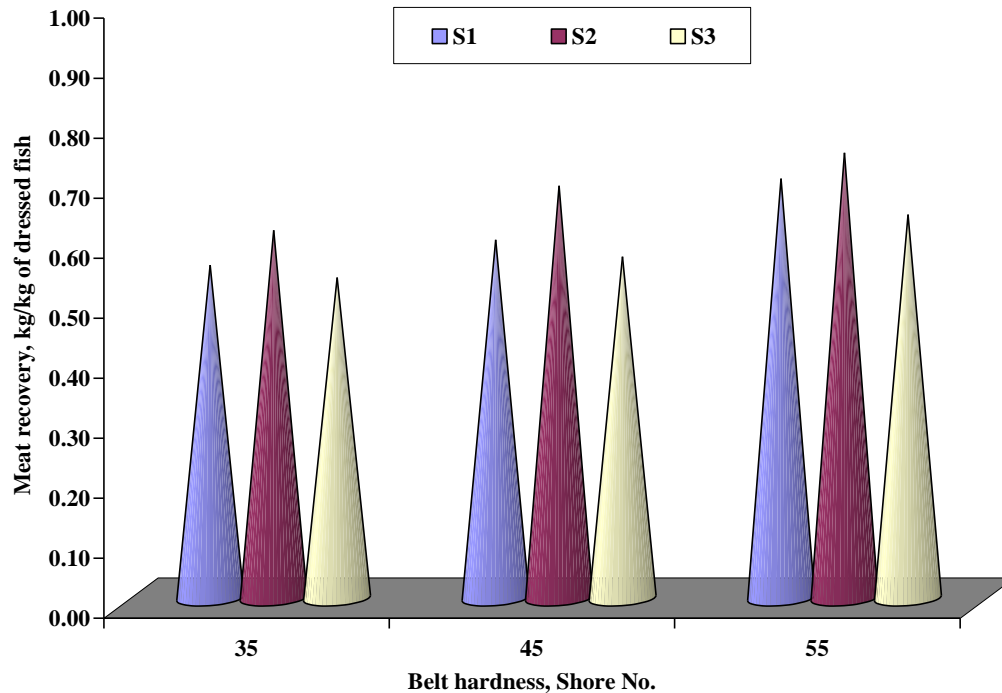
35, 45 and 55 Shore, respectively. Among all the combinations of S and B, highest meat recovery of 0.742 kg was obtained at the peripheral drum speed of 10.31 m min<sup>-1</sup> with belt hardness of 55 Shore whereas, least quantity (0.534 kg) of meat was recovered at peripheral speed of 12.37 m min<sup>-1</sup> with belt hardness of 35 Shore. The results of all the combinations have been found significant at one per cent level.

**Table 4.2 ANOVA for the effects of peripheral speed of perforated drum, belt hardness and perforation size on meat recovery in developed fish deboner**

Source	Degrees of freedom ( <i>df</i> )	Sum of squares ( <i>SS</i> )	Mean sum of squares ( <i>MS</i> )	<i>F</i> <sub>calculated</sub>	SEm±	CD @ 1%
<b>Peripheral drum speed (S)</b>	2	0.139	0.070	1241.642**	0.0014	0.0054
<b>Belt hardness (B)</b>	2	0.215	0.108	1923.993**	0.0014	0.0054
<b>Perforation size (P)</b>	2	0.232	0.116	2068.450**	0.0014	0.0054
<b>S × B</b>	4	0.009	0.002	38.413**	0.0025	0.0094
<b>S × P</b>	4	0.011	0.003	50.126**	0.0025	0.0094
<b>B × P</b>	4	0.022	0.006	98.814**	0.0025	0.0094
<b>S × B × P</b>	8	0.004	0.001	9.745**	0.0043	0.0163
<b>Error</b>	54	0.003				
<b>Total</b>	80	0.635				
<b>SD</b>	<b>0.089121</b>					
<b>CV</b>	<b>4.744563</b>					

\*\* Significant at 1 per cent level

It was also observed from the figure that, the meat recovery increased with increase in the belt hardness at the respective peripheral speeds of drum. Meat recovery was found to be increased by 21.04 per cent with belt hardness B3 followed by 12.07 per cent with B2 in comparison with B1. This might be due to the higher hardness of the belt which might have pressed fish pieces harder against the perforated drum to extract more meat. It was also seen that, peripheral speed of  $10.31 \text{ m min}^{-1}$  yielded maximum meat recovery for all the belt hardnesses whereas at higher peripheral speed of  $12.37 \text{ m min}^{-1}$ , the meat recovery was found to be lower. This might be because of the lesser time (0.63 seconds) of contact between belt and drum at higher peripheral speed might have resulted in lesser meat recovery.



Peripheral speeds of perforated drum (S)

S1 -  $07.22 \text{ m min}^{-1}$  (14 rpm)

S2 -  $10.31 \text{ m min}^{-1}$  (20 rpm)

S3 -  $12.37 \text{ m min}^{-1}$  (24 rpm)

**Fig. 4.6 Effect of peripheral speeds of perforated drum and belt hardness on meat recovery of developed fish deboner**

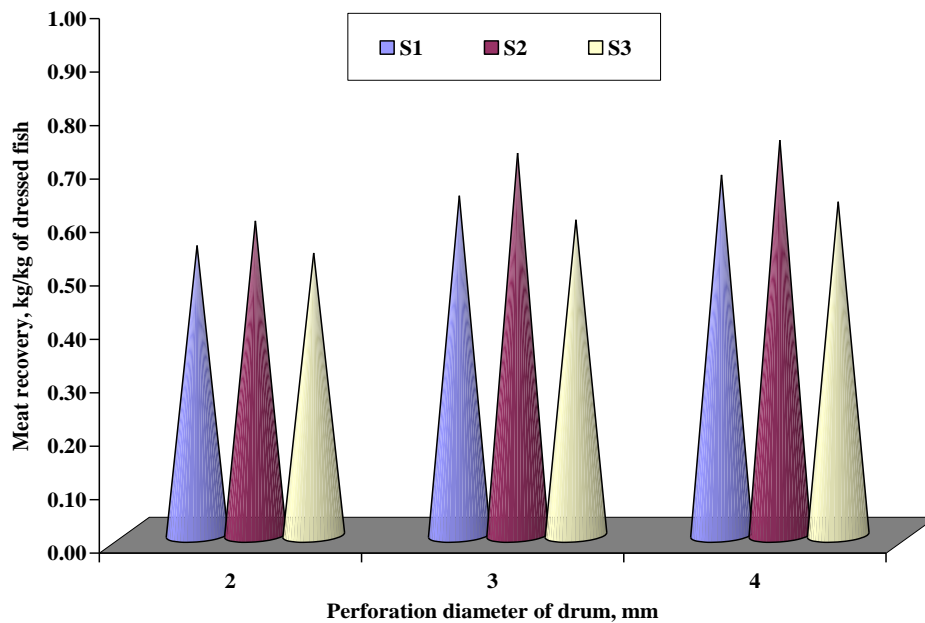
The highest meat recovery of 0.742 kg was obtained at medium peripheral drum speed (S2) with higher belt hardness (B3) followed by 0.687 kg with belt hardness B2. This might be because of the higher time of contact (0.75 seconds) and higher compression force offered by harder belt. Similar results of meat recovery at different tyre pressures and drum speeds for threadfin bream fish were reported by Robertson and Meritt (1985). The meat recoveries at peripheral drum speed of  $10.31 \text{ m min}^{-1}$  (S2) and belts having hardness of 45 (B2) and 55 Shore (B3) were found to be better and hence these levels of operational parameters may be considered for optimization of the operational parameters of the developed fish deboner.

#### **4.3.1.2 Effect of peripheral speed and perforation diameter of drum on meat recovery**

The variations in meat recovery at different drum peripheral speeds (7.22, 10.31 and  $12.37 \text{ m min}^{-1}$ ) and perforation diameter of drum (2, 3 and 4 mm) on meat recovery are presented in Fig. 4.7. From the Figure, it was seen that, at peripheral drum speed of  $7.22 \text{ m min}^{-1}$ , the meat recovered were 0.542, 0.635 and 0.674 kg per kg of dressed fish for perforation diameters of 2, 3 and 4 mm, respectively. Peripheral drum speeds of 10.31 and  $12.37 \text{ m min}^{-1}$  recovered 0.588, 0.715, 0.739 kg and 0.528, 0.590, 0.624 kg of meat for drum perforation of 2, 3 and 4 mm, respectively. The results of all the combinations were significantly different at one per cent level. Higher meat recovery of 0.739 was observed at peripheral drum speed of  $10.31 \text{ m min}^{-1}$  (S2) with perforation diameter of 4 mm and least quantity (0.528 kg) of meat was recovered at peripheral speed of  $12.37 \text{ m min}^{-1}$  with perforation diameter of 2 mm.

It was also observed that, meat recovery increased with increase in perforation diameter of the drum at all the peripheral speeds of drum. Larger perforation diameter (4 mm) yielded highest meat recovery followed by 3 and 2 mm. This might be due to increased area of opening/exposure for the meat to pass through the perforations resulting in extraction of more meat. It was also noticed from the Figure that, peripheral speed of  $10.31 \text{ m min}^{-1}$  (S2) yielded 39.96 per cent higher meat recovery, followed by 35.54 per cent through the perforation sizes of 4 and 3 mm, respectively in comparison with the lowest meat recovery of 0.588 kg per kg of dressed fish obtained at 2 mm diameter of perforation. The meat recoveries were found to be less at lower (S1) and higher (S3)

peripheral speeds at all the perforation diameters. This might be due to the smaller perforation diameter that might have resisted the entry of the meat at a particular speed but in case of higher peripheral speed, the lesser time of contact (1.07 seconds) between drum and belt might also have resulted in lesser meat yield.



Peripheral speeds of perforated drum

S1 -  $07.22 \text{ m min}^{-1}$  (14 rpm)

S2 -  $10.31 \text{ m min}^{-1}$  (20 rpm)

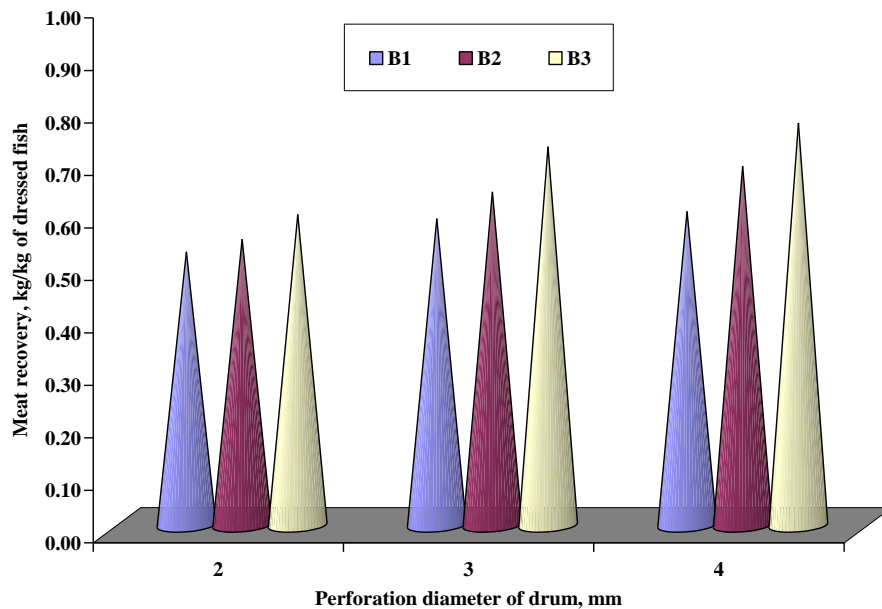
S3 -  $12.37 \text{ m min}^{-1}$  (24 rpm)

**Fig. 4.7 Effect of different peripheral speeds and perforation diameter of drum on meat recovery of developed fish deboner**

The highest meat recoveries obtained at medium peripheral drum speed ( $10.31 \text{ m min}^{-1}$ ) with 3 and 4 mm diameter perforations of the drum might be due to the optimum time of contact (0.75 second) and exposure of meat to larger size of perforations (3 and 4 mm) prevailed with the two variables. Peripheral drum speed of  $10.31 \text{ m min}^{-1}$  and perforation diameters of 3 and 4 mm may be considered for optimization of the operational parameters of the developed fish deboner as these variables yielded higher meat recovery in the experiment.

#### 4.3.1.3 Effect of belt hardness and perforation diameter of drum on meat recovery

The effect of belt hardness (35, 45 and 55 Shore) and drum perforation diameters (2, 3 and 4 mm) on meat recovery is presented in Fig. 4.8. From the Figure, it was observed that, highest meat recovery of 0.592, 0.721 and 0.766 kg per kg of dressed fish were recorded at belt hardness of 55 Shore for perforation diameters of 2, 3 and 4 mm, respectively. For belt hardness of 35 and 45 Shore, the quantity of meat recovered were found to be 0.521, 0.584, 0.598 kg and 0.545, 0.635, 0.684 kg for the perforation diameters of 2, 3 and 4 mm, respectively. The results of all the combinations of belt hardness and perforation size were significant at one per cent level.



#### **Belt hardness (B):**

B1 – 35 Shore No.

B2 – 45 Shore No.

B3 – 55 Shore No

**Fig. 4.8 Effect of different belt hardness and perforation diameter of drum on meat recovery of developed fish deboner**

Highest meat recovery of 0.766 kg was recorded at the belt hardness of 55 Shore with perforation diameter of 4 mm and lowest quantity (0.521 kg) of meat was recovered at belt hardness of 35 Shore with perforation diameter of 2 mm.

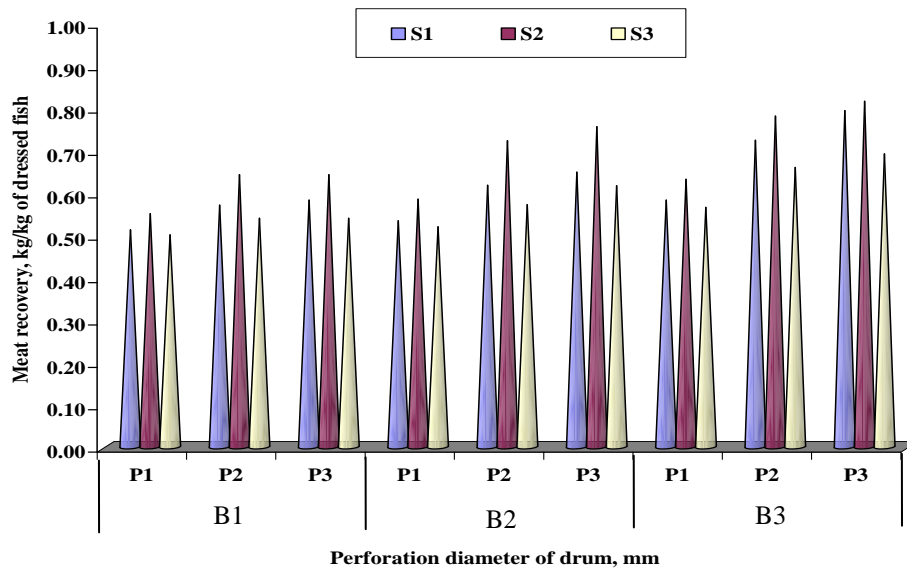
From the Figure 4.8, it was also observed that, the meat recovery increased with increase in belt hardness and perforation diameters of drum. This might be due to increased compression force by the harder belts against the larger perforation diameters of the drum resulting in extraction of more quantity of meat. It was also seen from the Figure that, belt having hardness of 55 Shore yielded maximum meat recovery for all the perforation sizes (2, 3 and 4 mm). The meat recovery was found to be least at lower belt hardness (35 Shore) at smaller perforation diameter of the drum (2 mm). This may be because of the lesser perforation diameter (2 mm) might have resisted the entry of the meat with the belts of different hardness. Amongst the studied combinations, B3×P3 recorded highest increase in meat recovery (29.39 per cent) followed by 21.79 per cent for B3×P2.

#### **4.3.1.4 Effect of peripheral speed, belt hardness and perforation diameter of drum on meat recovery**

The effects of peripheral speed of drum (7.22, 10.31, 12.37 m min<sup>-1</sup>), belt hardness (35, 45, 55 Shore) and perforation diameters of drum (2, 3 and 4 mm) on meat recovery are shown in Fig. 4.9. From the Figure, it was observed that, meat recovery ranged from 0.512 to 0.815 kg per kg of dressed fish at selected peripheral speeds of drum, belts having different hardness and drum perforations. Highest meat recoveries of 0.815, 0.793 and 0.691 kg were recorded when the fish deboner was operated at drum peripheral speeds of 10.31, 7.22 and 12.37 m min<sup>-1</sup> with belt hardnesses of 55, 35 and 45 Shore No., respectively. Least meat recovery of 0.500 kg was obtained for the combined effect of S3, B1 and P1. The effects of interactions of all the three variables on meat recovery obtained were significantly different at one per cent level except for the interactions of S1B1P1 and S1B2P1 as these were significant at 5 per cent level.

From the Figure 4.9, it was also observed that, the meat recovery increased with increase in belt hardness and perforation diameter at the respective peripheral speed. This might be due to increased compression force offered by the harder belts against the larger perforation diameters for a given peripheral speed resulting in extraction of more meat. It was also observed that, combined effect of belt having hardness of 55 Shore (B3) and perforation diameter of 4 mm yielded highest meat recovery of 0.815 kg at medium

peripheral speed of  $10.31 \text{ m min}^{-1}$ . The meat recoveries were found to be lesser at lower belt hardness (B1) and also at smaller perforation diameters of the drum (P1) for different drum speeds. The lesser perforation diameter (2 mm) might have resisted the entry of the meat with belt having lower hardness under consideration (35 Shore) at a given peripheral speed of the drum. The highest meat recovery of 0.815 kg obtained at medium peripheral speed (S2) for higher belt hardness (B3) with larger diameter of the perforation (P3). This might be due to optimum time of contact, harder pressing of meat against larger perforation diameter of drum at S2. An increase of 45.47 and 44.25 per cent increase in meat recovery was recorded for the combined effect of S2B2P3 and S2B3P3 followed by 39.11 and 38.05 per cent at S2B2P2 and S2B3P2, respectively.



**Peripheral speed (S):**

S1 -  $07.22 \text{ m min}^{-1}$  (14 rpm)

S2 -  $10.31 \text{ m min}^{-1}$  (20 rpm)

S3 -  $12.37 \text{ m min}^{-1}$  (24 rpm)

**Belt hardness (B):**

B1 – 35 Shore No.

B2 – 45 Shore No.

B3 – 55 Shore No.

**Perforation size (P):**

P1 – 2 mm Ø

P2 – 3 mm Ø

P3 – 4 mm Ø

**Fig. 4.9 Effect of different peripheral speeds, belt hardness and perforation diameter of drum on meat recovery of developed fish deboner**

Similar results of increased meat recovery from fish at larger drum perforation diameters of 5 and 7 mm were reported by Wong *et al.*, (1978) and Regenstein (1986) observed higher meat recovery at 3 to 5 mm compared to 2 mm perforation diameter. Wood and King (1985) observed highest meat recovery of 81.9 and 67.4 per cent at

larger perforation diameters (5.0 mm) for Mackerel and Silver belly fishes respectively. Robertson and Meritt (1985) obtained higher meat recoveries at higher tyre pressures of 40 and 50 psi (used tyre in place of belt hardness) and at moderate drum speed of 40 rpm for threadfin bream fish. The reported results are in confirmation with the findings of the present study.

#### **4.3.2 Bone content in minced meat**

The data were obtained from the experiments to study the effects of peripheral speeds of drum, belt hardness and perforation size on pin bone content in mg per 100 g of minced meat recovered from developed fish deboner are presented in Appendix II. The data were analysed statistically and reported in Table 4.3. From the ANOVA Table, it was observed that, the effects of peripheral speeds of drum (S), belt hardness (B) and perforation size (P) on pin bone content in minced meat were significant at 1 per cent level with  $F_{calculated}$  values of 293.113, 2083.824 and 7156.529 respectively. Two factor interactions namely, peripheral speeds of drum  $\times$  belt hardness; peripheral speeds of drum  $\times$  perforation size and belt hardness  $\times$  perforation size and three factor interaction (S  $\times$  B  $\times$  P) on meat recovery were also found to be significantly different at 1 per cent level.

##### **4.3.2.1 Effect of drum peripheral speed and belt hardness on bone content**

The data depicting effects of drum peripheral speeds (7.22, 10.31 and 12.37 m min<sup>-1</sup>) and belt hardness (35, 45 and 55 Shore) on pin bone content in minced meat are shown in Fig. 4.10. From the Figure, it was observed that, peripheral drum speed of 7.22 m min<sup>-1</sup> recorded highest bone content of 4.944, 5.633 and 8.667 mg per 100 g of minced meat for belt hardness of 35, 45 and 55 Shore respectively. Bone content at 10.31 and 12.37 m min<sup>-1</sup> peripheral drum speeds observed were 4.700, 4.783, 7.567 mg and 4.444, 4.451, 6.722 mg per 100 g of minced meat for belt hardness of 35, 45 and 55 Shore, respectively.

Among all the combinations of peripheral drum speeds (S) and belt hardness (B), highest bone content of 8.667 mg per 100 g of minced meat was found at the peripheral drum speed of 7.22 m min<sup>-1</sup> with belt hardness of 55 Shore whereas, least bone content of 4.444 mg per 100 g of minced meat was observed at peripheral speed of 12.37 m min<sup>-1</sup>

with belt hardness of 35 Shore. The effects of all the combinations of process variables on pin bone content found significant at one per cent level.

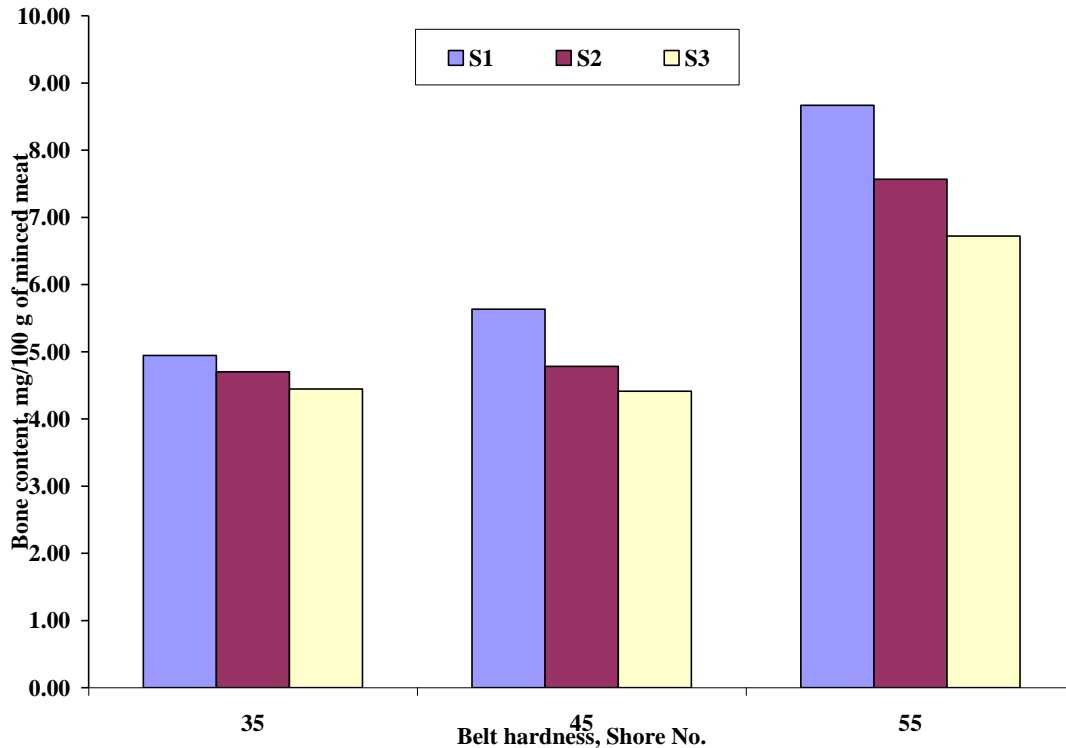
**Table 4.3 ANOVA of bone content in mg per 100 g of minced meat at different variables for optimization of operational parameters of developed fish deboner**

Source	Degrees of freedom ( <i>df</i> )	Sum of squares ( <i>SS</i> )	Mean sum of squares ( <i>MS</i> )	<i>F</i> <sub>calculated</sub>	SEm±	CD @ 1%
<b>Peripheral drum speed (S)</b>	2	20.427	10.214	293.113**	0.0359	0.1356
<b>Belt hardness (B)</b>	2	145.225	72.612	2083.824**	0.0359	0.1356
<b>Perforation size (P)</b>	2	498.748	249.374	7156.529**	0.0359	0.1356
<b>S × B</b>	4	4.874	1.219	34.970**	0.0662	0.2349
<b>S × P</b>	4	7.286	1.822	52.274**	0.0662	0.2349
<b>B × P</b>	4	91.302	22.826	655.048**	0.0662	0.2349
<b>S × B × P</b>	8	5.631	0.704	20.198**	0.1078	0.4069
<b>Error</b>	54	1.882	0.035			
<b>Total</b>	80	775.375				
<b>SD</b>	3.112997					
<b>CV</b>	17.65405					

\*\* Significant at 1 per cent level

It was also observed from the Figure that, the pin bone content in minced meat increased with increase in the belt hardness for all levels of peripheral speeds of drum whereas, bone content decreased with increase in peripheral speeds at a given belt hardness. At peripheral speeds of 10.31 and 12.37 m min<sup>-1</sup>, bone content in minced meat was found to be 4.93, 15.08, 12.69 per cent and 10.11, 20.98, 22.44 per cent less compared to bone content recorded at 7.22 m min<sup>-1</sup> for the belt hardness of 35, 45 and 55 Shore respectively. This might be due to quick passing of fish pieces at 10.31 and 12.37 m min<sup>-1</sup> peripheral speeds that might have avoided the pin bones to pass through the perforations. Bone contents at belt hardness of 45 and 35 Shore were found to be

42.95, 37.88, 33.88 per cent and 35.01, 36.79, 33.78 per cent than bone contents observed at belt hardness of 55 Shore at peripheral speeds of S1, S2 and S3 respectively. This might be because of higher hardness of belt B3 which might have compressed fish pieces harder leading to breaking of bones and passing through the perforations along with the meat.



Peripheral speeds of perforated drum

S1 -  $07.22 \text{ m min}^{-1}$  (14 rpm)

S2 -  $10.31 \text{ m min}^{-1}$  (20 rpm)

S3 -  $12.37 \text{ m min}^{-1}$  (24 rpm)

**Fig. 4.10 Effect of different peripheral speeds of perforated drum and belt hardness on bone content in mince meat recovered from developed fish deboner**

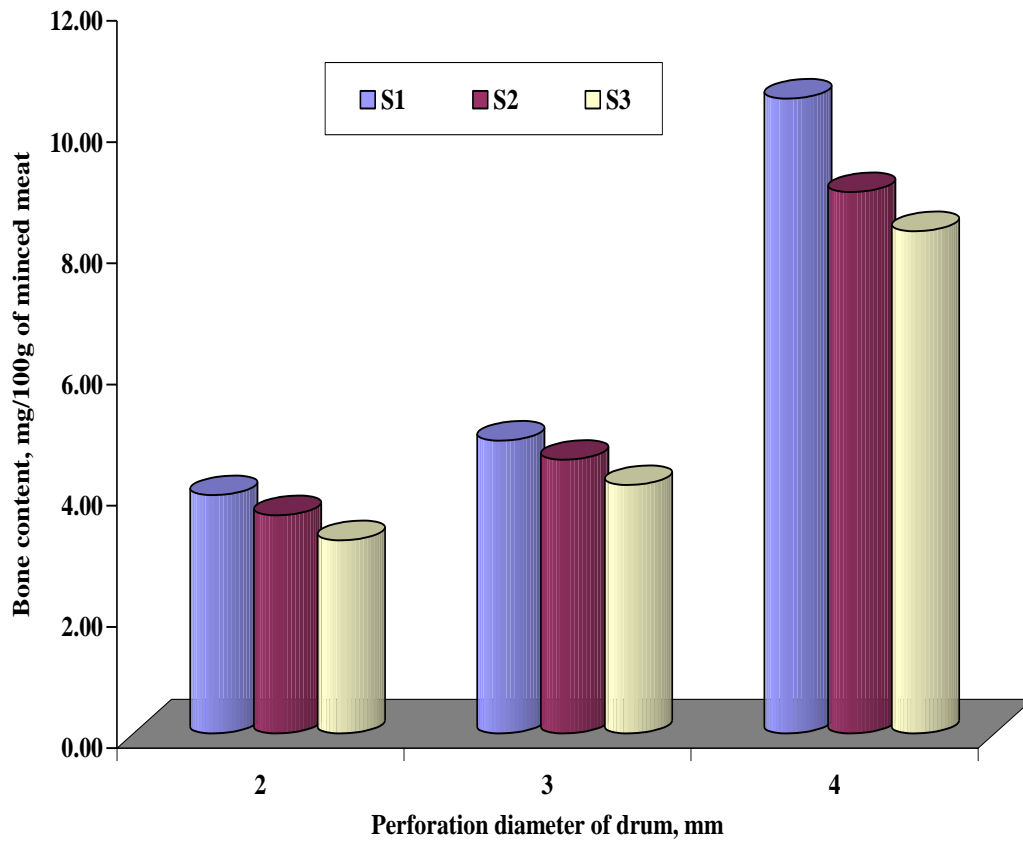
Similar results of higher bone content in minced meat at higher tyre pressures and lower drum speeds for threadfin bream fish were reported by Robertson and Meritt (1985). Higher peripheral drum speeds of  $10.31$  and  $12.37 \text{ m min}^{-1}$  and belts having lower hardness of 35 and 45 Shore yielded minced meat with less bone content may be considered for optimization of the operational parameters of the developed fish deboner.

#### **4.3.2.2 Effects of drum peripheral speed and perforation diameter of drum on bone content in minced meat**

The variations of bone contents in minced meat observed due to the interactions of drum peripheral speeds (7.22, 10.31 and 12.37 m min<sup>-1</sup>) and perforation diameters (2, 3 and 4 mm) are presented in Fig. 4.11. From the Figure, it was seen that, at peripheral drum speed of 7.22 m min<sup>-1</sup>, the bone contents were found to be 3.933, 4.833 and 10.478 mg per 100 g of minced meat for perforation diameters of 2, 3 and 4 mm, respectively. For peripheral drum speeds of 10.31 and 12.37 m min<sup>-1</sup> bone content in minced meat observed were 3.600, 4.517, 8.933 and 3.189, 4.100, 8.289 mg per 100 g of minced meat for belt hardness of 2, 3 and 4 mm, respectively.

The results of bone contents increased with the increase in perforation diameters of the drum and decreased with the increase in peripheral speed of the drum. All the combinations were significantly different at one per cent level. Highest bone content of 10.478 mg per 100 g of minced meat was observed at the peripheral drum speed of 7.22 m min<sup>-1</sup> with perforation diameter of 4 mm and the least bone content of 3.189 mg per 100 g of minced meat found at peripheral speed of 12.37 m min<sup>-1</sup> with perforation diameter of 2 mm.

It was also observed from the Figure that, perforation diameter had direct influence on bone content in minced meat for all the drum peripheral speeds. Bone content increased with increase in perforation diameter of the drum. Larger perforation diameter of 4 mm recorded highest bone content compared to 3 and 2 mm with all the drum peripheral speeds. This might be due to larger orifice which might have allowed more bones to pass through resulting in higher bone content in minced meat. Lower peripheral speed (7.22 m min<sup>-1</sup>) recorded higher bone contents than other two drum peripheral speeds (10.31 and 12.37 m min<sup>-1</sup>) through all the perforation diameters of the drum (2, 3 and 4 mm). The reason might be sufficient time of contact (1.07 seconds) between drum and the belt that might have allowed more bones to enter through the perforations along with the meat.



Peripheral speeds of perforated drum

S1 -  $07.22 \text{ m min}^{-1}$  (14 rpm)

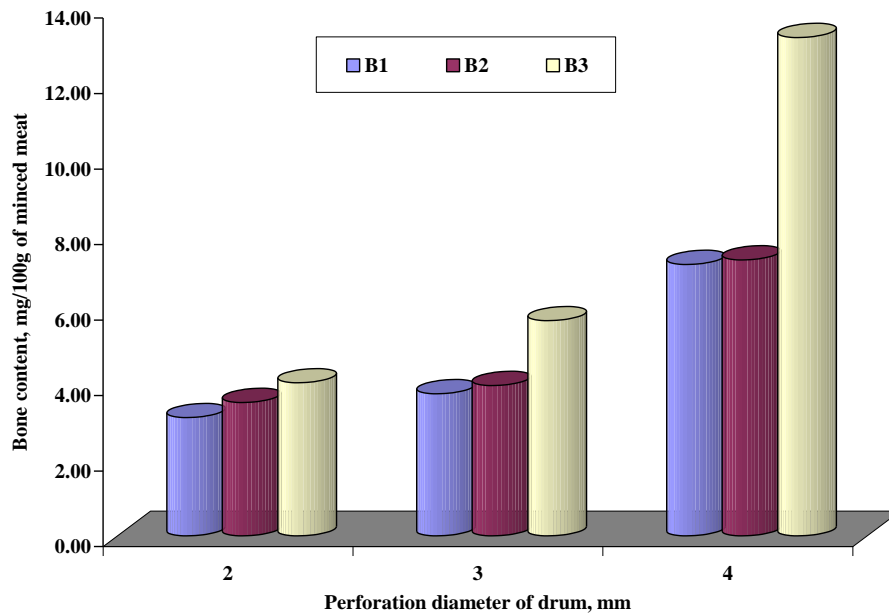
S2 -  $10.31 \text{ m min}^{-1}$  (20 rpm)

S3 -  $12.37 \text{ m min}^{-1}$  (24 rpm)

**Fig. 4.11 Effect of different peripheral speeds and perforation diameter of drum on bone content in mince meat recovered from developed fish deboner**

#### **4.3.2.3 Effect of belt hardness and perforation diameter of drum on bone content**

The changes in bone contents of minced meat recovered at belt hardness of 35, 45 and 55 Shore and perforation diameters of 2, 3 and 4 mm of the drum are shown in Fig. 4.12.



Belt hardness:

B1 – 35 Shore No.;

B2 – 45 Shore No.;

B3 – 55 Shore No.

**Fig. 4.12 Effect of different belt hardness and perforation diameter of drum on bone content in mince meat recovered from developed fish deboner**

It was observed from the Figure that, higher bone contents of 7.189, 7.311 and 13.200 mg per 100 g of minced meat were observed at perforation diameter of 4 mm for respective belt hardnesses (35, 45 and 55 Shore). Lesser bone contents of 3.133, 3.555, 4.056 and 3.767, 3.983, 5.700 mg per 100 g of minced meat were recorded at perforation diameters of 2 and 3 mm, respectively for belt hardnesses of 35 and 45 Shore. With reference to the bone content observed at 2 mm Ø perforation, the increase in bone contents for 3 mm and 4 mm perforations were found to be 20.23, 12.74, 40.53 per cent and 129.46, 106, 225.44 per cent for the belt hardnesses of 35, 45 and 55 Shore, respectively.

The bone contents in minced meat increased with the increase in both the belt hardness and perforation diameter of the drum. The increased bone contents in minced meat at higher belt hardness and larger perforation diameters of drum might be due to increased pressing of fish pieces through larger orifices allowing more pin bones to pass

through the perforations. The results of bone contents for all the combinations of belt hardness and perforation size were significantly higher at one per cent level.

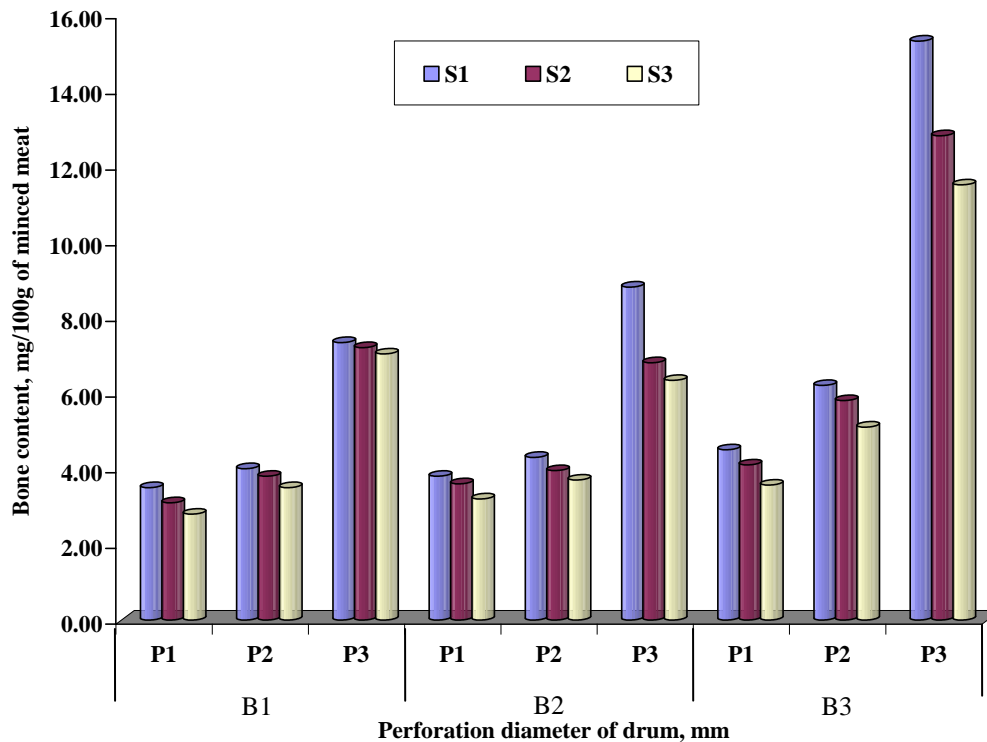
#### **4.3.2.4 Effect of peripheral speed of drum, belt hardness and perforation diameter of drum on bone content in mince meat**

The data obtained from interactions of peripheral speed of drum (7.22, 10.31, 12.37 m min<sup>-1</sup>), belt hardness (35, 45, 55 Shore No.) and perforation diameters of drum (2, 3 and 4 mm) on bone content in minced meat recovered from the developed fish deboner plotted in Fig. 4.13. From the Figure, it is observed that, bone content ranged from 2.80 to 7.33; 3.2 to 8.8 and 3.57 to 15.30 mg per 100 g of minced meat at different combinations of peripheral speeds of drum, belts hardnesses and drum perforation diameters.

Bone content was recorded highest (15.30, 12.80 and 11.50 mg per 100 g of minced meat) at drum peripheral speeds of 7.22, 10.31 and 12.37 m min<sup>-1</sup>, respectively for belt of hardness of 55 Shore and perforation diameter of 4 mm. Lowest bone contents of 2.80, 3.10 and 3.50 mg per 100 g of minced meat were observed for drum perforation diameter of 2 mm and belt hardness of 35 Shore at the respective peripheral speeds. The effects of interactions of all the three variables in all levels, the meat recovery obtained were significantly different at one per cent level.

From the Figure 4.13, it was also observed that, the bone contents increased with the increase in belt hardness and increase in perforation diameters of the drum, whereas decreased with the increase in peripheral speed of the drum. Among all the combinations, belt hardness having 55 Shore yielded the meat with higher bone content through larger perforations. This might be due to the combined effect of harder belt that pressed fish pieces harder towards larger perforations resulting in more bones in the minced meat.

It was also observed from the Figure that, the increase in peripheral speed of the drum decreased the bone content in the meat for a given belt hardness and perforation diameter. This might be due to faster movement of fish pieces preventing the entry of bones through the perforations.



Peripheral speeds of perforated drum (S):

S1 -  $07.22 \text{ m min}^{-1}$  (14 rpm)

S2 -  $10.31 \text{ m min}^{-1}$  (20 rpm)

S3 -  $12.37 \text{ m min}^{-1}$  (24 rpm)

Belt hardness (B):

B1 – 35 Shore No.

B2 – 45 Shore No.

B3 – 55 Shore No.

Perforation size (P):

P1 – 2 mm

P2 – 3 mm

P3 – 4 mm

**Fig. 4.13 Effect of different peripheral speeds, belt hardness and perforation diameter of drum on bone content in mince meat recovered from developed fish deboner**

Wong *et al.* (1978) observed higher bone content of 13.4 and 41.6 mg per 100 g of minced meat of Pollock fish at 5 and 7 mm perforation diameters respectively. Wood and King (1985) reported bone contents of 0.77, 1.67 and 1.92 per cent in minced meat recovered through 5 mm perforation for mackerel, sardine and silver belly fish species. Robertson and Meritt (1985) found higher bone content in minced meat of threadfin bream fish at higher tyre pressure (55 psi) and lower drum speed (30 rpm) through 3 mm perforation. The reported results confirmed the findings of the present study.

Peripheral speeds of  $10.31$  and  $12.37 \text{ m min}^{-1}$ , belt hardnesses of 35 and 45 Shore and drums having perforation diameters of 2 and 3 mm may be considered for optimization of the operational parameters of the developed fish deboner.

### 4.3.3 Summary of the experiment on meat recovery and bone content

The results of the experiment on meat recovery and bone content for optimization of peripheral speed of drum, belt hardness and perforation diameter are summarized in Table 4.4.

From the Table it was observed that, peripheral speeds of 10.31 and 7.22 m min<sup>-1</sup>, belt hardnesses of 55 and 45 Shore and perforation diameters of 4 and 3 mm yielded higher meat recovery of 0.74, 0.70, 0.69, 0.62, 0.68 and 0.65 kg per kg of dressed fish respectively. Lower bone contents in mg per 100 g of minced meat were observed at S3 (15.58 mg) and S2 (17.05 mg); B1 (14.09 mg) and B2 (14.82 mg) and P1 (10.72 mg) and P2 (13.45 mg) than S1 (19.58 mg), B3 (22.96 mg) and P3 (27.70 mg) respectively.

Considering, higher meat recovery per kg of dressed fish and lesser bone content in the minced meat, peripheral speed of 10.31 m min<sup>-1</sup> (S2), Belt hardness of 45 Shore (B2) and perforation diameter of 3 mm (P2) may be considered as optimized parameters for operating developed fish deboner.

**Table 4.4 Summarized effects of operational parameters on meat recovery and bone content in minced meat (Values in parenthesis are mean values)**

Variables	Higher meat recovery (kg/kg of dressed fish)	Lower bone content (mg per 100 g of minced meat)	Optimized levels
S × B	S2 (0.68) and S1 (0.62) better than S3 (0.58) B3 (0.69) and B2 (0.62) better than B1 (0.57)	S3 (5.19) and S2 (5.68) better than S1 (6.41) B1 (4.70) and B2 (4.94) better than B3 (7.65)	S2 and B2
S × P	S2 (0.68) and S1 (0.62) better than S3 (0.58) P3 (0.68) and P2 (0.65) better than P1 (0.55)	S3 (5.19) and S2 (5.68) better than S1 (6.41) P1 (3.57) and P2 (4.48) better than P3 (9.23)	S2 and P2
B × P	B3 (0.69) and B2 (0.65) better than B1 (0.55) P3 (0.69) and P2 (0.62) better than P1 (0.55)	B1 (4.70) and B2 (4.94) better than B3 (7.65) P1 (3.57) and P2 (4.48) better than P3 (9.23)	B2 and P2
S × B × P	S2 (0.74) and S1 (0.70) better than S3 (0.64) B3 (0.69) and B2 (0.62) better than B1 (0.57) P3 (0.68) and P2 (0.65) better than P1 (0.55)	S3 (15.58) and S2 (17.05) better than S1 (19.58) B1 (14.09) and B2 (14.82) better than B3 (22.96) P1 (10.72) and P2 (13.45) better than P3 (27.70)	S2, B2, P2

#### **4.3.4 Desirability test for optimization of operational parameters**

The data on meat recovery and bone content in minced meat obtained from different combinations of operational parameters were subjected to desirability test for optimization using factorials design of experiment in Design Expert version 7.0 software.

The test was carried out for maximum meat recovery and minimum bone content. The results of the desirability test with solution for 27 combinations of categorical factor levels obtained are presented in Appendix III. The variation in desirability index of different operational parameters of fish deboner are depicted in Fig. 4.14. Among these solutions, combined effect of peripheral speed of  $10.31 \text{ m min}^{-1}$ , belt hardness of 35 Shore No. and perforation diameter of 3 mm scored highest desirability coefficient of 0.79 indicating the best combination of operational parameters for achieving maximum meat recovery with minimum bone content. The results of the desirability test confirmed the selection of optimized operational parameters as depicted in Table 4.4.

#### **4.3.5 Effect of contact area (per cent) on meat recovery and bone content**

From the results of the experiments conducted for optimization of the operational parameters of the developed fish deboner, in-sufficient time of contact between conveyor belt and perforated drum was found to reduce the meat recovery at higher peripheral speeds of perforated drum. Contact area of 25 per cent between belt and drum was considered for the experiment based on the reviews (Robertson and Meritt, 1985) and data collected from manufacturers of commercial fish deboners.

The only way to increase the meat recovery is by increasing the contact area between the belt and the drum as the lower speed yielded higher bone content in the minced meat. Hence, it was decided to study the effect of increased contact areas on meat recovery and bone content in minced meat. The experiment was formulated with 25, 35, 45 and 55 per cent contact area with optimized operational parameters. The experiment was replicated four times. Meat recovery and bone content were recorded and the data were statistically analysed using single factor ANOVA. The effects of contact areas on meat recovery and bone content are presented in Fig. 4.15.

Design-Expert® Software

Desirability

X1 = A: Drum peripheral speed

X2 = B: Belt hardness

Actual Factor

C: Perforation size = Level 2 of C

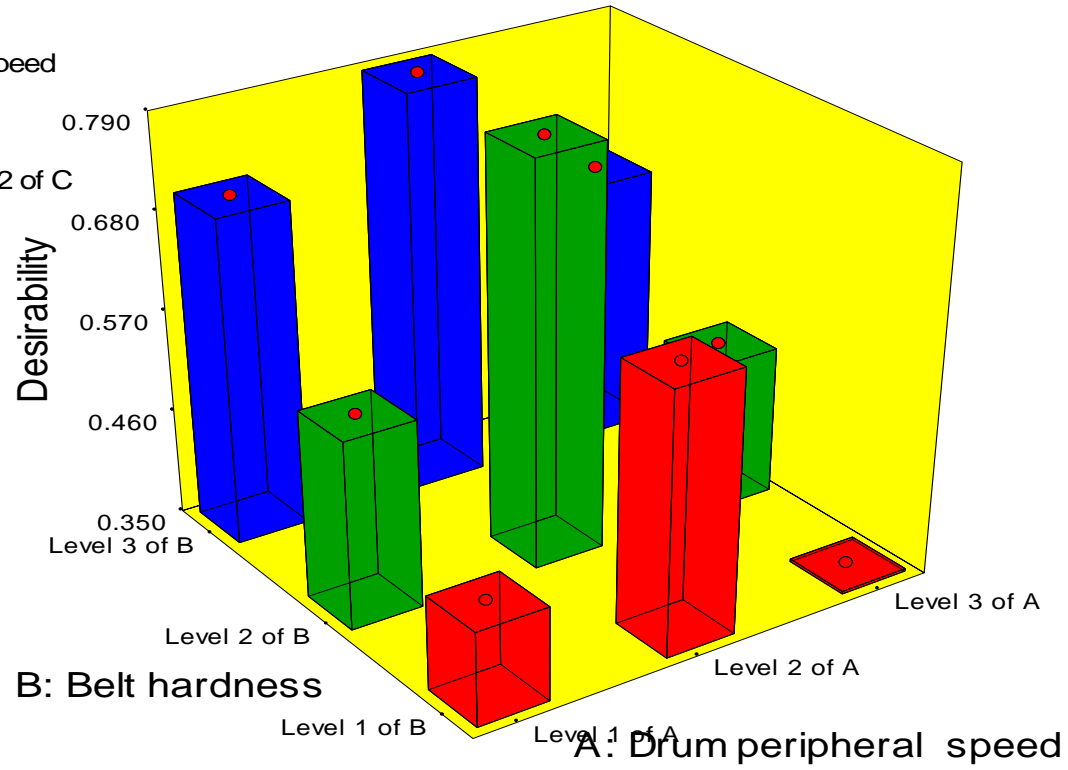
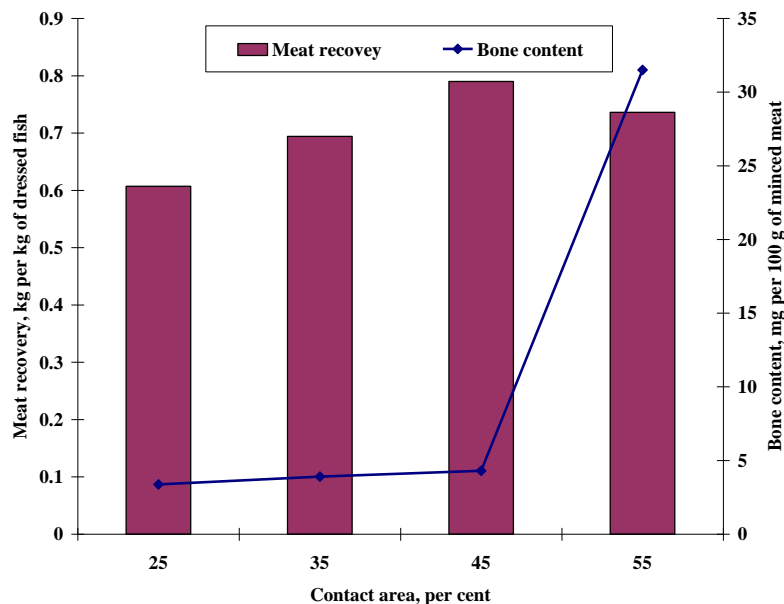


Fig. 4.14 Desirability levels of different operational parameters of developed fish deboner

From the Figure, it was observed that, the meat recoveries of 0.607, 0.694, 0.790 and 0.736 kg per kg of dressed fish and bone contents of 3.37, 3.90, 4.30 and 31.50 mg per 100 g of minced meat were recorded at contact areas of 25, 35, 45 and 55 per cent, respectively. Highest meat recovery of 0.790 kg was obtained at 45 per cent contact area and highest bone content of 31.50 mg per 100 g of minced meat was observed at 55 per cent contact area. The results showed non-significant difference at 25 and 35 per cent contact area whereas at 45 and 55 per cent the data were significantly different at 1 per cent level.

From the Figure, it was also observed that meat recovery increased with increase in contact area up to 45 per cent and decreased when contact area further increased. The increase in meat recovery was 30.15 per cent when the contact area was 45 per cent compared to 25 per cent contact area. It was also seen from the Figure that, the meat recovery decreased when the contact area was 55 per cent. This might be due to the increased angle of feeding; the fish pieces were not caught properly between belt and perforated drum immediately after feeding. The fish pieces were found folded at the outlet chute due to improper facing of meat portion to the perforations of the drum resulting inadequate meat recovery.



**Fig. 4.15 Effect of contact area (per cent) on meat recovery and bone content in minced meat at optimized operational parameters of developed fish deboner**

It was also noticed from the figure that, the bone content increased linearly with the increase in contact area up to 45 per cent and it increased exponentially when the contact area further increased yielding 31.50 mg per 100 g of minced meat. This might be because of the feeding angle that directed the bones directly towards the perforations leading to higher bone content in recovered meat. Considering the objective of developing a fish deboner that gives maximum meat recovery and minimum bone content, the optimum contact area between perforated drum and belt was found to be 45 per cent of drum surface area.

#### **4.3.6 Efficiency of developed fish deboner**

The developed fish deboner was tested for its efficiency in terms of percentage meat yield in kg per 100 kg of feed and the meat extraction efficiency (%) for three passes. The fish deboner was fed with dressed fish pieces at feed rates namely, 0.83, 1.00, 1.17, 1.33 and 1.50 kg per minute representing 50, 60, 70, 80 and 90 kg per hour. The quantity of meat recovered and waste (skin, bone and residual meat) collected at outlet chute after three passes were weighed and recorded. The residual meat retained with waste was manually separated, weighed and recorded. The experiment was replicated four times. The capacity and efficiency of the fish deboner were computed using the equations given in Section 3.3.8.

The results of the experiment are presented in Table 4.5. From the Table, it was seen that, the meat covered from the developed fish deboner at feed rates, 0.83, 1.00, 1.17, 1.33 and 1.50 kg per minute were recorded 0.680, 0.790, 0.885, 0.935 and 0.980 kg with the waste yield of 0.150, 0.210, 0.285, 0.395 and 0.520 kg, respectively. The residual meat in waste observed was 0.032, 0.046, 0.068, 0.145 and 0.285 kg at the respective feed rates. The percentage meat yield of the developed fish deboner found to be 81.63, 79.00, 78.97, 70.30 and 65.33 per cent (meat recovered per 100 kg feed) and meat extraction efficiency observed to be 95.51, 94.50, 92.86, 86.57 and 77.47 per cent, respectively for the feed rates under consideration.

Meat yield and meat extraction efficiency of fish deboner at 80 and 90 kg per hour feed rates were significantly less at one per cent level compared to the values at 50, 60 and 70 kg per hour feed rates. From the Table it was also observed that, the

percentage meat yield and meat extraction efficiency decreased as the feed rate increased. The reduction in meat yield and efficiency were found to be 3.22, 3.25, 13.88, 19.97 per cent and 1.06, 2.77, 9.36, 12.52 per cent for feed rates of 60, 70, 80 and 90 kg per hour, respectively compared to feed rate of 50 kg per hour.

**Table 4.5 Efficiency of developed fish deboner at different feed rates**

<b>Feed rate, kg/h</b>	<b>Feed rate, kg/min</b>	<b>Meat recovered, kg</b>	<b>Waste, kg</b>	<b>Residual meat in waste, kg</b>	<b>Meat yield, %</b>	<b>Meat extraction efficiency, %</b>
50	0.83	0.680	0.150	0.032	81.63 NS	95.51 NS
60	1.00	0.790	0.210	0.046	79.00 NS	94.50 NS
70	1.17	0.885	0.285	0.068	78.97 NS	92.86 NS
80	1.33	0.935	0.395	0.145	70.30**	86.57**
90	1.50	0.980	0.520	0.285	65.33**	77.47**
SD	-	-	-	-	1.471	1.748
CD@1%	-	-	-	-	6.593	7.836
CV	-	-	-	-	3.395	3.388

\*\* - Significant at 1 per cent level

NS - Non-significant

These values revealed that, feed rates did not have appreciable effect on the efficiency of fish deboner up to 70 kg per hour feed rate beyond which effect was considerable. This might be due to the overlapping of fish pieces at the inlet at higher feed rates which might have resulted in lesser meat recovery and higher residual meat in the waste. Similar results of reduced efficiencies at higher feed rates 60 to 100 kg per hour were reported by Robertson and Meritt (1985) for tyre and drum mechanism of fish deboner using threadfin bream fish .

#### 4.4 Performance Evaluation of Developed Fish Deboner at Optimized Operational Parameters

Performance of the developed fish deboner was evaluated in terms of meat recovery, bone content, colour of minced meat, textural and rheological properties of the minced meat. Three freshwater fish species namely, Tilapia (*Oreochromis mossambicus*), Rohu (*Labeo rohita*) and Mrigal (*Cirrhinus cirrhinus*) were used for the experiment. The fish deboner was assembled and set for the optimized operational parameters viz., 10.31 m min<sup>-1</sup> peripheral speed of the drum, 45 Shore belt hardness and 3 mm perforation diameter of drum. The drum and belt contact area of 45 per cent and feed rate of 60 kg per hour were considered for the experiment. The meat separation process was carried out for three passes for each sample of three fish species. The experiments were replicated six times. The results were recorded and statistically analysed by performing single factor ANOVA.

##### 4.4.1 Proximate composition and meat bone ratio of three fish species

Proximate composition of minced meat and meat bone ratio of three fish species were determined by analyzing six samples in each fish and the mean with standard deviation values of respective parameters are presented in Table 4.6.

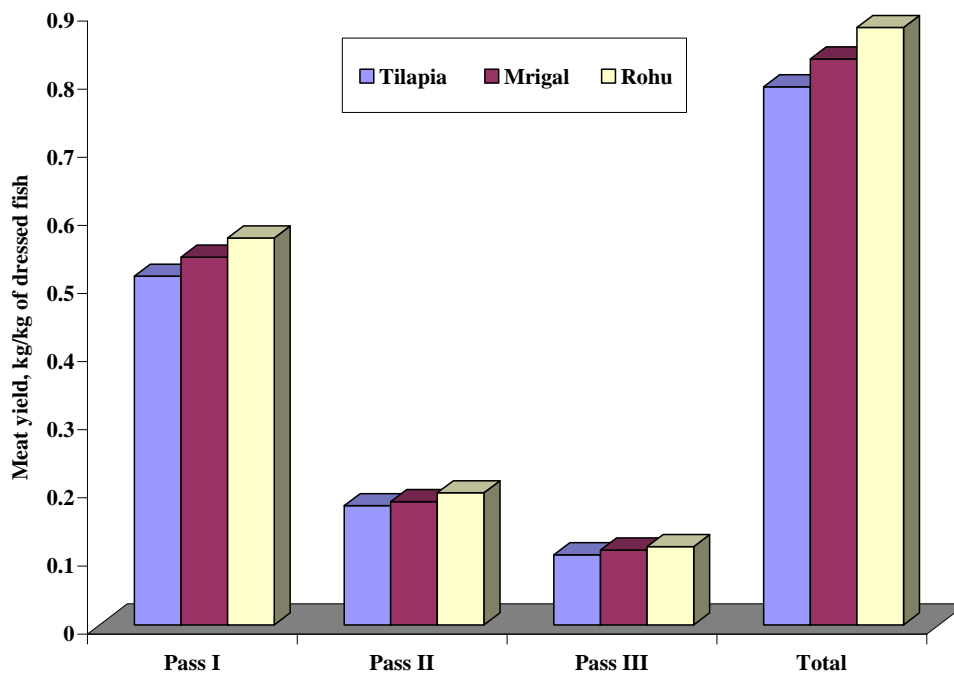
**Table 4.6 Proximate composition and meat bone ratio of three fish species**

Parameters	Fish species		
	Tilapia	Mrigal	Rohu
Moisture (%)	81.73 ± 0.55	81.30 ± 1.90	81.82 ± 1.10
Protein (%)	13.69 ± 0.12	13.46 ± 0.77	13.20 ± 0.35
Fat (%)	1.88 ± 0.09	0.73 ± 0.08	0.57 ± 0.10
Carbohydrate (%)	1.65 ± 0.07	2.50 ± 0.33	2.43 ± 0.11
Ash (%)	1.05 ± 0.07	2.01 ± 0.12	1.98 ± 0.16
Meat Bone Ratio	22.56 ± 1.06	24.16 ± 3.20	26.78 ± 1.75

From the Table, it was observed that, protein (13.69%) and fat (1.88%) contents were found to be higher in Tilapia whereas carbohydrates (2.50 and 2.43%) and ash (2.10 and 1.98%) were higher in Mrigal and Rohu fish species. Highest meat bone ratio of 26.78 was recorded for Rohu followed by Mrigal (24.16%) and Tilapia (22.56%). Similar proximate compositions of these fishes have been reported by Hassan (1996) and Abdul (2007).

#### 4.4.2 Meat recovery

The results of meat recovery from three fish species during Pass I, Pass II and Pass III are presented in Fig. 4.16. From the Figure, it was seen that, the meat recovery from Tilapia, Mrigal and Rohu recorded were 0.512, 0.175, 0.103 kg; 0.540, 0.181, 0.110 kg and 0.568, 0.194, 0.115 kg during Pass I, Pass II and Pass III with total meat yield of 0.79, 0.831 and 0.877 kg respectively. The meat recovered from Rohu was found to be significantly higher than Tilapia at 1 per cent level. The difference in meat recovery from Tilapia:Mrigal and Mrigal:Rohu were observed to be non-significant.



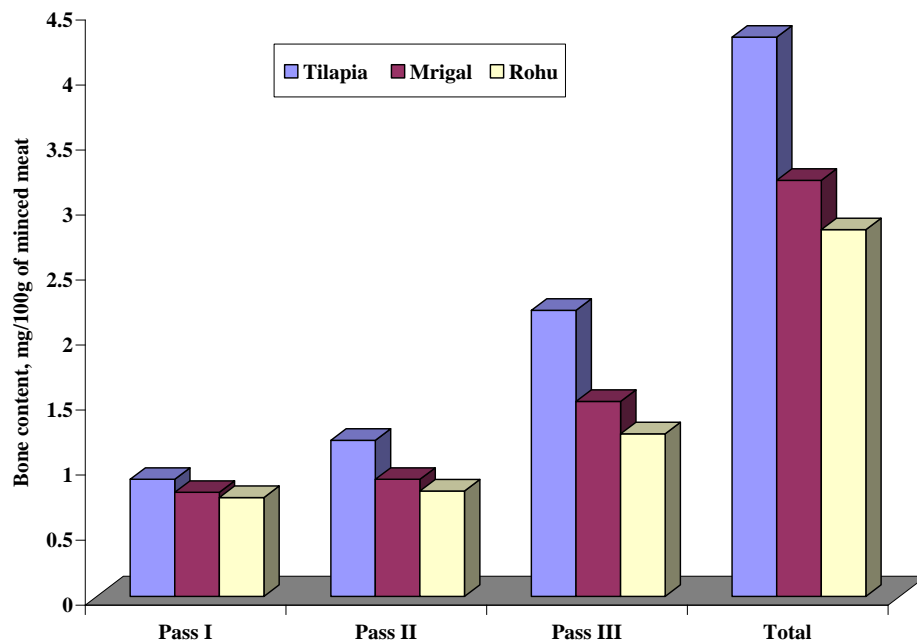
**Fig. 4.16 Comparison of meat yield of three fish species during three passes**

This might be because of higher meat content in Rohu compared to Tilapia and Mrigal (Hassan, 1996 and Abdul, 2007). It is also inferred from the Figure that, major portion of meat was squeezed in Pass I and the meat recovery decreased during Pass II and Pass III as less meat was available for extraction during later passes. Similar results of meat extraction during three passes have been reported by Robertson and Meritt (1985) for different marine fish species.

#### 4.4.3 Bone content in minced meat

The results of bone content in minced meat recovered from three fish species during three passes are plotted in Fig. 4.17. From the Figure, it is seen that, the bone content in minced meat of Tilapia, Mrigal and Rohu recorded were 0.90, 1.20, 2.20; 0.80, 0.90, 1.50 and 0.76, 0.81, 1.25 mg per 100 g of minced meat during Pass I, Pass II and Pass III with a total bone content of 4.30, 3.20 and 2.82 mg per 100 g of minced meat, respectively.

From the Figure, it was also observed that, bone content in minced meat of all the three fishes increased with the increase in number of passes. This might be due to the fact that, the fish pieces had more bones and less meat to feed during Pass II and Pass III.



**Fig. 4.17 Bone content in minced meat of three fish species during three passes**

Maximum bone content of 4.3 mg was recorded in minced meat of Tilapia and least (2.82 mg) in Rohu. This might be because of the lower meat bone ratio of Tilapia (22.56%) and higher of Rohu (26.78%). The results of bone contents of three fishes obtained during each pass and also the total of three passes were found to be significantly different at one per cent level.

Similar results on bone content in minced meat during different passes in Bibun make commercial deboner have been reported by Patashnik *et al.* (1974). Wong *et al.* (1978) reported higher bone content in minced meat recovered from *Herrings* fish species, Wood and King (1985) reported that the bone content in minced meat depends on meat:bone ratio of the fish species.

#### **4.4.4 Colour of minced meat**

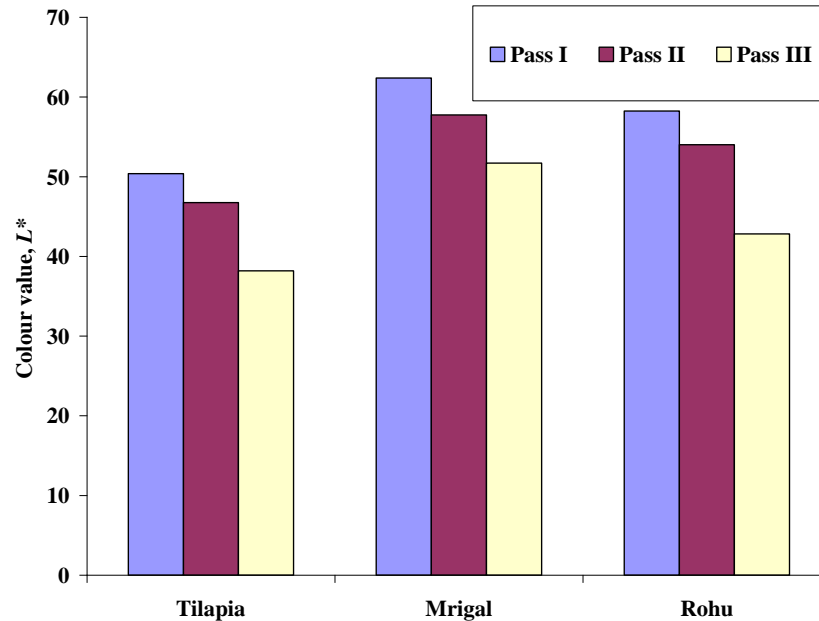
Colour of the minced meat recovered during three passes from three fishes was measured by using Hunter lab colourimeter. The data obtained on measurement of colour of minced meat were expressed in terms of colour values,  $L^*$ ,  $a^*$  and  $b^*$  and are shown in Fig. 4.18, Fig. 4.19 and Fig. 4.20.

From the Fig. 4.18, it was seen that, colour value,  $L^*$  of minced meat recovered from three fishes namely, Tilapia, Mrigal and Rohu was observed to be 50.372, 46.746, 38.181; 62.381, 57.746, 51.698 and 58.226, 53.998, 42.814 during Pass I, Pass II and Pass III, respectively.  $L^*$  value scored by the meat obtained from Mrigal during Pass I was found to be highest (62.381) and lowest (50.372) was observed in Tilapia.

From the Fig. 4.19 and Fig. 4.20, the colour values,  $a^*$  and  $b^*$  of minced meat recovered from Tilapia, Mrigal and Rohu scored were found to be 0.363, 1.790, 2.150; 0.328, 1.119, 1.740; 0.115, 1.020, 1.396 and 11.740, 13.740, 14.135; 10.559, 11.989, 12.889; 10.459, 12.275 during Pass I, Pass II and Pass III, respectively. It was also seen that, both the colour values  $a^*$  and  $b^*$  found highest (2.15) in Rohu and lowest (0.363) in Tilapia.

$L^*$ ,  $a^*$  and  $b^*$  values of the meat recovered from different fishes were significantly different at 1 per cent level indicating species specific difference in colour of meat. However, in subsequent passes (Pass II and Pass III) also the difference in  $L^*$ ,  $a^*$  and  $b^*$  values continued to decrease due to mechanical degradation of the feed at

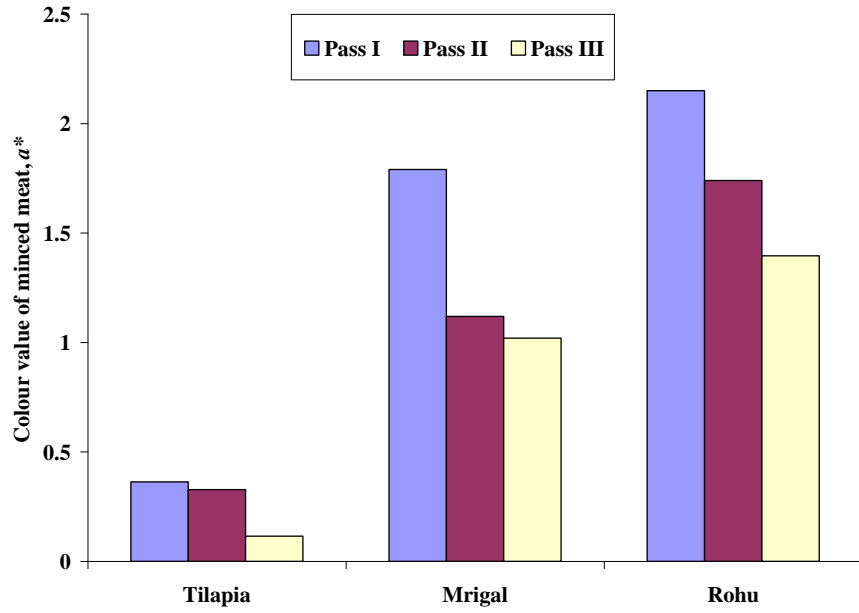
every pass. Tilapia showed least  $L^*$ ,  $a^*$  and  $b^*$  values among all fishes as it had gray white coloured meat indicating the colour of lesser white ( $L^*$ ), lower redness ( $a^*$ ) and yellowness ( $b^*$ ). On the contrast, Mrigal had white flesh, hence the meat was scored highest  $L^*$  and Rohu had white flesh with light red shade recorded maximum  $a^*$  and  $b^*$  values among three fishes. The higher values of  $a^*$  and  $b^*$  obtained by Rohu might be due to the presence of red muscle (myoglobin) in its meat (Benjamin, 2012),



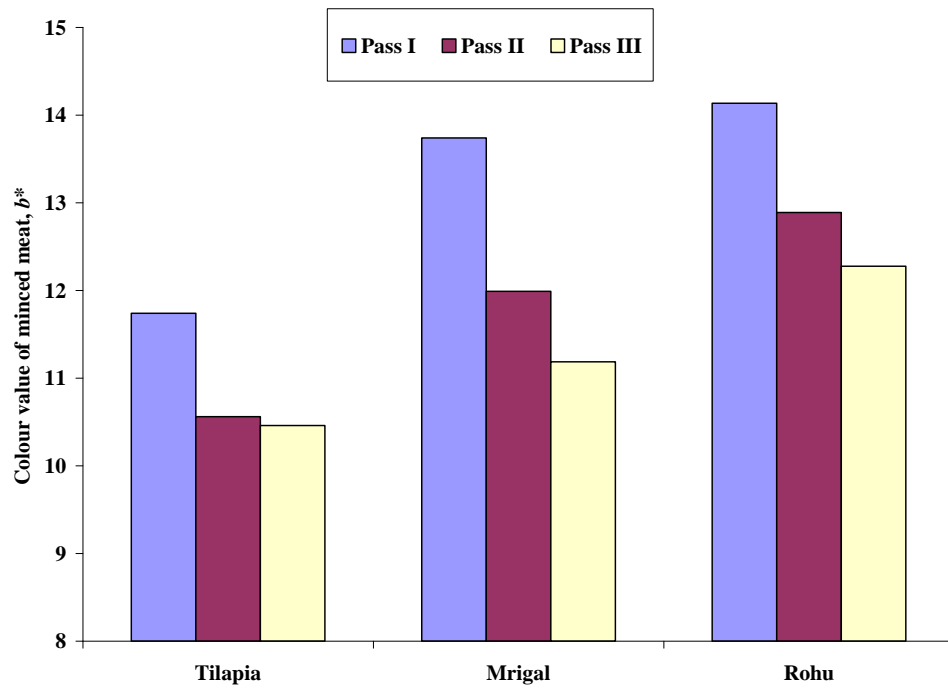
**Fig. 4.18 Variation in colour value ( $L^*$ ) of minced meat obtained from three fishes during three passes**

It was also observed from the Figure that,  $L^*$ ,  $a^*$  and  $b^*$  values decreased in the meat extracted during Pass II and Pass III in all the fish species. This might be because of the repeated mincing of meat that resulted in darker meat which might have been contributed by the contamination of melanoid pigments of the peritoneum (Young, *et al.* 1979).

Similar results of lower colour values of minced meat recovered from Tilapia were reported by Oliveira Filho *et al.* (2010) and relatively higher values for Mrigal and Rohu were reported by Benjamin (2012). The colour values of several marine fishes have also been reported by Murphy *et al.* (2003) and Manat *et al.* (2010). The findings of colour values are in confirmation with the colour values reported by Hassan (1996) for tilapia, Abdul (2007) for Rohu and Mrigal.



**Fig. 4.19** Variation in colour value ( $a^*$ ) of minced meat obtained from three fishes during three passes



**Fig. 4.20** Variation in colour value ( $b^*$ ) of minced meat obtained from three fishes during three passes

#### 4.4.5 Texture profile analysis of minced meat

Texture profile analysis (TPA) of minced meat recovered from three fishes was carried out using Texture Analyzer (Stable Micro System, Surrey, UK). TPA was performed using a cylinder probe (P50) having 50 mm Ø. Meat samples of three fishes recovered during three passes were compressed to 50% of initial height using a compression speed of 2 mm s<sup>-1</sup>. Hardness, adhesiveness, cohesiveness, gumminess and chewiness were recorded. The experiment was replicated for seven times. The results obtained from TPA of meat samples recovered from Tilapia, Rohu and Mrigal during Pass I, Pass II and Pass III are presented in Table 4.7, Table 4.8 and Table 4.9.

**Table 4.7 Variation in textural properties of minced meat recovered during Pass I from three different freshwater fish species in developed fish deboner**

Fish species	Textural properties of minced meat recovered during Pass I				
	Hardness (gf)	Adhesiveness (g.s)	Cohesiveness (g.s)	Gumminess (g.s)	Chewiness (g.s)
<b>Tilapia</b>	231.187**	-8.47**	0.438**	100.69**	50.05**
<b>Mrigal</b>	228.013 NS	-5.82**	0.410 NS	85.33 NS	46.76**
<b>Rohu</b>	204.092 NS	-3.61**	0.383 NS	78.78 NS	35.88**
<b>SD</b>	5.947	0.157	0.011	2.34	1.18
<b>CD @ 1%</b>	22.049	0.58	0.041	8.67	4.37
<b>CV</b>	3.29	3.23	3.34	3.25	3.27

\*\* Significant at 1 per cent level      NS – Non-significant

From the Table 4.7, it was seen that, hardness, adhesiveness, cohesiveness, gumminess and chewines ranged from 231.187 to 204.092 gf, -8.47 to -3.61 g.s, 0.438 to 0.383 g.s, 100.69 to 78.78 g.s and 50.05 to 35.88 g.s, respectively during Pass I. Similarly, from the Table 4.8 and Table 4.9 it was observed that, the textural properties ranged from 227.859 to 194.76 gf and 192.50 to 166.60 gf; -10.19 to -8.45 g.s and -10.29 to -6.09 g.s; 0.43 to 0.38 g.s and 0.416 to 0.376 g.s; 99.14 to 69.78 g.s and 79.78 to 55.86 g.s; 38.66 to 30.45 g.s and 32.76 to 26.70 g.s during Pass II and Pass III, respectively.

**Table 4.8 Variation in textural properties of minced meat recovered during Pass II from three different freshwater fish species in developed fish deboner**

Fish species	Textural properties of minced meat recovered during Pass II				
	Hardness (gf)	Adhesiveness (g.s)	Cohesiveness (g.s)	Gumminess (g.s)	Chewiness (g.s)
<b>Tilapia</b>	227.859**	-10.19**	0.43**	99.14**	38.66**
<b>Mrigal</b>	205.571**	-6.01**	0.40 NS	84.11**	36.86**
<b>Rohu</b>	194.76**	-8.45**	0.38 NS	69.78**	30.45**
<b>SD</b>	5.589	0.217	0.011	2.23	0.945
<b>CD @ 1%</b>	20.733	0.815	0.0408	8.273	3.503
<b>CV</b>	3.27	3.24	3.32	3.24	3.28

\*\* Significant at 1 per cent level      NS – Non-significant

**Table 4.9 Variation in textural properties of minced meat recovered during Pass III from three different freshwater fish species in developed fish deboner**

Fish species	Textural properties of minced meat recovered during Pass III				
	Hardness (gf)	Adhesiveness (g.s)	Cohesiveness (g.s)	Gumminess (g.s)	Chewiness (g.s)
<b>Tilapia</b>	192.50**	-10.29**	0.416**	79.78**	32.76**
<b>Mrigal</b>	183.20 NS	-8.99**	0.401 NS	66.84**	27.74 NS
<b>Rohu</b>	166.60 NS	-6.09**	0.376 NS	55.86**	26.70 NS
<b>SD</b>	4.846	0.221	0.011	1.78	0.771
<b>CD @ 1%</b>	17.967	0.834	0.026	6.137	2.86
<b>CV</b>	3.28	3.26	3.35	3.24	3.25

\*\* Significant at 1 per cent level

Tilapia meat had recorded highest values in all the textural properties indicating relatively firm meat and the lowest values were observed in Rohu referring to soft meat among the three fishes. Mrigal meat was found to be softer than Tilapia and harder than Rohu. Similar trends were observed in the values obtained during Pass II and Pass III. Among the fishes, Tilapia showed significantly higher values in all the textural properties of minced meat recovered during Pass I, Pass II and Pass III at 1 per cent level, whereas other two fishes were found to be significantly higher in one or two properties and non-significant in rest of the properties.

It was also seen that, Tilapia meat scored 1.39 per cent and 13.28 per cent higher hardness than Mrigal and Rohu meat and also shown higher values in other textural properties indicating the good quality meat with higher firmness compared to other two fish species.

This might be because of the lower moisture content and higher protein content in Tilapia than other fishes that provided higher firmness to the structure of the meat. Higher firmness of the meat supported other textural properties namely, cohesiveness, adhesiveness, gumminess and chewiness better in Tilapia. The values of textural properties scored by Mrigal and Rohu were found to be lesser than Tilapia. This might be due to higher moisture, carbohydrate and ash content that provided soft meat compared to Tilapia.

It was also observed that, the textural properties of minced meat recovered from all the three fishes were highest during Pass I and found decreased in the meat obtained after Pass II and Pass III. This might be due to the successive mincing of meat retained with the waste after each pass that damaged the structure of the meat.

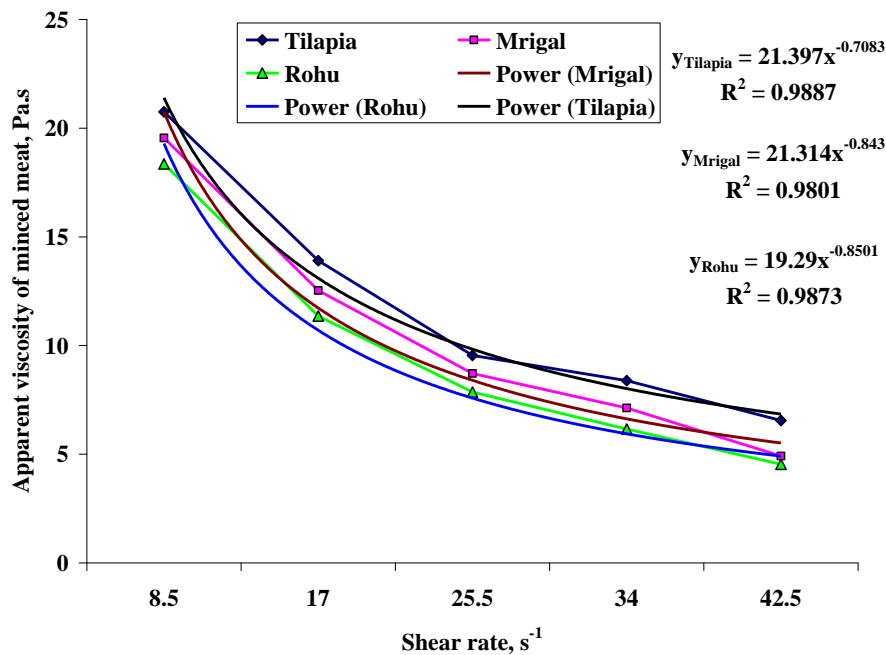
Similar results of higher textural values of minced meat recovered from Tilapia were reported by Oliveira Filho *et al.* (2010) and relatively lower values for Mrigal and Rohu were reported by Benjamin (2012). The proximate composition and textural properties of different marine, brackish water and freshwater fishes have also been reported by Femeena *et al.* (1997). The findings of textural properties of tilapia are in confirmation with the results reported by Hassan (1996) and Abdul (2007) for Rohu and Mrigal.

#### 4.4.6 Rheological properties of minced meat

The data on rheological properties expressed in terms of apparent viscosity (Pa.s) and shear stress (Pa) of the minced meat of three fishes recovered during Pass I, Pass II and Pass III were recorded and analysed statistically by performing two factor ANOVA. The results are presented in Fig. 4.21 and Fig. 4.22.

##### 4.4.6.1 Apparent viscosity

From the Figure, it was also noticed that, apparent viscosity value of Tilapia meat was highest followed by Mrigal and least was Rohu. This might be due the hardness of the minced meat that resisted the flow under the applied shear force. It was also observed that, the apparent viscosity of the meat in all the three fishes decreased with the increase in shear rate denoting non-newtonian fluid with pseudoplastic behaviour which is also termed as shear thinning fluid (Murphy and Rose, 1994). This might be because of the structural damage of the meat at higher shear rates. The apparent viscosity values of minced meat among the three fish species in all the three passes were found to be significantly different at 1 per cent level.



**Fig. 4.21 Effect of shear rate on viscosity of minced meat obtained from three fishes during Pass I**

The apparent viscosity data were tested for different rheological models described by Adebawale (2010) for non-newtonian fluids, among which Power law model found to be best suited to minced meat. The equations obtained from the analysis are as given below.

$$\eta_{(\text{Tilapia})} = 21.397 \times \gamma^{(-0.708)} \quad R^2 = 0.9887 \quad \dots (4.1)$$

$$\eta_{(\text{Mrigal})} = 21.314 \times \gamma^{(-0.843)} \quad R^2 = 0.9801 \quad \dots (4.2)$$

$$\eta_{(\text{Rohu})} = 19.290 \times \gamma^{(-0.850)} \quad R^2 = 0.9873 \quad \dots (4.3)$$

Where,

$\eta$  = Apparent viscosity, Pa.s

$\gamma$  = Shear rate,  $s^{-1}$

$k$  = Consistency index

$n$  = Power law index

The parameters influencing the flow of the meat for three fishes are summarized and are presented along with  $R^2$  value in Table 4.10.

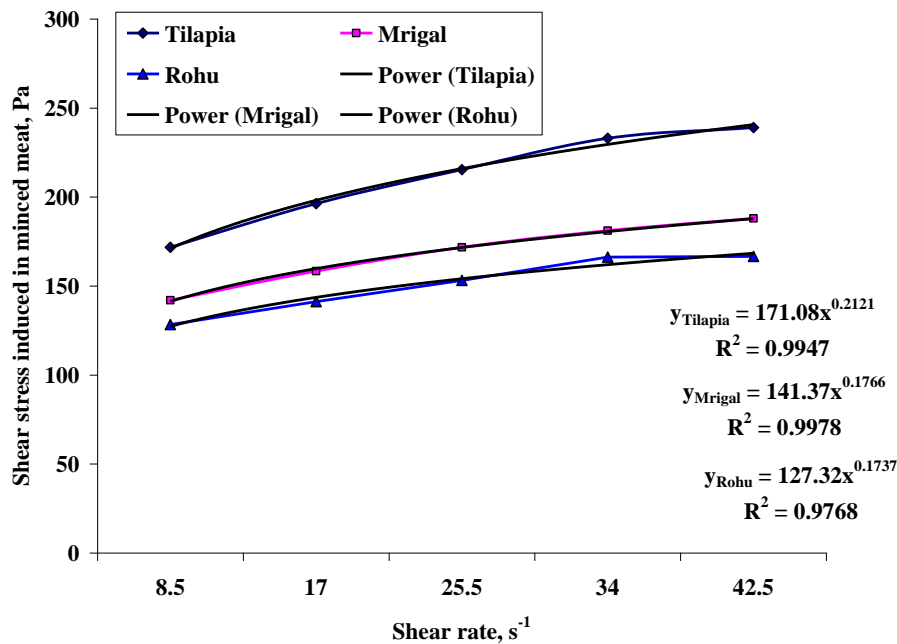
**Table 4.10 Rheological constants with regression coefficients for apparent viscosity curves**

<b>Fish</b>	<b><math>n</math></b>	<b><math>k</math></b>	<b><math>R^2</math></b>
Tilapia	0.292	21.397	0.9887
Mrigal	0.157	21.314	0.9801
Rohu	0.149	19.290	0.9873

From the above Table, it is evident that, the meat obtained from three fishes fall in the category of non-newtonian fluid with pseudoplastic flow behaviour as higher values of consistency index ( $k$ ) and Power law index ( $n < 1$ ) indicated shear thinning of meat at higher shear rates. The curves have shown best fit to the Power law model with higher  $R^2$  values. Similar trends for the meat recovered during Pass II and Pass III have been noticed.

#### 4.4.6.2 Shear stress

From the Fig. 4.22, it was seen that, shear stress induced in the meat recovered from three fishes during Pass I, Pass II and Pass III ranged from 128.33 to 239.01 Pa; 111.41 to 216.10 Pa and 89.63 to 166.43 Pa respectively. Among the fishes, Tilapia meat was scored higher values followed by Mrigal and lowest values were obtained by Rohu. The effect of increase in shear rate on shear stress of minced meat of three fishes recovered in Pass I could be observed in Fig. 4.23.



**Fig. 4.22 Effect of shear rate on shear stress induced in minced meat of obtained from three fishes during Pass I**

It was also noticed from the Figure that, shear stress value of Tilapia meat was highest followed by Mrigal and Rohu. This might be due the difference in protein content that provided higher firmness to the minced meat of Tilapia fish to absorb higher shear stress under the applied shear force. The shear stress of the meat in all the three fishes increased with the increase in shear rate denoting pseudoplastic behaviour as reported by Murphy and Rose (1994) for non-newtonian fluids. This might be because of the decreased values of viscosity of the meat that induced higher shear stress in the meat at

higher shear rates. Similar results of reduction in shear stress values at increasing shear rates have been reported by Nakayama *et al.* (1988) for fresh fish meat.

The curves showing the effect of shear rates on shear stresses induced in meat of three fishes during Pass I were described using Power law model and the equations are presented hereunder.

$$\tau_{(\text{Tilapia})} = 171.08 \times \gamma^{(0.2121)} \quad R^2 = 0.9942 \quad \dots (4.4)$$

$$\tau_{(\text{Mrigal})} = 141.37 \times \gamma^{(0.1766)} \quad R^2 = 0.9978 \quad \dots (4.5)$$

$$\tau_{(\text{Rohu})} = 127.32 \times \gamma^{(0.1737)} \quad R^2 = 0.9768 \quad \dots (4.6)$$

The parameters influencing the flow of the meat for three fishes are summarized and are presented along with  $R^2$  value in Table 4.11.

**Table: 4.11 Rheological constants with regression coefficients for shear stress curves**

Fish	$n$	$k$	$R^2$
Tilapia	0.2121	171.08	0.9942
Mrigal	0.1766	141.37	0.9978
Rohu	0.1737	127.32	0.9768

From the above Table, it is inferred that the meat obtained from three fishes fall in the category of non-newtonian fluid with pseudoplastic flow behaviour as higher values of consistency index ( $k$ ) and Power law index ( $n < 1$ ) indicated shear thinning of meat at higher shear rates. The curves have shown best fit to the Power law model with higher  $R^2$  values. Similar trends were noticed for the meat recovered during Pass II and Pass III.

Similar results of decrease in viscosity and shear stress for increasing shear rates have been reported by Nakayama *et al.* (1980) for fresh fish meat and Matveichuk *et al.* (2012) for chicken meat.

## **4.5 Economics of Developed Fish Deboner**

The economics of the developed fish deboner was studied through the computation of the production cost of the fish deboner, cost of operation, payback period, benefit-cost ratio and net present worth. The details of the economics of the developed fish deboner are presented in Appendix V.

### **4.5.1 Production cost of the machine**

The production cost of the developed fish deboner was found to be Rs. 68,842 .65. The costs of major components namely, stainless steel perforated drum (Rs. 20,000/-) and food grade conveyor belt (Rs. 4500/-) contributed more (38.59 per cent) to the total cost of the machine. These parts were not readily available in the market and were specially given order to the fabricators.

### **4.5.2 Cost of operation**

The annual fixed cost and operating cost of the fish deboner were estimated as Rs. 24,955.55 and Rs.79,684.27 as the life of fish deboner considered was assumed as five years. The annual cost of operation of the deboner was found as Rs.1,04,640.00. Considering, the number of working days and number of working hours per day, the cost of operation found to be Rs. 523.20 per day and Rs. 65.40 per hour. The cost of meat separation was found to be Rs. 1.31 per kg of dressed fish as the capacity of the deboner considered was 50 kg per hour.

Considering, the meat separation charges as Rs. 5.00 per kg of dressed fish equal to the manual meat separation charges practicing in local fish market. The expected returns per day were found to be Rs.1,250.00, hence the expected annual returns were Rs. 2,50,000.00 with annual profit of Rs.1,45,360.00.

### **4.5.3 Payback period**

Pay back period of the fish deboner was calculated as the ratio of the investment made on the machine to the net annual returns obtained by operating the machine for meat separation work. It was found to be 0.47 years or 94.27 days of operation. The pay back period was found to be less than half of the annual working days (200 days).

#### **4.5.4 Net returns**

Net returns of the developed fish deboner were obtained by deducting the value of discounted cost in discounted returns and were found to be Rs. 9,35,584.93 for a period of five years with average net returns of Rs. 1,55,930.82 per year.

#### **4.5.5 Benefit-cost (B-C) ratio**

Considering, the values of discounted returns and discounted cost for a period of five years, the benefit-cost ratio of fish deboner was found to be 3.51.

#### **4.5.6 Net present worth (NPW)**

Net present worth is the present worth of cash flow stream of the operation and NPW of the developed fish deboner was computed as the difference of discounted returns and discounted cost for a period of five years. NPW was found to be Rs. 830493.00.

Manual meat separation is labourious and requires knowledge of bone structure in the fish. It was observed that, a person can separate meat from 15-20 kg fish per hour. One labour works for 5 hours in 8 hours work schedule separating meat from an average 75 kg of fish (Robertson and Meritt, 1985). Expecting the number of working days as 200 per annum, the returns he/she gets towards meat separation charges would be  $200 \times 75 \times 5$  amounting to Rs. 75,000.00. After deduction of his own labour (as Rs. 150/- per day) the net returns would be Rs. 45,000.00 per year. The net returns are considerably less compared to the net returns of Rs. 1,45,360.00 per year of developed fish deboner. Therefore, the technology would be a boon for the poor fishermen, unemployed rural youths and small entrepreneurs. Adoption of the technology opens the avenue for utilization of low value and under-utilized fish fishes thereby reducing the demand level of fish foods through supply of valuable protein to the consumers.

Similar results of economics with better B:C ratios for belt and drum type deboners have been reported by Robertson and Meritt (1985), Andrew M. Lazur (1997) for small scale meat bone separation unit and by Gunnar Knapp (2008) for small fish processing unit.

## **4.6 Development of Fortified Fish Sausage**

Tilapia, a low value freshwater fish was deboned in the developed fish deboner machine and the minced meat was used for the development of a ready-to serve fish sausage fortified with omega-3 fatty acids and iodine. The proximate composition, fatty acid profile, biochemical and microbial quality of tilapia mince, sausage paste and the developed sausages with different levels of fortification were analysed by following standard procedures. The colour values and rheological properties of the sausages were measured using colourimeter and rheometer respectively. Sensory evaluation of the sausages was also carried out for the selected attributes. The data obtained from the experiments were statistically analysed using one way and two ways ANOVA (depending on the design of experiment). The summarized results are discussed hereunder.

### **4.6.1 Proximate composition**

The proximate composition constituting moisture, crude protein, crude fat, total minerals and total carbohydrates content of fresh fish mince obtained from the deboner, sausage paste, commercial sausage and sausages prepared with different levels of fortification are presented in Table 4.12.

#### **4.6.1.1 Moisture content**

From the Table 4.12, it was observed that the moisture content of fish mince, sausage paste and sausage (control) recorded 79.73, 69.83 and 68.93 per cent, respectively and for fortified sausages (T2, T3, T4, T5) and commercial sausage (T6) it was determined to be 68.93, 68.68, 68.64, 68.62 and 68.37 per cent, respectively. Highest moisture content was observed in fish mince followed by sausage paste. The moisture content in sausage paste was less than the mince since starch and other ingredients added to the mince. The moisture slightly reduced in the sausages which might be due to the gelatinization of the starch during thermal processing of the sausage. There was non-significant difference in the moisture content between the treatments as similar ingredients were added during preparation of sausage.

#### **4.6.1.2 Crude protein content**

From the Table 4.12, it was seen that the crude protein content in the mince, paste and sausage (control) was 16.19, 16.09 and 15.86 per cent, respectively. The small reduction in protein content of sausage might be due to the protein denaturation during thermal processing of sausage. The protein content in sausages prepared with different levels of fortification ranged from 14.28 to 15.94 per cent. The slight reduction in the protein content of sausages compared to that of fish mince might be due to the reduction in moisture content of the sausages. The protein content of 14.28 per cent found in commercial sausage was the lowest among all the sausages and significantly different from control at 1 per cent level. This might be due to the use of lesser proportion of fish mince in the commercial preparations of fish sausage. It was also observed that the protein content decreased with the increase in fortification levels of fish oil. This might be due to increase in fat level in the fortified sausages.

#### **4.6.1.3 Crude fat content**

The crude fat content of fish mince, sausage paste and sausage (control) observed from the table was 2.38, 7.18 and 7.06 per cent, respectively and in sausages of different treatments ranged from 7.06 to 7.63 per cent. However, commercial sausage recorded highest fat content of 10.0 per cent among all the sausages and it was found to be significantly higher at 1 per cent level compared to the control (T1).

The fat content increased in sausage paste itself as the vegetable oil was one of the ingredients that boosted the fat level. It was also evident from the higher fat contents of fortified sausages and also in commercial sausage.

#### **4.6.1.4 Total mineral content**

The total mineral content in the mince, paste and sausage (control) observed from the Table was 1.65, 2.78 and 7.06 per cent, respectively. The minerals content in sausages prepared with different levels of fortification ranged from 2.96 to 3.21 per cent. The increase in mineral content observed might be because of the addition of spices, potassium iodide and oil that added minerals in the sausage paste and the sausages. However, the commercial sausage recorded lowest mineral content of 2.43 per cent.

**Table 4.12 Proximate composition of fish meat, sausage paste, sausages of different treatments**

Parameters	Fish mince	Sausage paste	Sausages with different treatments						SEd±	CD @ 1%	CV (%)
			T1	T2	T3	T4	T5	T6			
Moisture (%)	79.73	69.83	68.93	68.93	68.68	68.64	68.62	68.37	11.64	6.25	3.74
Crude Protein (%)	16.19	16.09	15.86	15.94	15.86	15.78	15.44	14.28**	0.48	1.41	3.77
Crude Fat (%)	2.38	7.18	7.06	7.06	7.15	7.32	7.63	10.00**	0.22	0.67	4.03
Total Minerals (%)	1.65	2.78	2.96	3.05	3.12	3.15	3.21	2.43**	0.09	0.26	3.97
Total Carbohydrates (%)	0.05	4.12	5.19	5.15	5.12	5.13	5.10	4.29**	0.14	0.42	4.22

\*\* : Significant at 1 per cent level

T1: Control

T2: With KI @ 150 µg/100g of sample;

T3: With KI @ 150 µg/100g of sample and Fish oil @ 5 per cent of vegetable oil

T4: With KI @ 150 µg/100g of sample and Fish oil @ 10 per cent of vegetable oil

T5: With KI @ 150 µg/100g of sample and Fish oil @ 15 per cent of vegetable oil

T6: Commercial sausage

This might be due to higher fat content and use of lesser proportion of spice ingredients in the recipe. The mineral content of commercial sausage found significantly less (at 1 per cent level) and found to be lesser than control (T1)

The mineral content increased in sausage paste as the spice ingredients added minerals to the mince. The increase in mineral content of fortified sausages was also observed as the fortification with fish oil and potassium iodide might have improved the mineral content of the sausages. Lower level of mineral content was observed in commercial sausage. The increase in mineral content of T2, T3, T4 and T5 found to be 3.0, 5.4, 6.4 and 8.4 per cent, respectively compared to the control (T1) whereas in commercial sausage, 17.9 per cent reduced level of mineral content observed. This might be because of the use of higher mineral contents of spices added in the sausages.

#### **4.6.1.5 Total carbohydrates**

The total carbohydrates content in the fish mince, paste and sausage recorded was 0.05, 4.12 and 5.19 per cent, respectively and T2, T3, T4, T5 and T6 recorded 5.15, 5.12, 5.13, 5.10 and 4.29 per cent, respectively. Highest carbohydrate content was observed in control (T1) and the carbohydrate content in sausages prepared with different levels of fortification was found to be non-significant at one per cent level. The lowest carbohydrate content was noticed in commercial sausage and was significantly less than control (T1) at one per cent level.

Tilapia contained negligible amount of carbohydrates (0.05 per cent) and the content increased to 4.12 per cent in sausage paste as corn starch of 10 per cent by weight was mixed in the mince while preparing the sausage. The carbohydrate content further increased in the final product and per cent increase recorded was in the range of 23.78 to 25.97 per cent in fortified sausages. This might be due to gelatinization of starch content of ingredients added in recipe. The lesser carbohydrate content in commercial sausage might be due to the lesser proportion of starch in the formulation of the sausage.

#### **4.6.2 Biochemical properties**

The biochemical properties *viz.*, total volatile base nitrogen (TVB-N), peroxide value (PV), free fatty acid (FFA) content, iodine value (IV), pH and water activity of

fresh fish mince, sausage paste and sausages prepared with different levels of fortification including commercial sausage are presented in Table 4.13 and discussed below.

#### **4.6.2.1 Total volatile base nitrogen**

From the Table 4.13, it was seen that TVB-N of fish mince, sausage paste and sausage (control) recorded was 7.63, 6.63 and 6.56 mg N per 100 g of sample respectively and the values for fortified sausages (T2, T3, T4, T5) and commercial sausage (T6) were 6.58, 6.73, 6.81, 6.89 and 9.23 mg N per 100 g of sample, respectively. The sausages prepared were found in the acceptable range of 35–40 mg N/100 g.

Higher TVB-N content was observed in fish mince and the content was lesser in paste and final product. TVB-N content in the fortified sausages found non-significant with the control. However, commercial sausage (T6) recorded highest (9.23 mg N per 100 g of sample) among all sausages and found significantly higher at 1 per cent level than the control.

The TVB-N was higher in fish mince and decreased during the preparation of sausage due to thermal treatment and denaturation of protein at high temperature. It was also observed that the TVB-N content increased with the increased levels of fish oil fortification. However, TVB-N content in commercial sausage was 40.7 per cent more than the control. The higher TVB-N value of commercial sausage showed lesser freshness of the product than the lower values of fortified sausages prepared from fresh flesh.

#### **4.6.2.2 Peroxide value**

From the Table, it was seen that, peroxide value (PV) of fish mince, sausage paste and sausage (control) was 4.42, 12.56 and 12.42 mMoles of O<sub>2</sub> per kg of fat, respectively whereas the fortified sausages (T2, T3, T4 and T5) and commercial sausage (T6) the values were 12.46, 12.89, 13.56, 14.88 and 15.35 mMoles of O<sub>2</sub> per kg of fat, respectively. The values were in the acceptable range of 20 to 40 mMoles of O<sub>2</sub> per kg of fat (Pearson, 1970). Highest peroxide value observed in commercial sausage was found to be significantly more than the control.

**Table 4.13 Biochemical and microbiological characteristics of fish mince, sausage paste and sausages of different treatments**

Parameters	Fish mince	Sausage paste	T1 (Control)	T2	T3	T4	T5	T6	SEd±	CD @ 1%	CV (%)
TVBN (mg N / 100 g of meat)	7.63	6.63	6.56	6.58	6.73	6.81	6.89	9.23**	0.21	0.64	3.77
PV (mMoles of O <sub>2</sub> / kg fat)	4.42	12.56	12.42	12.46	12.89	13.56	14.88	15.35**	0.40	1.19	4.06
FFA (% of Oleic acid)	3.52	2.56	2.28	2.25	2.38	2.56**	2.82**	3.64**	0.08	0.24	3.77
Iodine value (µg/100g of sample)	26.58	29.32	19.95	134.13**	135.12**	134.56**	133.25**	26.36**	23.00	9.45	4.96
pH	6.70	6.80	6.60	6.60	6.60	6.60	6.60	6.30	0.20	0.59	3.77
Water activity	9.14	8.22	8.98	8.98	8.72	8.74	8.72	8.82	0.26	0.78	3.76
Total Plate Count (cfu / g)	4.60×10 <sup>-2</sup>	8.0×10 <sup>-3</sup>	3×10 <sup>-3</sup>	3×10 <sup>-3</sup>	4×10 <sup>-3</sup>	6×10 <sup>-3</sup>	8×10 <sup>-3</sup>	1.5×10 <sup>-4</sup> **	3 × 10 <sup>-3</sup>	1× 10 <sup>-3</sup>	3.50
Aerobic spore former (cfu / g)	0.0	21	31	33	32	31	32	42**	0.95	2.79	4.22

\*\* : Significant at 1 per cent level

T1: Control

T2: With KI @ 150 µg/100g of sample;

T3: With KI @ 150 µg/100g of sample and Fish oil @ 5 per cent of vegetable oil

T4: With KI @ 150 µg/100g of sample and Fish oil @ 10 per cent of vegetable oil

T5: With KI @ 150 µg/100g of sample and Fish oil @ 15 per cent of vegetable oil

T6: Commercial sausage

The PV value was 4.42 mMoles of O<sub>2</sub> per kg of fat in fish mince as it was fresh and then rose to 12.42 mMoles of O<sub>2</sub> per kg of fat in T1 sausage (control). The addition of fat (vegetable oil) contributed to the rise in PV value of sausage. It was also observed that the PV value increased (3.7, 9.2 and 19.8 per cent) with the increased levels of fish oil fortification (5, 10 and 15 per cent in T3, T4 and T5, respectively). However, PV value in commercial sausage was 23.59 per cent more than the control. The higher PV value of commercial sausage might be because of the higher fat content (10.0 per cent).

#### **4.6.2.3 Free fatty acids**

The free fatty acids (FFA) in fish mince, sausage paste and sausage (T1) was 3.52, 2.56 and 2.28 per cent of oleic acid, respectively. T3, T4 and T5 sausages recorded 2.38, 2.56 and 2.82 per cent of oleic acid, respectively. The values were found to be in acceptable range of 5.0 per cent. However, commercial sausage had 3.64 per cent of oleic acid and found significantly higher than the control.

The sausages prepared without fish oil fortification had lower FFA values whereas the FFA values of fortified sausages namely T3, T4 and T5 were 4.4, 12.3 and 23.7 per cent higher than the control respectively as the fish oil incorporation increased from 5 to 15 per cent in the fortified sausages. Lower levels of free fatty acids indicated the relatively higher freshness of the product. It was also seen that the FFA value of commercial sausage was 3.64 per cent of oleic acid which was 47.36 per cent higher than fish sausage (control). This might be due to the higher fat level used in the preparation of commercial sausage that influenced rise in the FFA value.

#### **4.8.2.4 Iodine value**

The iodine value in fish mince, fish paste and sausage (T1) recorded was 26.58, 29.32 and 19.95 µg per 100 g of sausage, respectively. The sausages T2, T3, T4, T5 and T6 recorded 134.13, 135.12, 134.56, 133.25 and 26.36 µg per 100 g of sausage, respectively. Iodine values of fortified sausages were found to be significantly higher than commercial sausage and control. However, 25 to 30 per cent of iodine added through iodized salt and potassium iodide lost due to the high temperature treatment during the preparation of sausage. Iodine loss observed in the sausages fortified with potassium iodide was up to 30 per cent. However, the commercial sausage was found to

be lacking in iodine content and had only 26.36 µg per 100 g of product. The iodine requirement of 150 µg per day by an adult could be met by adding fortified sausage in the diet and the iodine lost in sausage preparation might be compensated by other food items in the diet.

#### **4.6.2.5 pH**

The pH value of fish mince, paste and sausage (control) recorded was 6.7, 6.8 and 6.60, respectively. There was no significant difference in the pH levels in the fortified sausages samples as these recorded an average pH value of 6.6. The commercial sausage T6 had a lower pH level of 6.3. The lesser value of pH in commercial sausage might be due to breakdown of starch by bacterial activity. The acceptable limit for pH in sausages is more than 4.6 (FAO, 2008)

#### **4.6.2.6 Water activity**

The water activity in the fish mince, paste and sausage (control) recorded was 9.14, 8.22 and 8.98, respectively. Water activity of T2, T3, T4, T5 and T6 recorded was in the range of 8.72 to 8.98. There was no significant difference in the water activity of fortified sausages samples. The water activity of fish meat was found to be higher and reduced in paste and sausage due to the addition of ingredients and gelatinization of starch during thermal processing of sausage.

#### **4.6.3 Microbial analysis**

Fish mince, sausage paste, sausages prepared with different levels of fortification including sausage (T1) and commercial sausage (T6) were subjected to microbial analyses. The total plate count and aerobic spore formers observed in the samples are presented in Table 4.13 and discussed hereunder.

##### **4.6.3.1 Total plate count**

From the Table 4.13, it was observed that, total plate count (TPC) in fish mince, sausage paste and fish sausage (T1) recorded was  $4.6 \times 10^{-2}$ ,  $8.0 \times 10^{-2}$  and  $3.0 \times 10^{-2}$  cfu per g of sample, respectively. Similarly, the sausages T2, T3, T4, T5 and T6 recorded  $3.0 \times 10^{-3}$ ,  $4.0 \times 10^{-3}$ ,  $6.0 \times 10^{-3}$ ,  $8.0 \times 10^{-3}$  and  $1.5 \times 10^{-4}$  cfu per g, respectively. Highest TPC was observed in commercial sausage indicating higher microbial content and found

significantly higher than T1 whereas and lowest was found in T1 and T2. The counts were found within the maximum acceptable limit of  $10^6$  cfu per gram of sausage (FAO, 2008).

#### **4.6.3.2 Aerobic spore formers**

It was observed that the fresh mince had no aerobic spore formers (ASF) whereas the sausage paste and sausage (T1) recorded 21 and 31 cfu per g of product, respectively. The treatments T2, T3, T4, T5 and T6 recorded 33, 32, 31, 32 and 42 cfu per g, respectively. Highest ASFs observed in commercial sausage (T6) and found significantly higher than the control (T1) whereas lower values were found in fortified sausages. However, the counts were found less than the maximum acceptable limit of  $10^3$  cfu per gram of sausage.

The results of proximate composition, biochemical and microbial analysis revealed that the sausages prepared with fortification of fish oil and iodine content were superior in quality as well as in nutritional value compared to the control and commercial sausage. The values of different parameters were within the acceptable ranges.

Similar results of proximate composition, biochemical and microbial analysis of sausages have been reported by Delange (1993), Lee *et al.*(1997), Romens *et al.*(2001), Haldimann *et al.*(2005) and Kim (2006) for sausages prepared from fish and meat. The findings are in confirmation with the results reported by Raju *et al.*(2003) for marine fish, threadfin bream and Panpipat and Jirawat (2008) for fortified sausage prepared from freshwater fishes, Rohu and African cat fish.

#### **4.6.4 Fatty acids composition**

The fatty acids composition of fat extract of tilapia mince recovered from fish deboner and sardine oil used for the fortification of sausages were analysed by using gas chromatograph and fatty acids profile is presented in Table 4.14. From the Table it was seen that, a total of saturated fatty acids ( $\Sigma$ SFA), comprising myristic acid (C14:0), palmitic acid (C16:0), margaric acid (C:17.0) and stearic acid (C18:0) recorded 29.3 and 36.4 g per 100 g of sardine oil and fat extract of tilapia mince respectively.

The summation of all the mono unsaturated fatty acids ( $\Sigma$ MUFA) comprising pamic acid (C16:1), heptadecenoic acid (C17:1), oleic acid (C18:1n9c) and docosenoic acid (C20:1n11) recorded 36.2 and 27.5 g per 100 g of sardine oil and the

extract of tilapia mince, respectively. Similarly, a total of polyunsaturated fatty acids ( $\Sigma$ PUFA) comprising linoleic acid (C18:2n6c), linolenic acid (c18:3n3), stearidonic acid (c18:4n3), arachidonic acid (C20:4n6), eicosapentaenoic acid (C20:5n3), docosapentaenoic acid (C22:5n3) and docosahexaenoic acid (C22:6n3) recorded were 31.6 and 32.1 g per 100 g of sardine oil and fat extract of tilapia mince, respectively.

**Table 4.14 Fatty acid compositions of sardine fish oil and lipids extracted from Tilapia mince**

<b>Fatty acids (g per 100 g of sample)</b>	<b>Sardine fish oil</b>	<b>Tilapia mince</b>
Myristic acid (C 14:0)	9.2 (1.2)	2.3 (0.6)
Palmitic acid (C 16:0)	17.3 (1.9)	24.6 (1.5)
Margaric acid (C 17:0)	0.9 (0.05)	0.4 (0.1)
Stearic acid (C 18:0)	1.9 (0.15)	9.1 (1.2)
<b><math>\Sigma</math>SFA</b>	<b>29.3</b>	<b>36.4</b>
Palmitoleic acid (C 16:1)	15.8 (2.2)	4.1 (0.6)
Heptadecenoic acid (C 17:1)	0.4 (0.05)	ND
Oleic acid (C18:1n9c)	19.8 (1.50)	19.8 (1.8)
Docosenoic acid (C 20:1n11)	0.2 (0.02)	3.6 (0.8)
<b><math>\Sigma</math>MUFA</b>	<b>36.2</b>	<b>27.5</b>
Linoleic acid (C18:2n6c)	0.8 (0.05)	22.5 (1.6)
Linolenic acid (C18:3n3)	2.4 (0.15)	1.0 (0.2)
Stearidonic acid (C 18:4n3)	0.9 (0.05)	ND
Arachidonic acid (C20:4n6)	1.7 (0.15)	5.8 (1.1)
Eicosapentaenoic acid (C20:5n3)	16.5 (1.7)	0.3 (0.1)
Docosapentaenonic acid (C22:5n3)	1.0 (0.05)	1.2 (0.2)
Docosahexaenoic acid (C22:6n3)	8.3 (0.45)	1.3 (0.4)
<b><math>\Sigma</math>PUFA</b>	<b>31.6</b>	<b>32.1</b>
n-6 fatty acids	2.5	28.3
n-3 fatty acids	29.1	3.8
<b>n-6/n-3 ratio</b>	<b>0.086</b>	<b>7.44</b>

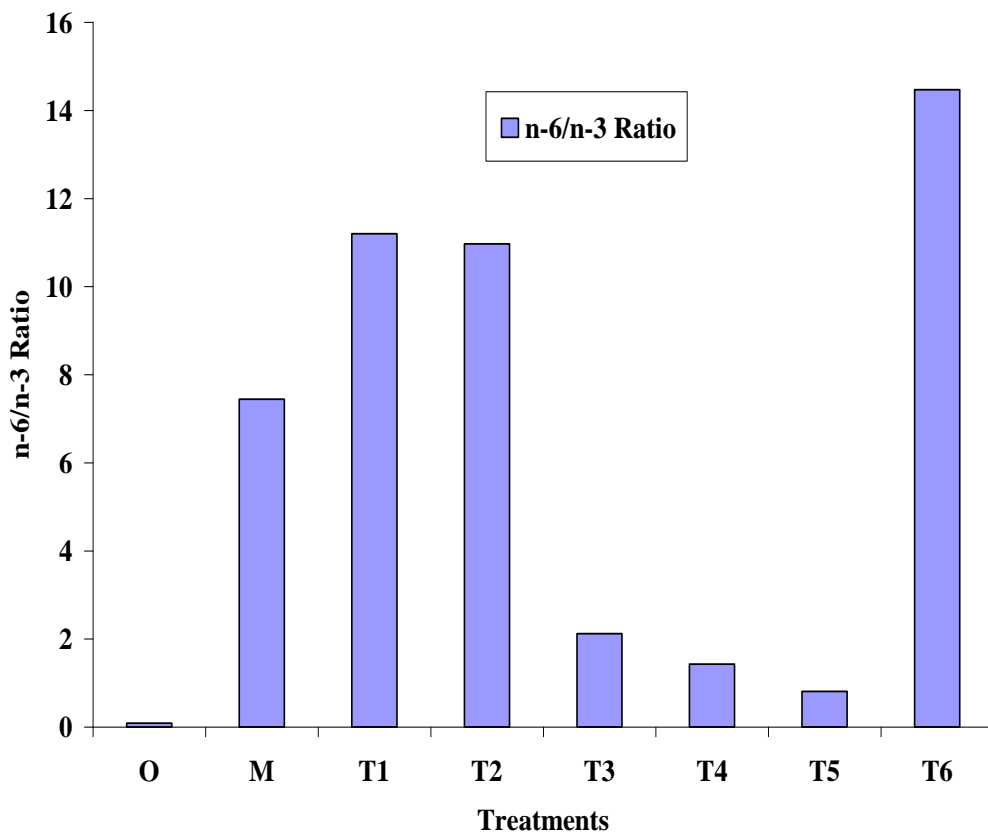
Based on these fatty acids the ratio of n-6 to n-3 was calculated and were found to be 0.086 and 7.44 for sardine fish oil and tilapia mince fat, respectively. It was also observed that, tilapia mince contained higher saturated fatty acids (36.4 g /100 g of sample) than sardine fish oil whereas sardine fish oil was found to be rich in monounsaturated and polyunsaturated fatty acids. The higher n-6 / n-3 ratio of tilapia mince (7.44) is due to the higher levels of n-6 fatty acids compared to n-3 fatty acids.

#### **4.6.4.1 Poly-unsaturated fatty acids composition of sausages**

The composition of polyunsaturated fatty acid of sardine fish oil, fat extract of tilapia mince and the sausages prepared with different treatments including commercial sausages are given Table 4.15. From the Table, it was observed that, commercial sausage recorded highest linoleic acid (34.18 g/ 100g of sample) among all the sausages and lowest recorded in T5 (18.4 g /100 g of sample). Similarly, T1, T2 and T6 treatments recorded the arachidonic acid content of 5.6, 6.6 and 6.5 g per 100 g of sample whereas T3, T4 and T5 recorded the values of 2.2, 1.6 and 1.2 g per 100 g of sample. These two acids belonged to omega-6 fatty acids. The remaining fatty acids namely, linolenic acid (LNA), eicosapentaenoic acid (EPA), docosapentaenoic acid (DPA) and docosohexaenoic acid (DHA) constituted omega-3 fatty acids. The total poly-unsaturated fatty acids of T1, T2, T3, T4, T5 and T6 were 42.7, 41.9, 40.6, 40.7, 43.65 and 42.53 g per 100 g of sample, respectively. The ratios of n-6 to n-3 of T1, T2, T3, T4, T5 and T6 was observed to be 11.2, 10.97, 2.12, 1.43, 0.81 and 14.47, respectively against 0.086 and 7.44 of sardine fish oil and tilapia mince.

The variation in n-6 / n-3 ratio of sardine fish oil, fat extract of tilapia mince and the sausages with different levels of treatments are presented in Fig. 4.23.

It was observed from the Figure that, though the total PUFA was highest in the sausages prepared without incorporation of fish oil (T1, T2 and T6), the ratios of n-6 to n-3 were less than fortified sausages. This might be due to higher levels of omega -6 fatty acids in the sausages. The n-6 / n-3 ratios of T3, T4 and T5 sausages improved due to the fortification of fish oil. These ratios were better than the recommended ratio of daily diet.



**Fig 4.23 Effect of fortification on n-6/n-3 ratio of sausages prepared with different treatment**

Similar results on fatty acid profile analysis of fish oil and fish sausages have been reported. Chakraborty *et al.* (2009) found n-6 to n-3 of sardine oil as 0.075, Karolyi and Curic (2012) reported n-6 to n-3 ratio of 11.26 for slavonian kulen, a dry fermented sausage and Tamas *et al.* (2012) observed n-6 to n-3 ratio of 7.8 for tilapia mince. Panpipat and Jirawat (2008) reported the reduction in n-6 to n-3 ratio of 9.97 to 1.72 and 8.86 to 1.25 in the fortified sausages prepared from African catfish and rohu with tuna fish oil. The findings are in confirmation with the results reported by Panpipat and Jirawat (2008).

**Table 4.15 Comparison of polyunsaturated fatty acids (PUFA) of fish oil and fat extracts of tilapia mince and sausages**

Fatty acids (g per 100 g of sample)	Sardine fish oil	Tilapia mince	T1 Control	T2	T3	T4	T5	T6	SEd±	CD @ 1%	CV
Linoleic acid (LA)	0.80	22.50	32.60	31.90	25.40**	22.40**	18.40**	34.18**	0.77	2.27	4.05
Linolenic acid (LNA)	2.40	1.00	0.80	0.80	1.70**	1.50**	1.10**	0.70 NS	0.04	0.11	4.00
Eicosapentaenoic acid (EPA)	16.50	0.30	0.80	0.80	2.30**	3.90**	5.60**	0.70 NS	0.15	0.46	5.02
Arachidonic acid (AA)	1.70	5.80	6.60	6.50	2.20**	1.60**	1.20**	5.60**	0.12	0.36	3.95
Docosapentaenoic acid (DPA)	1.00	1.20	0.30	0.30	0.70**	0.85**	1.15**	0.25 NS	0.02	0.07	4.40
Docosahexaenoic acid (DHA)	8.30	1.30	1.60	1.60	8.30**	10.45**	16.20**	1.10**	0.28	0.82	5.70
<b>ΣPUFA</b>	<b>31.60</b>	<b>32.10</b>	<b>42.70</b>	<b>41.90</b>	<b>40.60</b>	<b>40.70</b>	<b>43.65</b>	<b>42.53</b>	<b>1.24</b>	<b>3.63</b>	<b>3.86</b>
n-6 fatty acids	2.50	28.30	39.20	38.40	27.60	24.00	19.60	39.78	0.89	2.61	3.99
n-3 fatty acids	29.10	3.80	3.50	3.50	13.00	16.70	24.05	2.75	0.48	1.40	4.88
n-6/n-3 ratio	<b>0.086</b>	<b>7.44</b>	<b>11.2</b>	<b>10.97</b>	<b>2.12</b>	<b>1.43</b>	<b>0.81</b>	<b>14.47</b>	<b>0.22</b>	<b>0.65</b>	<b>4.54</b>

\*\* : Significant at 1 per cent level

T1: Control

T2: With KI @ 150 µg/100g of sample;

T3: With KI @ 150 µg/100g of sample and Fish oil @ 5 per cent of vegetable oil

T4: With KI @ 150 µg/100g of sample and Fish oil @ 10 per cent of vegetable oil

T5: With KI @ 150 µg/100g of sample and Fish oil @ 15 per cent of vegetable oil

T6: Commercial sausage

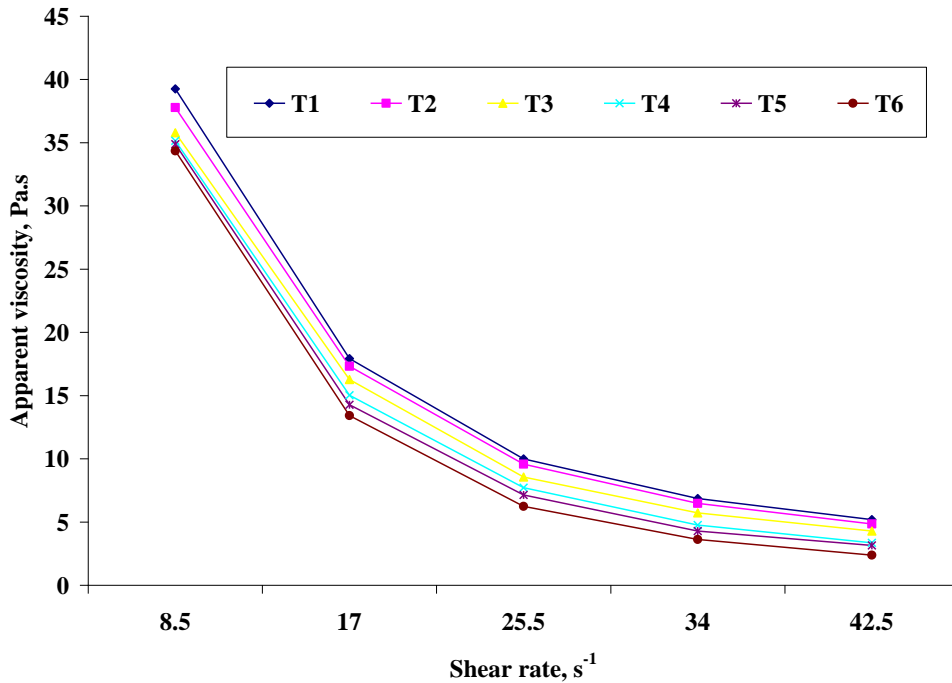
#### **4.6.5 Rheological properties**

The sausages prepared with different levels of fortification including control and commercial sausage were subjected to rheological analysis using PVS rheometer the variation in apparent viscosity of sausages prepared with different levels of fortification is shown in Fig. 4.24.

It was observed from the Figure that, the apparent viscosity decreased as the shear rate increased whereas apparent viscosity decreased as the fat content in sausage increased at a given shear rate. The highest apparent viscosity of 39.26 Pa.s was in the sausage T1 (control) and treatment T2 was on par with T1 with a value of 37.77 Pa.s. The sausages T3, T4 and T5 showed significantly lower values of apparent viscosity compared to the control. However, commercial sausage recorded lowest (34.35 Pa.s) among all the treatments. It was also observed that apparent viscosity of sausages decreased with increase in shear rate. The values of fortified sausages at increasing levels of shear rates showed that, the fat content of the sausage had direct influence on viscosity of the sausages.

It was also seen from the Figure that, the viscosities recorded by T3, T4 and T5 were 16.88, 19.98 and 22.02 per cent less than T1 (control). However, reduction in viscosity was found to be 24.79 per cent in T6 (commercial) as it contained highest fat of 10.0 per cent among all the recipes. The Figure also illustrated no significant effect of incorporation of potassium iodide on viscosity of the sausages as the reduction in viscosity of T2 found only 4.6 per cent that of T1 (control).

The results clearly indicated that the firmness of the sausage decreased with increase in fat percentage in the recipe. The viscosity curve resembled the behaviour of shear thinning fluid.



T1: Control

T2: With KI @ 150 µg/100g of sample;

T3: With KI @ 150 µg/100g of sample and Fish oil @ 5 per cent of vegetable oil

T4: With KI @ 150 µg/100g of sample and Fish oil @ 10 per cent of vegetable oil

T5: With KI @ 150 µg/100g of sample and Fish oil @ 15 per cent of vegetable oil

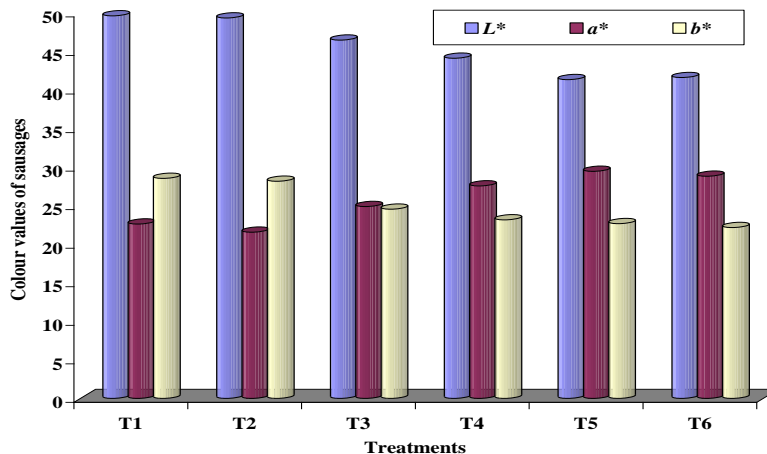
T6: Commercial sausage

**Fig 4.24 Effect of fortification on apparent viscosity of sausages prepared with different treatment levels at different levels of shear rates**

Similar results on reduction in gel strength, breaking force and deformation of fortified sausages have been reported by Panpipat and Jirawat (2008) and Nowsad and Hoque (2009) observed decrease in textural values of sausages prepared from washed mince blend (UM) of low-cost marine fish *viz.*, red jewfish, sea catfish, horse mackerel, jeweled shad and skipjack tuna. The findings on decrease in viscosity of sausages are in confirmation results reported by Khem (2009) for the sausages prepared using marine fish species riebroly and benjakul having different fat contents.

#### 4.6.6 Colour value

The variations in colour values of different sausages are shown in Fig. 4.25. It was observed from the Figure, that  $L^*$ ,  $a^*$  and  $b^*$  values ranged from 41.62 to 49.62; 21.55 to 29.46 and 21.16 to 28.54, respectively. T1 was scored highest  $L^*$  and  $b^*$  values whereas T5 was observed to be highest in  $a^*$  values among all the sausages. From the Figure, it was also observed that, fortified sausages T3, T4 and T5 had lower  $L^*$  values indicating less white in appearance and were par with  $L^*$  values of T6 (commercial sausage). These sausages had dark pink colour preferred by consumers. This lesser whiteness might be attributed to the dark colour imparted by the addition of fish oil in the sausages. However, T1 and T2 scored higher value of  $L^*$  as these appeared whiter compared with other sausages.



T1: Control

T2: With KI @ 150  $\mu\text{g}/100\text{g}$  of sample;

T3: With KI @ 150  $\mu\text{g}/100\text{g}$  of sample and Fish oil @ 5 per cent of vegetable oil

T4: With KI @ 150  $\mu\text{g}/100\text{g}$  of sample and Fish oil @ 10 per cent of vegetable oil

T5: With KI @ 150  $\mu\text{g}/100\text{g}$  of sample and Fish oil @ 15 per cent of vegetable oil

T6: Commercial sausage

**Fig 4.25 Effect of fortification on colour values of sausages prepared with different treatment levels**

Similarly, T3, T4, T5 scores were found to be having higher  $a^*$  values and were on par with T6 (commercial sausage) showing the products with higher red colour shade compared to T1 and T2. This might be due to addition of fish oil that might have enhanced the intensity of pink colour added in the sausage. The  $a^*$  value of commercial sausage was 28.82 which might be due to the addition of more red colour in the sausage.

The  $b^*$  values scored by T1 (control) and T2 (fortified with KI alone) scores were found to be higher resembling yellow shade in the product whereas T3, T4 and T5 scored lower values which might be due to the incorporation of fish oil in these treatments. T1 scored highest  $b^*$  value as it did not contain fish oil in the recipe.

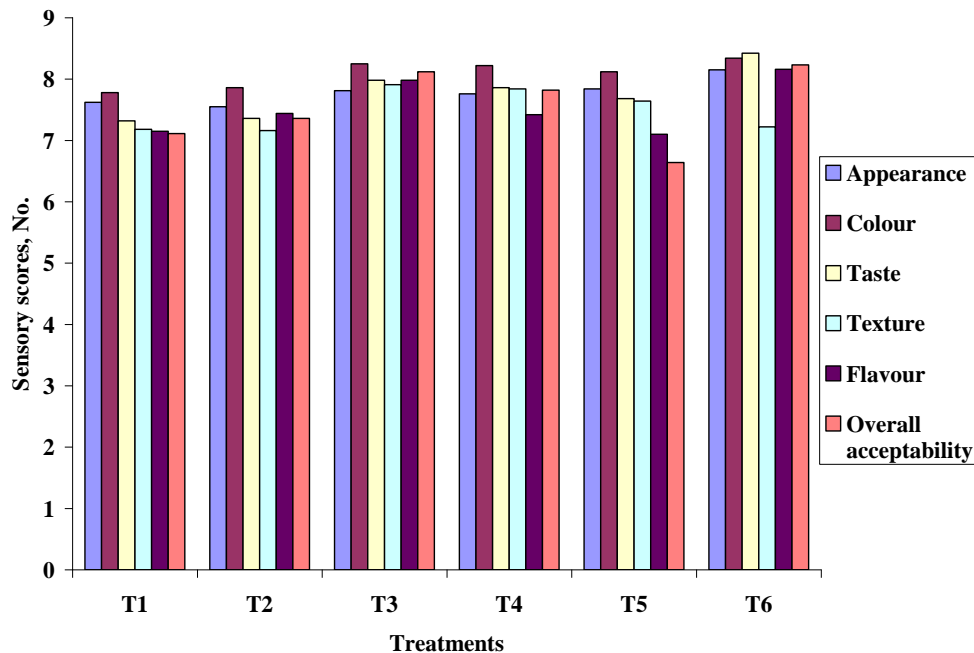
Similar results on colour analysis of sausages have been reported by Khem (2009) for sausages prepared with marine fishes of different fat contents. The findings of improvement in colour values of the sausages are in confirmation with the results reported by Panpipat and Jirawat (2008) for sausages prepared with African catfish and with tuna oil fortification.

#### **4.6.7 Sensory evaluation of sausages**

The results of the sensory evaluation of sausages carried out using 9-point hedonic scale are presented in Figure 4.26. From the Figure, it was observed that the scores obtained by sensory attributes namely appearance, colour, taste, texture and flavour ranged between 7.55 to 8.15; 7.78 to 8.34, 7.32 to 8.42, 7.18 to 8.22, 7.10 to 8.16 and 6.64 to 8.23 for T<sub>1</sub>, T<sub>2</sub>, T<sub>3</sub>, T<sub>4</sub>, T<sub>5</sub> and T<sub>6</sub>, respectively. Commercial sausage scored highest in all the attributes except in texture followed by the fish oil fortified sausages. Sausage fortified with 5 per cent fish oil (T3) scored was found to be highest for texture attribute followed by 10 (T4) and 15 (T5) per cent fortified sausages.

From the Figure, it was also observed that, sausage T6 scored highest in appearance attribute compared to fortified sausages and control. This might be due to the attractive packing and appearance of the commercial sausage. The colour scores obtained by the treatments T3, T4 and T5 found on par with each other and higher compared to T1 and T2 which might be due to the incorporation of fish oil in the recipe that provided glossiness to the product. However T6 was found to be highest (8.23) among all the treatments as the colour used in the preparation of commercial sausage might be more.

Among the sausages fortified with fish oil, T3 scored highest value of taste attribute followed by T4 and T5, whereas T1 and T2 obtained comparatively lower scores. However T6 scored highest compared to all the sausages. Texture value of T3 found highest among all the treatments, with a score of 7.98 followed by T4 and T5. Lower values observed in T1, T2 and T6. This might be due to the higher fat content in commercial sausage that might have softened the product. The flavour obtained by commercial sausage was highest (8.16) and among the fortified sausages, T3 scored highest followed by T2 and T4. T5 recorded least score of 7.10 as the higher value of fish oil might have attributed to the fishy smell in the product.



T1: Control

T2: With KI @ 150 µg/100g of sample;

T3: With KI @ 150 µg/100g of sample and Fish oil @ 5 per cent of vegetable oil

T4: With KI @ 150 µg/100g of sample and Fish oil @ 10 per cent of vegetable oil

T5: With KI @ 150 µg/100g of sample and Fish oil @ 15 per cent of vegetable oil

T6: Commercial sausage

**Fig 4.26 Effect of fortification on sensory attributes scored by sausages prepared with different treatment levels**

Considering the mean scores obtained by the sausages, T2 (8.01) was on par with the scores of commercial sausage (8.07) with added advantage of higher iodine and omega 3 fatty acids contents. The treatment T4 and T5 scored less with higher levels of fortification due to the dominance of fishy flavour in the respective sausages.

Similar results on sensory evaluation of sausages have been reported by Nowsad and Hoque (2009) for fortified sausages prepared from unwashed mince blend (UM) of low-cost marine fishes (LMF) and Lorenzo *et al.* (2011) for dry cured duck sausages. The findings are in confirmation with the results of above researchers.

#### **4.7 Economics of Preparation of Fortified Fish Sausage**

The economics of production of fortified fish sausage (100 kg) using tilapia, a low value freshwater fish based on present costs of raw materials and selling price of the product was worked out. Total cost of fortified fish sausage was found to be Rs. 10,915.00. Total returns by selling 100 kg sausages @ Rs. 25.00 each was estimated to be Rs. 25,000.00 with net profit of per batch of 100 kg sausage was Rs. 14,085.00. The B:C Ratio was observed to be 2.29.

The B:C ratio of 2.29 clearly indicated that the use of low value fish in preparation of value added product like fortified fish sausage would be profitable. Large scale production of fortified sausage would not only provide solution to utilize under-utilized fishes but also make availability of nutritious product to both rural and urban consumers. Adoption of the technology would provide additional income among Indian fisher folk and might lead to generate employment opportunity for unemployed rural as well as urban youths.

## CHAPTER V

### SUMMARY AND CONCLUSION

Aquatic food resources are vital sources of nutrients, vitamins and minerals. With the increase in population, demand for fish as a food is increasing since fish products are considered as health foods by the consumers. Efforts are being made to increase the fish production through intensive aquaculture technologies. The demand would also be partially met by using the under-utilized fish species through efficient use of the by-catch. These low value fish constitute a sizable part of the country's total fish production. Discarding of these fishes, which are rich in protein, is therefore a loss to the nation and these fishes could be utilized as cheap protein source through isolation and separation of meat and development of value added fish products such as surimi, surimi-based products, sausages and fermented products.

Manual methods of meat-bone separation are inefficient, time consuming and expensive, and hence new techniques and improvements to old methods, efficient meat recovery and introduction of novel foods are all becoming increasingly important. Among the various meat-bone separation methods *viz.*, chemical, biochemical, mechanical, thermal, ultrasonic, cryogenic, water jet etc., mechanical method of meat bone separation has been reported as efficient and economical. Many mechanical meat-bone separation techniques such as tearing, scraping, flailing with rotating chains, pressing between drum and belt, stamping type and auger type are in commercial use. Of these above mentioned methods, the belt and drum principle is by far the most effective for deboning of fish since highest meat recovery could be achieved with little preparation of the fish, other than gutting and cleaning.

Most of the commercial fish meat-bone separators are of one to ten tonne per hour capacity and expensive (Rs. 10 lakh to 200 lakh) which are not affordable to small entrepreneurs and small scale fish processors. These machines have lower efficiency (80-90 per cent) leaving behind the valuable meat (protein) with the skin and bones. However, the efficiency of this type of deboner could be achieved by proper designing of different machine components for adequate separation of meat, by selection of durable belt material to reduce damage upon friction, by providing motor power to drive both belt

and drum and by fixing the scraper blades to provide sufficient cleaning of the mass after deboning.

Keeping in view of the above facts, an economically feasible belt and drum type fish deboner of 50-75 kg per hour capacity was designed and developed for effective removal of meat from low value and under utilized fishes.

The developed fish deboner consisted of a stainless steel drum of 6 mm thickness with different sizes of perforations through which the flesh portion of the fish is squeezed inside the drum. An endless belt runs over the rollers opposite to the direction of rotation of the drum and fish pieces are pressed between the conveyor belt and the stainless steel drum. The rollers can be adjusted to tighten the conveyor belt for maximum meat recovery.

An electric motor of 1 hp provided the power which was being transmitted to the main shaft on which the perforated drum was mounted. The power from the motor was transmitted to the stainless steel drum through a cast iron flexible jaw coupling and a 30:1 speed reduction gear box by using the chain and sprocket mechanism. Cast iron spur gears changed the direction of rotation and transmitted the power from main shaft to the secondary shaft on which driving rollers of the conveyor belt are mounted. Three sprocket gears with 16, 20 and 28 teeth connected with the main shaft provided three different peripheral speeds to the perforated drum when connected with heavy duty single row roller chain.

The developed deboner also consisted of two scraper blades made up of 5 mm thick food grade HDPE sheet one to scrap the outer surface of the drum to keep the perforations clean and another inside the drum to collect the minced meat and stainless steel feeding tray and outlet chute. The components of the fish deboner were mounted on base and supporting frames made up of heavy duty mild steel channels and angles.

The operational parameters of the fish deboner namely, peripheral speed of the drum (7.22, 10.31 and 12.37 m per min.), belt hardness (35 45 and 45 Shore No.) and perforation diameter of the drum (2, 3 and 4 mm) were optimized for maximum meat recovery and minimum bone content in the minced meat. Minced meat recovered from tilapia, a low value fish was used to prepare fortified fish sausage and its quality characteristics were analysed. The results of the study are summarized and presented below.

During the optimization process, when the effect of peripheral speed of the perforated drum and belt hardness was studied, highest meat recovery of 0.742 kg per kg of dressed fish was obtained at the drum speed of  $10.31 \text{ m min}^{-1}$  and belt hardness of 55 Shore and least bone content of 4.44 mg per 100 g of minced meat was observed at  $12.37 \text{ m min}^{-1}$  drum speed and 35 Shore belt hardness.

Highest meat recovery of 0.73 kg per kg of dressed fish was obtained at drum speed of  $10.31 \text{ m min}^{-1}$  and drum perforation diameter of 4 mm and least bone content of 3.189 mg per 100 g of minced meat was obtained at  $12.37 \text{ m min}^{-1}$  peripheral speed of drum and 2 mm perforation diameter when the effect of drum peripheral speed and perforation diameter of the drum was studied.

In the study of effect of belt hardness and perforation diameter, belt hardness of 55 Shore and 4 mm perforation diameter yielded the highest meat recovery of 0.766 kg per kg of dressed fish followed by same belt hardness with 3 mm perforation diameter of the drum. Least bone content of 3.13 mg per 100 g of minced meat was recorded for belt hardness of 35 Shore and 2 mm perforation diameter.

In the interaction effect of drum peripheral speed, perforation diameter and belt hardness, the meat recovery ranged from 0.572 to 0.815 kg per kg of dressed fish and the highest (0.815 kg per kg of dressed fish) recovery obtained at drum speed of  $10.31 \text{ m min}^{-1}$  with the belt hardness of 55 Shore and perforation diameter of 4 mm.

Considering the highest meat recovery and lowest bone content in minced meat, among 27 solutions of categorical factor levels obtained by desirability test, the operational parameters namely, peripheral speed of  $10.31 \text{ m min}^{-1}$ , belt hardness of 45 Shore and perforation diameter of 3 mm were found to be the optimum levels.

When the deboner was operated at optimized process parameters *viz.*,  $10.31 \text{ m min}^{-1}$  drum peripheral speed, 45 Shore belt hardness and 3 mm perforation diameter contact area of 45 per cent of drum surface recorded maximum meat recovery of 0.79 kg per kg of dressed fish and minimum bone content of 4.30 mg per 100 g of minced meat. Higher meat yield and meat extraction efficiency were recorded at 50 to 70 kg per hour feed rate.

The performance of the developed fish deboner was evaluated in terms of meat recovery, bone content, colour of minced meat, textural and rheological properties of the minced meat recovered from three freshwater fish species namely, Tilapia (*Oreochromis mossambicus*), Rohu (*Labeo rohita*) and Mrigal (*Cirrhinus cirrhinus*).

When the deboner was operated at optimized conditions, highest meat recovery of 0.865 kg per kg of dressed fish and minimum bone content of 2.82 mg per 100 g of minced meat were recorded for Rohu followed by Mrigal and Tilapia. The colour of Mrigal was whiter with higher  $L^*$  value of 62.381, Rohu as reddish with higher  $a^*$  value of 2.15 and Tilapia as bluish with lower  $b^*$  value of 10.459.

Textural properties of the minced meat recovered from tilapia fish were found better with higher values of hardness (231.187 gf), cohesiveness (0.438 g.s), gumminess (100.69 g.s) and chewiness (50.05 g.s) and lowest value of adhesiveness (-8.47 g.s) compared to other two fishes. Tilapia recorded higher values of apparent viscosity and shear stress indicating the meat of higher firmness of the meat compared to Rohu and Mrigal. Power law model found best suited for the curves showing changes in apparent viscosity and shear stress induced in the meats of three fishes at selected shear rates with  $r^2$  value above 0.98 denoting non-newtonian fluids with pseudoplastic behaviour. The power law index ( $n$ ) and consistency index ( $k$ ) were found highest for tilapia (0.292 and 21.397).

Mince meat recovered from Tilapia, a low value freshwater fish was used for the development of a ready-to serve fish sausage fortified with omega-3 fatty acids and iodine through the addition of sardine fish oil (0.25, 0.50 and 0.75 g per 100 g of product) and potassium iodide (150  $\mu$ g per 100 g of product) in the sausage recipe. The proximate composition, biochemical and microbiological, fatty acid profile and quality characteristics of sausages prepared with different levels of fortification were analysed in comparison with commercial fish sausage.

Moisture, crude protein, crude fat, total minerals and total carbohydrate contents of sausages prepared with selected levels of fortification ranged from 68.93 to 68.62 per cent, 14.28 to 15.94 per cent, 7.06 to 7.63 per cent, 2.96 to 3.21 per cent and 5.10 to 5.15 per cent, respectively. However, the commercial sausage had higher fat content of 10.0 per cent and lower values of protein and minerals.

Biochemical parameters namely, total volatile base nitrogen, peroxide value, free fatty acids, iodine value, pH and water activity in sausages prepared with selected levels of fortification ranged from 6.58 to 6.89 mg N per 100 g of sample, 12.46 to 14.88 mMoles of O<sub>2</sub> per kg of fat, 2.38 to 2.82 per cent of oleic acid, 19.95 to 135.12 µg per 100 g of sausage, 6.6 to 6.8 and 8.72 to 8.98, respectively. The biochemical properties were found in the acceptable range. The commercial sausage had higher values indicating inferior in quality compared to fortified sausages.

Total plate count and aerobic spore formers in fortified sausages ranged from  $3.0 \times 10^{-3}$  to  $8.0 \times 10^{-3}$  cfu per g and 31 to 33 cfu per g, respectively. The commercial sausage showed higher values and the counts in all the treatments were within the acceptable limit.

Total poly-unsaturated fatty acids and n-6 to n-3 ratio of sausages prepared with different treatments ranged from 40.0 to 43.65 g per 100 g of sample and 11.2 to 0.81, respectively. However, commercial sausage had highest value (14.47) of n-6 to n-3 ratio indicating lower content of omega-3 fatty acids.

Sausages without fish oil fortification namely T1 (control) and T2 (with KI alone) showed higher apparent viscosity (34.35 to 39.26 Pa.s) values at the selected shear rates compared to fish oil fortified sausage treatments. However, commercial sausage showed lowest of all the treatments.

Sausage T1 (control) scored highest  $L^*$  (49.62) and  $a^*$  (29.46) values indicating relatively whiter with pink shade whereas sausage T5 (fortified with fish oil @ 0.75 g per 100 g and KI @ 150 µg per 100 g of sausage) recorded highest  $b^*$  value denoting more yellowish among all the treatments.

The sensory scores obtained by the sausages with different fortification levels ranged between 7.55 to 8.15; 7.78 to 8.34, 7.32 to 8.42, 7.18 to 8.22, 7.10 to 8.16 and 6.64 to 8.23 for attributes namely appearance, colour, taste, texture and flavour, respectively. The scores were found to be above seven for all fortified sausages indicating the product of highly acceptable quality.

The production cost of the developed fish deboner was found to be Rs. 68,845/-. The cost of operation found as Rs. 523/- per day and Rs. 65/- per hour. The cost of meat separation observed was Rs. 1.31 per kg of dressed fish. The expected returns found to be Rs. 1,250/- per day and the expected annual returns of Rs. 2,50,000/- with annual profit of Rs.1,45,360/-. Pay back period of the fish deboner was found to be 95 days of operation with benefit-cost ratio of 3.51.

The production cost of 100 kg of fortified fish sausage using tilapia, a low value fish found to be Rs. 10,915.00 with a net profit of Rs. 14,085.00. The B:C ratio was found to be 2.29 indicating a good venture for entrepreneurship.

**The following are the specific conclusions drawn from the study;**

- A portable belt and drum type fish deboner of 50-75 kg per hour capacity was designed and developed for meat separation from low value and under-utilized fish species
- The operational parameters namely drum peripheral speed of  $10.31 \text{ m min}^{-1}$ , belt hardness of 45 Shore and perforation diameter of 3 mm found optimum for maximum meat recovery and minimum bone content in minced meat
- The contact area (between perforated drum and belt) of 45 per cent and feed rate of 50 to 70 kg per hour recorded higher meat yield with minimum bone content
- Highest meat recovery of 0.865 kg per kg of dressed fish and minimum bone content of 2.82 mg per 100 g of minced meat was recorded for Rohu fish followed by Mrigal and Tilapia.
- The colour values of the meat decreased with the increase in number of passes
- Tilapia recorded higher values of apparent viscosity and shear stress indicating the meat of higher firmness compared to Rohu and Mrigal
- The production cost of the developed fish deboner was found to be Rs. 68,845/- and the cost of operation as Rs. 1.31 per kg of dressed fish. The net pay back period was 95 days of operation with benefit-cost ratio of 3.51

- Mince meat recovered from Tilapia, a low value freshwater fish was used for the development of a ready-to serve fish sausage fortified with omega-3 fatty acids and iodine through the addition of sardine fish oil and potassium iodide in the sausage recipe and the fortification improved the n-6 to n-3 ratio indicating the developed sausage would be recommended as a nutritious and healthy food product
- The production cost of 100 kg of fortified fish sausage was found to be Rs. 10,915.00 with a net profit of Rs. 14,085.00 and B:C ratio of 2.29 indicating a good venture for entrepreneurship
- Both the technologies would open the avenues for utilization of low value and under-utilized fishes as a cheap protein source thereby reducing the demand level of fish foods through supply of valuable protein to the consumers

## **SUGGESTIONS FOR FUTURE WORK**

1. Attempts may be made to improve the meat extraction efficiency of deboner with single pass of fish pieces by providing additional drums with extended belt mechanism.
2. Shelf life of mechanically deboned meat from low value marine fishes may be investigated
3. Development of functional foods using the deboned meat from under utilized marine/freshwater fishes
4. A low cost manually operated fish deboner for the use of household level may be developed for effective utilization of low value fishes

## REFERENCES

- Abdul Mateen. 2007. Effect of androgen on the sex reversal, growth and meat quality of tilapia (*Oreochromis niloticus*). M.Phil. Thesis. University of Agriculture, Faisalabad, Pakistan.
- Alford, C. and W. Salem. 1969. German Federal Republic Patent No. 1 802980.
- Amano, K. (1965). Fish sausage manufacturing. Fish as Food, Vol. 3 (edited by G. Borgstrom), New York: Academic Press. Pp. 265–279.
- Amaral, J., S. Mafra, L. Isabel, M. Soares and E.F. Sonia. 2008. Fatty acid profile of commercial Frankfurt type sausages. ICETA Report, Porto, Portugal.
- Anonymous. 2005. Minced meat. Report published by Canadian Institute of Fisheries Technology, Nova Scotia, Canada.
- Anonymous. 2011. Manual on Fishery Statistics. Ministry of Statistics and Programme Implementation, GOI. 3-37.
- Anonymous. 2012. How made imitation of crab meat. [www.howmadeimitationofcrabmeatmade.mht](http://www.howmadeimitationofcrabmeatmade.mht).
- AOAC. 1995. Official Methods of Analysis, 16th Edition, AOAC, Arlington, VA, USA.
- APHA. 1992. Microbiological Examination of Water In: Standard methods evaluation of water and wastewater 18th Edition. American Public Health Association, Washington, D.C.
- Ayyappan, S. and A.D. Diwan. 2006. Fisheries research and development in India. *Fishing Chimes*. 26(1):19-23.
- Barbetti, R.R. 1975. Fish meat picking machine. USSR Patent No. 460042.
- Beatty, S.A. and N.E. Gibbons. 1937. The measurement of spoilage in fish. *Journal of Biological Broad of Canada* 3:77-91.
- Benjamin K. Simpson. 2012. Chemical and bio-chemical aspects of colour in muscle based foods. Food Biochemistry and Food Processing. Second Edition. Pp 231-234.

- Bhandari, V.B. 1997. Chain drives. Design of Machine Elements, Tata McGraw-Hill Publishing Company, New Delhi, Ch. 14: Pp 399-402.
- Bhat, M.G. and Ramachandra Bhatta. 2006. Mechanization and technical interactions in multispecies Indian fisheries. *Marine Policy*, 30(3):237-248
- Bilek, E.M. 2009. Machine cost analysis using the traditional machine-rate method and charge-out. Proceedings of COFE Conference: Pp: 1-12
- Branscheid, W., M. Judas. and R. Horeth. 2009. The morphological detection of bone and cartilage particles in mechanically separated meat. *Meat Science*, 81: 46-50.
- Burgess, J.A. and F.W. Cabbage. 1989. Comparison of machine rate and cash flow approaches for estimating forest harvesting equipment costs. *ASAE Paper*, 89-7548, revised on 2/12/90. New Orleans.
- Butler, D.A. and D.P. Dykstra. 1981. Logging equipment replacement. A quantitative approach. *Forest Science*. 27(1):2-12
- Bykowski, P. and D. Dutkiewicz. 1996. Freshwater fish processing and equipment in small plants. FAO Fisheries Circular No. 905.
- Castro, P., J.C.P. Padrón, M.J.C. Cansino, E.S. Velázquez and R.M. De Larriva. 2006. Total volatile base nitrogen and its use to assess freshness in European sea bass stored in ice. *Food Control*. 17: 245-248.
- Chakrabarti, R. 1989. The use of selective dense media in separation of meat and preparation of an intermediate moisture product from small shrimps. *International Journal of Food Science and Technology*. 24: 211-215.
- Chakrabarti, R. 1993. Separation and prolongation of storage life of meat from small fish using dense media. *ASEAN Food Journal*. 8:105-109.
- Chakraborty Kajal, P. Vijay Gopal, D. Rekha, R. Chakraborty and K.K. Vijayan. 2009. Preparation of eicosapentaenoic acid concentrates from sardine oil by *Bacillus Circulans* lipase. *Food Chemistry*. 120: 433-442.
- Conrad, L. and W. Salem. 1971. Method and apparatus for disconnecting the component of composite food pieces, Canadian Patent No. 865 672.

- Delange, F. 1993. Requirements of iodine in humans. Iodine Deficiency in Europe, Plenum Press, New York, Pp 5-16.
- Devadasan, K. 2005. Value added fishery products and their marketing: A review. *Fishing Chimes*. 75 (11).
- Dilk, W.L. 1976. Investigation of the physical feasibility of mobile fish processing plants. Fisheries and marine service, Canada. Technical Report No. 634: Pp 2–27.
- Dingle, J.R., W.D. Aubut, D.W. Lemon and W. Robson. 1974. The measurement of bone content in minced fish flesh. Fisheries and Marine Services New Series Circular No. 44.
- Draper, J.E. 1971. Process of removing meat from bone. US Patent No. 3 570050.
- Duckworth, L.J., Pettinga, P.V. and McGowan, P.G. 1969. Method for deboning eviscerated whole fowl, US Patent No. 3471 299.
- Durst, W.P. 1999. Apparatus for deboning fish fillets, US Patent No. 5911621.
- Engelhardt, J. and R.S. Rousseau. 1974. Separating meat from bones, US Patent No. 3841 569.
- Ermakov, Y.P., E.I. Kaukhcheshvili, V.V. Ilyukhin and N.A. Sintsov. 1972. Electrostatic technique for meat separation. USSR Patent No. 356986
- Eslinger, M.J., J.E. Dicks and H.R. Nordin. 1972. Recovery of adhering meat from bones, Canadian Patent No. 899 713.
- FAO. 2002. Fisheries - The State of World Fisheries and Aquaculture, Rome.
- FAO. 2008. Fisheries - The State of World Fisheries and Aquaculture, Rome.
- FAO. 2008. Fisheries Circular. No. 905. Rome, FAO. Pp. 59-60
- Femeena, H., G. Sajjan, M. Saleena and M. Mukundan. 1997. Evaluation of Colour values of (*Leiognathus Spp.*), Mackerel (*Scomber scombrus*) and the Sardine like species. *Harvest and post harvest technology of fish*. 34(2): 15–20.
- Field, R.A. 1981. Mechanically deboned red meat. *Advances in Food Research*. 27: 23-107.

- Flick, G.J., M.A. Barua and L.G. Enriquez. 1990. Processing fin fish. In: The sea food industry. Martin, R.E. and Flick, G.J. (Eds.). Van Nostrand Reinhold. N. York, I (1): Pp 7-164.
- Folch, J., M. Lees and Sloane-Stanely. 1957. A simple method for the isolation and purification of total lipids from animal tissues. *Journal of Biological Chemistry*, 226:497–507.
- Garg, M.L., L.G. Wood, H. Singh and P.J. Moughan. 2006. Means of delivering recommended levels of long chain n-3 polyunsaturated fatty acids in human diets. *Journal of Food Science*, 71 (5):22-47.
- George, M. Hall. 2011. Fish processing – Sustainability and new opportunities. Blackwell publishing limited. Pp. 105-110.
- Ghadi, S.V., V.N. Madhavan and U.S. Kumta. 1975. Expansion in utility of trash fish for preparation of comminuted meat products. In: Proc. Symp. Fish Processing Industry in India, at Association of Food Scientists and Technologists, Mysore, Feb.13-14. p. 111.
- Ghadi, S.V., V.N. Madhavan and U.S. Kumta. 1976. Expansion in utility of trash fish for preparation of comminuted meat products. In: Proc. Symp. Fish Processing Industry in India, Mysore, Pp. 111-113.
- Giesler, S. 1956. Apparatus for separating meat from bones and method of separating bones, US Patent No. 2:734 537, 2:734 540.
- Goldstone. 1998. Deboning machine with slotted chamber, US Patent No. 5813909.
- Gopakumar, K. 1989. Minced fish based products. Recent trends in processing low cost fish, Society of Fisheries Technologists, Kochi, India, p. 89.
- Gopakumar, K., V. Muraleedharan and S.K. Bhattacharyya. 1992. Preparation of surimi from tropical fish, *Food Control*. 3(2), p. 109.
- Grabau T., G. Ulrich and M. Wolfgang. 1999. Methods for removing the bones from fish and apparatus for carrying out the method, US Patent No. 5871395.

- Gram, L., and H.H. Huss. 1996. Microbial spoilage of fish and fish products. *International Journal of Food Microbiology*, 33:121-137.
- Gunnar Knapp. 2008. Simple financial analysis for a small fish processing plant. Report published by University of Alaska, USA: Pp 2-8.
- Haldimann, M., A. Alt, A. Blanc and K. Blondeau. 2005. Iodine content of food groups. *Journal of Food Composition and Analysis*. 18: 461-471.
- Harris, P. 1958. Method of recovering the meat of poultry. US Patent No. 2: 858 222.
- Hassan Mohammad. 1996. Influence of pond fertilization with broiler droppings on growth performance and meat quality of major carps. Ph.D. Thesis. University of Agriculture, Faisalabad, Pakistan. Pp 134-136.
- Hassan, F. and S. Mathew. 1999. Distribution of collagen in muscle tissue of commercially important tropical fish. *Journal of Food Science and Technology*. 33:121-123.
- Hassan, M.A. 1996. Body weight characteristics and physical composition of some fish  
Weight Characteristics and physical Composition of Some Fish species from Lake Nubia. M.Sc. Thesis, Faculty of Animal Production, University of Khartoum.
- Helgeson, G.L., J.A. Tonjum and J.G. Lunn. 1968. Apparatus for deboning meat, US Patent No. 3402423.
- Henckel, P., V. Mogens, T. Soren and H. Svend. 2004. Assessing the quality of mechanically and manually recovered chicken meat, *LWT - Food Science and Technology*. 37(6): 593-601.
- Herrmann, H. and W. Nitzsche. 1975. Meat picking method. *Fleischwirts*. 29(3), p. 57.
- Huber, L.J. 1963. Meat products. US Patent No. 3 129455.
- Huda, N., T.L.J. Alistair, H.W. Lim and R. Nopianti. 2012. Some quality characteristics of Malaysian commercial fish sausage. *Pakistan Journal of Nutrition*. 11(8): 700-705.
- Hussain, B. 2002. Total lipids of fatty acid profile of Liver, Gonadsan Muscles, from wild and farmed *Labeo rohita*. M.Sc. Thesis, University of the Punjab, Lahore. P. 109.

- IDRC. 1985. International Development Research Centre and International Development Research Information System (IDRIS), Project Title: Fish Deboner (CIFT/Thailand)-Phase II. Project Number 861001.
- Ilyukhin, V., Y.U. Armakov and N. Sintsov. 1976. Floation techniques for meat separation. *Myasnaya Industriya*. SSSR, 4, 39.
- IS: 10763-1983. Specification for frozen minced fish meal, Bureau of Indian Standards.
- IS: 2403-1991. Specification for chain sprockets, Bureau of Indian Standards.
- Karolyi Danijel and Curic Tomislav. 2012. Total fatty acids composition of raw and ripe slavian kulen in relation to raw material used. *Acta Argiculturae Slovenica*, Supplement. 3, 231-234.
- Kaukhcheshvili, E. I., V.V. Ilyukhin and Y.P. Ermakov. 1975. *Myasnaya Industriya*. SSSR, 5, 40.
- Kaukhcheshvili, E.I., Y.P. Ermakov, V.V. Ilyukhin and N.A. Sintsov. 1972. *Myasnaya Industriya*. SSSR, 43(12), 43.
- Kaukhcheshvili, E.I., Y.P. Ermakov, W.V. Ilyukhin and N.A. Sintsov. 1976. USSR Patent No. 507 292.
- Ke, P., J.C.W. Reyier and R.G. Ackman. 1976. News Series Fisheries and Oceans 60.1m, Canada, Halifax : 60 pp
- Khurmi, R.S. and J.K. Gupta. 2005. A Textbook of Machine Design, first multicolour edition, S. Chand and Company Publication, New Delhi, India.
- Kim, M.K. 2006. Impact of temperature and pH on the survival of *Listeria monocytogenes* in Souse meat. <http://www.lib.ncsu.edu/theses/available/etd-11012006-153559/unrestricted/etd.pdf>.
- King, F. J. 1972. Characteristics, uses and limitations of comminuted fish using different species. Paper presented at 2<sup>nd</sup> technical seminar on Mechanical recovery and utilization of fish flesh, Oak Brook, I-11., Sept. 21-22.
- Lapeyre. 1963. Shrimp peeling machine. US Patent No. 3 070832.

- Lee, T.G., S.K. William, D. Solan and R. Littell. 1997. Development and evaluation of a chicken breakfast sausage manufactured with mechanically deboned chicken meat. *Poultry Science*, 76: 415-421.
- Lepetit, J. and J. Culioli. 1994. Mechanical properties of meat. *Meat Science*, 36, 203-237.
- Li, J., J. Solus, Q. Chen, Y.H. Rho and D. Darbar. 2010. Role of inflammatory and oxidative stress in atrial fibrillation. *Heart Rhythm*. 7: 438-444.
- Lindall, J. 1963. Method of removing meat from bones. US Patent No. 3 089 775.
- Lindall, R. 1963. Removing flesh by short blasting. British Patent No. 942 182.
- Linke, H. and W. Arneth. 1974. Method for producing protein from meat. *Fleischwirts*. 54(10):p.1657.
- Lorenzo, J.M., S. Temperan, R. Bermudez, L. Purrinos and D. Franco. (2011). Physicochemical and nutritional composition of dry-cured duck breast. *Poultry Science*. 90, 931-940.
- Maage, A., T. Jogeir, S.A. Mathilda, A.B. Ebenezer and L. Einar. 2008. Inclusion of marine fish in traditional meals improved iodine status of children in an iodine deficient area. *African Journal of Food Science*. 2 (1): 045-053.
- Manat Chaijan, Akkasit Jongjareonrak, Suttirug Phatcharat, Soottawat Benjakul, Saroat Rawdkuen. 2010. Chemical compositions and characteristics of farm raised giant catfish (*Pangasianodon gigas*) muscle, *LWT - Food Science and Technology* 01/2010. 43(3): 452-457
- Merrill, A.L. and B.K. Watt. 1963. Composition of foods, raw, processed and prepared. USDA Agriculture Handbook No. 8, US Print Office, Washington.
- Merrill, A.L. and B.K. Watt. 1973. Energy value of foods - Basis and derivation. USDA handbook: 74.
- Michael, A.M. and T.P. Ojha. 2003. Tractor power trains, traction devices, cost analysis, servicing, Principle of Agricultural Engineering, Vol. I. 4<sup>th</sup> Edn, Jain Brothers, New Delhi, India. 4.13, Pp: 176-179.

- Miyauchi, D. 1972. Progress report on minced fish studied at National Marine Fisheries Service. Paper presented at 2<sup>nd</sup> technical seminar on Mechanical Recovery and Utilization of Fish Flesh, Boston, Mass.
- Miyazaki D.L. 1974. Centrifugation method of meat separation. Japanese Patent No. 5 004741.
- Mohammad, S.R., A.L. Humaid and K. Stefan. 2007. Instrumental-sensory evaluation of texture for fish sausage and its storage stability. *Fisheries Science*. 73:1166–1176.
- Murphy, G. L. and B.H. Ross. 1994. Predictions from uncertain categorizations. *Cognitive Psychology*. 27: 148–193.
- Murphy, M.G., D.L. Skongberg, M.E. Carmire, M.P. Dougherty, R.C. Bayer and J.L. Briggs. 2003. Chemical composition and physical properties of extruded snacks containing crab-processing by-product. *Journal of Science for Food and Agriculture*. 83:1163-1167.
- Nakayama, A. and H. Koyama. 1988. Analysis for friction and heat transfer characteristics of power law Newtonian fluid flow past bodies of arbitrary geometrical configuration. *Warme-und Stoffubertragung*, 22, 29-37.
- Nettleton, J.A. 1995. Omega-3 Fatty acid and Health. Published by Chapman and Hall, New York. Pp: 21-30.
- Newman, P.B. 1981. The separation of meat from bone: A review of the mechanics and the problems, *Meat Science*. 5(3): 171-200.
- Nowak, P., B. Barqasho, C.J. Treutiger, H.E. Harris, K.J. Tracey, J. Anderson and A. Sonnerborg. 2006. HMGB1 activates replication of latent HIV-1 in a monocytic cell-line, but inhibits HIV-1 replication in primary macrophages. *Cytokine* 34, Pp 17–23.
- Nowsad, A.A. and M.S. Hoque. 2009. Standardization and production of fish sausage from unwashed mince blend of low-cost marine fish. *Asian Fisheries Science*. 22: 347-357.
- Oelker, P. 1972. Enzymatic method of separation of meat. *Fleischwirts*. 26(12), p. 236.

- Oliveira Filho, S. Carmen, A.T. Marco, C.B. Júlio and M.M. Elisabete. 2010. Quality of sausage elaborated using minced Nile Tilapia submitted to cold storage. *Scientia. Agricola*. 67 (2): 183-190.
- Panpipat, W. and Y. Jirawat. 2008. Stability of potassium iodide and omega-3 fatty acids in fortified freshwater fish emulsion sausage. *LWT. Food Science and Technology*. 41: 483-492.
- Paoli, S. 1965. Apparatus for removing meat from bone, US Patent No. 3256555.
- Paoli, S. 1966a. Methods of deboning, British Patent No. 1 125 161, 1 125 162.
- Paoli, S. 1966b. Method of producing boneless comminuted meat and machine for separating fragments of bones, gristle or sinew from comminuted meat, US Patent No. 3 266 542, 3 266 543.
- Paoli, S. 1976. Machine for processing bones - in cuts of meat and the like, British Patent No. 1 464642.
- Patashnik, M., G. Kudu and D. Miyauchi. 1974. Bone particle content of some minced fish muscle products, *Journal of Food Science*. 39: 588-591.
- Pearson, D. 1970. The chemical analysis of foods. Chemical publishing company. INC. Newyork, Pages: 376.
- Petchrat, V., S. Suchat, S. Ussadang and W. Somkwon. 1997. Unpublished B.S. (Production Technology) Project Report: Fish Deboner Machine, King Mongkut's Institute of Technology, North Bangkok, Thailand.
- Peter, M., Nicklason, Harold Barnett, and K.B. Jerry. 2008. A high-speed fish evisceration system for by-catch and underutilized fish stocks. *Marine Fisheries Review*, 74 (1): 7-14.
- Pfeiffer, G. 1975. Integrated method for producing meat. *Fleischwirts*. 55 (7):910.
- Prince, J.A., A.L. Wayne and L.C. Justin. 1981. Deboning methods and apparatus. US Patent No. 4303206.

- Raju, C.V., B.A. Shamasundar and K.S. Udupa. 2003. The use of nisin as a preservative in fish sausage stored at ambient ( $28 \pm 2^{\circ}\text{C}$ ) and refrigerated ( $6 \pm 2^{\circ}\text{C}$ ) temperatures. *International Journal of Food Science and Technology*. 38: 171–185.
- Reddy, S.S., P.R. Ram, T.V. Sastry and I.B. Devi. 2004. Agricultural Economics. Oxford and IBH Publication Pvt. Ltd. New Delhi, India. Ch. 41: Pp 474-479.
- Regenstein, J.M. 1986. The potential for minced fish. *Food Technology*. 40(3): 101-106.
- Robert Allou. 2012. Technology adoption and economics of small-scale fish processing in the Nzema East District of Ghana. The Case of Smoked Fish: Report. pp: 24-28.
- Robertson, W. 1962. Method of producing bone free meat. US Patent No. 3 012 519.
- Robertson, G.W. and J.H. Merritt. 1985. Research report on Small Deboner for Fish. International Development Research Centre, P.O. Box 8500, Ottawa, Canada K1G3H9. Project number: 811004, Centre file: 3-P-81-1004/2.
- Shanks, T.K. 1968. Recovery of meat from bones, Canadian Patent No. 743 694.
- Simopoulos, A.P. 1999. Essential fatty acids in health and chronic disease. *American Journal of Clinical Nutrition*. 70, S560-S569.
- Siddaiah, D., G.S.V. Reddy, C.V. Raju and T.C. Chandrasekhar. (2001). Changes in lipids, proteins and kamaboko forming ability of silver carp (*Hypophthalmichthys molitrix*) mince during frozen storage. *Food Research International*, 34, 47–53.
- Sirilak Suwanrangsi. 1987. Development of minced fish industry in Thailand. Proc. 20<sup>th</sup> Anniversary Seminar on Development of Fish Products in Southeast Asia. Oct 27-31. SEAFDEC, Singapore. Pp: 81-86.
- Sirilak Suwanrangsi. 1988. Small scale fish deboner. Report submitted to IDRC Cannada: Pp 6-49.
- Somasegaran, P. and H. Hoben. 1994. Handbook for Rhizobia: Methods in Legume-rhizobium Technology. Springer-Verlag, New York.
- Sonu, C. 2002. Surimi supply, demand, and market of Japan. Report No. N OM-TM -N M FS-S W R-039 submitted to US Dept. of Commerce: Pp 2-15.

- Steinberg, M.A. 1972. New opportunities through the use of comminuted flesh. Paper presented at the seminar on Mechanical Recovery and Utilization of Fish Flesh, Oak Brook, Ill, Sept. 21-22.
- Subhendu Datta. 2010. Value added fish products. [www. valueaddedfishproducts.mht](http://www.valueaddedfishproducts.mht).
- Suerbaum, E. 1974. Machine for recovering meat, US Patent No. 3 829931.
- Sutanuka Ghosh. 2013. Fish Production in West Bengal may cross 2k metric tones by 2015. *The Economic Times News*, 6-11-2012.
- Suvanich, V., M.L. Jahncke and D.L. Marshall. 2000. Changes in selected chemical quality characteristics of channel catfish frame mince during chill and frozen storage. *Journal of Food Science*, 65 (1): 24-29.
- Suzuki, T. 1981. Fish and krill protein: processing technology. London: Applied Science Publishing.
- Swett, J.B. 1962. Carrier tray, Canadian. Patent No. 711 884.
- Tamas, M., B. Janka, H. Csaba, R. Robert, V. Daniel, H. Peter and S. Andras. 2012. Fatty acid profile of fillet, liver and mesenteric fat in tilapia fed vegetable oil supplementation in the finishing period of fattening. *Archiv Tierzucht*. 55(2):194-205.
- Ugoala, Chakwumeka, G.I. Ndukwe and T.O. Audu. 2008. Comparison of fatty acids profile of some fresh water and marine fishes. *Internet Journal of Food Safety*. 10: 9-17.
- Uresti, R. M., N. Lo´pez-Arias, J. Gonza´lez-Cabriales, J.A. Rama´rez and M. Vazquez. 2003. Use of amidated low methoxyl pectin to produce fish restructured products. *Food Hydrocolloids*, 17(2), 171–176.
- USDA. 1975. United States Department of Agriculture, preparation of mechanical deboned meat and meat poultry inspection. Bull. No. 865. Animal and Plant Health Inspection Service USDA, Washington D.C. USA.
- Venugopal, V. 2005. Adding value through quick freezing, retortable packaging and cook-chilling. *Seafood processing*. CRC press, Chapter 8: Pp 215-257.

- Venugopal, V. and F. Shahidi. 2009. Traditional methods to process underutilized fish species for human consumption. *Food Reviews International*. 19 (1): 35-97.
- Wadsworth, R.G. 1998. Total bone removal system. US Patent No. 5830052.
- Wang, J. and D.K. Shanmugam. 2009. Cutting meat with bone using an ultrahigh pressure abrasive water jet. *Meat Science*. 81: 671-677.
- Weiss. 1970. Separation systems of frozen-thawed spermatozoa. US Patent No. 777 1921.
- Weyand, P.J. 1988. Tool and method for deboning fish. US Patent No. 4771511.
- Wijnker, J.J., G. Koop and L.J.A. Lipman. 2006. Antimicrobial properties of salt (NaCl) used for the preservation of natural casings. *Food Microbiology*. 23, 657-662.
- Wong, J., Y.C. Lau and M. Yamamoto. 1978. Mechanical Fish Deboners: Influence of Various perforation sizes on bone content and texture of minced fish flesh, *Journal of Food Science*. 43(3): 807-809.
- Wood, C.D. and D. King. 1985. Recovery and yields of minces from Silver Belly.
- Young, K.W., S.L. Neumann, A.S. McGill and A.D. Hardy. 1979. The use of dilute solution of hydrogen peroxide to whiten fish flesh, in "Advances in Fish Sciences and Technology", Eds. J.J. Connell and Staff of Torry Research Station, Fishing News Book Ltd., Farnham, Surrey England, p. 242.
- Young, L.L. 1975. Aqueous extraction of protein isolate from mechanically deboned poultry meat, *Journal of Food Science*. 40(6): 1115-1118.
- Zartman, W.A. 1962. Method of separation of meat and bone, US Patent No. 3017661.
- Ziener, O. 1974. Meat processing and separating apparatus, Canadian Patent No. 965 297.
- Zwiep, T.C., Weits, J. and Ferdinand. 1969. Deboning Methods US Patent No. 317, 2344.

## APPENDIX-I

### ANOVA of meat recovery for three factors of three levels each

Factor 1: Peripheral speed of drum (S) : Three levels S1- 7.22, S2 – 10.31 and S3 – 12.37 m min<sup>-1</sup>

Factor 2: Belt hardness (B) : Three levels B1- 35, B2 – 45 and B3 – 55 shore No.

Factor 3: Perforation diameter (P) : Three levels P1- 2, P2 – 3 and P3 – 4 mm

Replications : Three

			<b>Meat Recovery (kg/kg of dressed fish)</b>						
			R1	R2	R3	TOTAL	MEAN	REP	3
S1	B1	P1	0.508	0.515	0.514	1.537	0.512	<b>S</b>	<b>3</b>
		P2	0.570	0.576	0.565	1.711	0.570	<b>B</b>	<b>3</b>
		P3	0.584	0.581	0.582	1.747	0.582	<b>P</b>	<b>3</b>
	B2	P1	0.533	0.528	0.538	1.599	0.533	<b>TOTAL</b>	<b>81</b>
		P2	0.615	0.608	0.612	1.835	0.612		
		P3	0.640	0.648	0.655	1.943	0.648		
	B3	P1	0.582	0.588	0.575	1.745	0.582	<b>CF</b>	<b>31.755</b>
		P2	0.730	0.714	0.725	2.169	0.723	<b>S ss</b>	<b>0.139</b>
		P3	0.796	0.810	0.774	2.380	0.793	<b>B ss</b>	<b>0.215</b>
S2	B1	P1	0.5397	0.555	0.5565	1.651	0.550	<b>P ss</b>	<b>0.232</b>
		P2	0.635	0.65	0.64	1.925	0.642	<b>SXB</b>	<b>0.363</b>
		P3	0.6384	0.655	0.651	1.944	0.648	<b>INTE</b>	<b>0.009</b>
	B2	P1	0.58	0.585	0.588	1.753	0.584	<b>SXP</b>	<b>0.382</b>
		P2	0.7287	0.715	0.723	2.167	0.722	<b>INTE</b>	<b>0.011</b>
		P3	0.758	0.7413	0.7644	2.264	0.755	<b>BXP</b>	<b>0.469</b>
	B3	P1	0.626	0.631	0.635	1.892	0.631	<b>INTE</b>	<b>0.022</b>
		P2	0.7707	0.7728	0.7959	2.339	0.780	<b>SXBXP</b>	<b>0.632</b>
		P3	0.821	0.808	0.815	2.444	0.815	<b>INTE</b>	<b>0.004</b>

S3	B1	P1	0.495	0.501	0.505	1.501	0.500	<b>ESS</b>	<b>0.003</b>
		P2	0.550	0.534	0.532	1.616	0.539	<b>Total ss</b>	<b>0.635</b>
		P3	0.565	0.568	0.560	1.693	0.564		
	B2	P1	0.522	0.515	0.519	1.556	0.519		
		P2	0.575	0.570	0.568	1.713	0.571		
		P3	0.610	0.616	0.622	1.848	0.616		
	B3	P1	0.568	0.561	0.565	1.694	0.565		
		P2	0.656	0.660	0.662	1.978	0.659		
		P3	0.685	0.695	0.692	2.072	0.691		
		TOTAL	16.8815	16.9011	16.9338	50.716	16.91		
		MEAN	0.625241	0.625967	0.627178	1.878385	0.63		

SV	DF	SSQ	MSSQ	F cal	F 5%	F 1%	Sign		S.Em±	CD 1 %
<b>S</b>	2	0.139	0.070	1241.642	3.168	5.02	SIGNIFICANT	<b>S</b>	0.0014	0.0054
<b>B</b>	2	0.215	0.108	1923.993	3.168	5.02	SIGNIFICANT	<b>B</b>	0.0014	0.0054
<b>P</b>	2	0.232	0.116	2068.450	3.168	5.02	SIGNIFICANT	<b>P</b>	0.0014	0.0054
<b>S X B</b>	4	0.009	0.002	38.413	2.543	3.69	SIGNIFICANT	<b>S X B</b>	0.0025	0.0094
<b>S X P</b>	4	0.011	0.003	50.126	2.543	3.69	SIGNIFICANT	<b>S X P</b>	0.0025	0.0094
<b>B X P</b>	4	0.022	0.006	98.814	2.543	3.69	SIGNIFICANT	<b>B X P</b>	0.0025	0.0094
<b>S X B X P</b>	8	0.004	0.001	9.745	2.115	2.86	SIGNIFICANT	<b>S X B X P</b>	0.0043	0.0163
<b>Error</b>	54	0.003	0.000							
<b>Total</b>	80	0.635								

<b>CV</b>	<b>4.744563</b>
<b>t TABLE</b>	<b>2.669985</b>
<b>SD</b>	<b>0.089121</b>

**Mean tables for interaction of two factors – Meat recovery**

MEAN TABLE FOR S X B

SXB

	C1	C2	C3	TOTAL	MEAN
S1	0.56	0.60	0.70	1.85	0.62
S2	0.61	0.69	0.74	2.04	0.68
S3	0.53	0.57	0.64	1.74	0.58
TOTAL	1.70	1.85	2.08	5.64	1.88
MEAN	0.57	0.62	0.69	1.88	0.63

MEAN TABLE FOR S X T

SXP

	T1	T2	T3	TOTAL	MEAN
S1	0.54	0.64	0.67	1.85	0.62
S2	0.59	0.71	0.74	2.04	0.68
S3	0.53	0.59	0.62	1.74	0.58
TOTAL	1.66	1.94	2.04	5.64	1.88
MEAN	0.55	0.65	0.68	1.88	0.63

MEAN TABLE FOR C X T

BXP

	T1	T2	T3	TOTAL	MEAN
C1	0.52	0.58	0.60	1.70	0.57
C2	0.55	0.63	0.67	1.85	0.62
C3	0.59	0.72	0.77	2.08	0.69
TOTAL	1.66	1.94	2.04	5.64	1.88
MEAN	0.55	0.65	0.68	1.88	0.63

**Mean Table for interaction of three factors**

	B1			B2			B3			TOTAL	MEAN
	P1	P2	P3	P1	P2	P3	P1	P2	P3		
S1	1.537	1.711	1.747	1.599	1.835	1.943	1.745	2.169	2.380	16.666	1.852
S2	1.651	1.925	1.944	1.753	2.167	2.264	1.892	2.339	2.444	18.379	2.042
S3	1.501	1.616	1.693	1.556	1.713	1.848	1.694	1.978	2.072	15.671	1.741
TOTAL	4.689	5.252	5.384	4.908	5.715	6.055	5.331	6.486	6.896	50.716	5.635
MEAN	1.563	1.751	1.795	1.636	1.905	2.018	1.777	2.162	2.299	16.905	1.878

## APPENDIX-II

### ANOVA of bone content in minced meat for three factors of three levels each

Factor 1: Peripheral speed of drum (S) : Three levels S1- 7.22, S2 – 10.31 and S3 – 12.37 m min<sup>-1</sup>

Factor 2: Belt hardness (B) : Three levels B1- 35, B2 – 45 and B3 – 55 shore No.

Factor 3: Perforation diameter (P) : Three levels P1- 2, P2 – 3 and P3 – 4 mm

Replications : Three

			Bone content (mg/100 g of minced meat)							
			R1	R2	R3	TOTAL	MEAN	REP	3	
S1	B1	P1	3.6	3.45	3.45	10.500	3.500	<b>S</b>	<b>3</b>	
		P2	4.1	4	3.9	12.000	4.000	<b>B</b>	<b>3</b>	
		P3	7.35	7.4	7.25	22.000	7.333	<b>P</b>	<b>3</b>	
	B2	P1	3.6	3.9	3.9	11.400	3.800	<b>TOTAL</b>	<b>81</b>	
		P2	4.3	4.4	4.2	12.900	4.300			
		P3	8.85	8.9	8.65	26.400	8.800			
	B3	P1	4.55	4.35	4.6	13.500	4.500	<b>CF</b>	<b>2690.727</b>	
		P2	6.15	6.3	6.15	18.600	6.200	<b>S ss</b>	<b>20.427</b>	
		P3	15.1	15.5	15.3	45.900	15.300	<b>B ss</b>	<b>145.225</b>	
S2	B1	P1	3.200	3.100	3.000	9.300	3.100	<b>P ss</b>	<b>498.748</b>	
		P2	3.850	3.900	3.650	11.400	3.800	<b>SXB</b>	<b>170.526</b>	
		P3	7.200	7.300	7.100	21.600	7.200	<b>INTE</b>	<b>4.874</b>	
	B2	P1	3.500	3.400	3.900	10.800	3.600	<b>SXP</b>	<b>526.462</b>	
		P2	3.900	3.950	4.000	11.850	3.950	<b>INTE</b>	<b>7.286</b>	
		P3	6.950	6.750	6.700	20.400	6.800	<b>BXP</b>	<b>735.275</b>	
	B3	P1	3.950	4.200	4.150	12.300	4.100	<b>INTE</b>	<b>91.302</b>	
		P2	5.950	5.900	5.550	17.400	5.800	<b>SXBXP</b>	<b>773.493</b>	
		P3	12.400	12.900	13.100	38.400	12.800	<b>INTE</b>	<b>5.631</b>	

S3	B1	P1	2.800	2.600	3.000	8.400	2.800	<b>ESS</b>	<b>1.882</b>
		P2	3.450	3.550	3.500	10.500	3.500	<b>Total ss</b>	<b>775.375</b>
7.050	7.000	7.050				21.100	7.033		
3.350	3.100	3.150				9.600	3.200		
3.650	3.750	3.700				11.100	3.700		
6.250	6.300	6.450				19.000	6.333		
3.600	3.450	3.650				10.700	3.567		
4.950	5.200	5.150				15.300	5.100		
10.800	11.800	11.900				34.500	11.500		
<b>TOTAL</b>			154.4	156.35	156.1	466.850	155.62		
<b>MEAN</b>			5.718519	5.790741	5.781481	17.29074	5.76		

<b>SV</b>	<b>DF</b>	<b>SSQ</b>	<b>MSSQ</b>	<b>F cal</b>	<b>F 5%</b>	<b>F 1%</b>	<b>sign</b>	<b>S.Em±</b>	<b>CD 1 %</b>
<b>S</b>	2	20.427	10.214	293.113	3.168	5.02	SIGNIFICANT	0.0359	0.1356
<b>B</b>	2	145.225	72.612	2083.824	3.168	5.02	SIGNIFICANT	0.0359	0.1356
<b>P</b>	2	498.748	249.374	7156.529	3.168	5.02	SIGNIFICANT	0.0359	0.1356
<b>S X B</b>	4	4.874	1.219	34.970	2.543	3.69	SIGNIFICANT	0.0622	0.2349
<b>S X P</b>	4	7.286	1.822	52.274	2.543	3.69	SIGNIFICANT	0.0622	0.2349
<b>B X P</b>	4	91.302	22.826	655.048	2.543	3.69	SIGNIFICANT	0.0622	0.2349
<b>S X B X P</b>	8	5.631	0.704	20.198	2.115	2.86	SIGNIFICANT	0.1078	0.4069
<b>Error</b>	54	1.882	0.035						
<b>Total</b>	80	775.375							

<b>CV</b>	<b>18.00517</b>
<b>t TABLE</b>	<b>2.669985</b>
<b>SD</b>	<b>3.113228</b>

**Mean tables for interaction of two factors – Bone content**

MEAN TABLE FOR S X B

	C1	C2	C3	TOTAL	MEAN
S1	4.94	5.63	8.67	19.24	6.41
S2	4.70	4.78	7.57	17.05	5.68
S3	4.44	4.41	6.72	15.58	5.19
TOTAL	14.09	14.83	22.96	51.87	17.29
MEAN	4.70	4.94	7.65	17.29	5.76

MEAN TABLE FOR S X T

SXP

	T1	T2	T3	TOTAL	MEAN
S1	3.93	4.83	10.48	19.24	6.41
S2	3.60	4.52	8.93	17.05	5.68
S3	3.19	4.10	8.29	15.58	5.19
TOTAL	10.72	13.45	27.70	51.87	17.29
MEAN	3.57	4.48	9.23	17.29	5.76

MEAN TABLE FOR C X T

BXP

	T1	T2	T3	TOTAL	MEAN
C1	3.13	3.77	7.19	14.09	4.70
C2	3.53	3.98	7.31	14.83	4.94
C3	4.06	5.70	13.20	22.96	7.65
TOTAL	10.72	13.45	27.70	51.87	17.29
MEAN	3.57	4.48	9.23	17.29	5.76

**Mean table for interaction of three factors**

	B1			B2			B3			TOTAL	MEAN
	P1	P2	P3	P1	P2	P3	P1	P2	P3		
S1	10.50	12.00	22.00	11.40	12.90	26.40	13.50	18.60	45.90	173.20	19.24
S2	9.30	11.40	21.60	10.80	11.85	20.40	12.30	17.40	38.40	153.45	17.05
S3	8.40	10.50	21.10	9.60	11.10	19.00	10.70	15.30	34.50	140.20	15.58
TOTAL	28.20	33.90	64.70	31.80	35.85	65.80	36.50	51.30	118.80	466.85	51.87
MEAN	9.40	11.30	21.57	10.60	11.95	21.93	12.17	17.10	39.60	155.62	17.29

### APPENDIX-III

Results of desirability test carried out for optimization of operational parameters of developed fish deboner using factorial design (Design Expert Version 7.0 software). The following Table consists of 27 solutions of categoric factor levels for maximum meat recovery and minimum bone content in minced meat for 27 combinations of operational parameters of fish deboner.

Sl No	Combinations of operational parameters	Meat recovery	Bone content	Desirability	Remarks
1	Level 2 of A    Level 2 of B    Level 2 of C	0.722	3.95	0.792	Selected
2	Level 2 of A    Level 3 of B    Level 2 of C	0.76	5.88	0.787	
3	Level 2 of A    Level 2 of B    Level 3 of C	0.75	6.8	0.733	
4	Level 1 of A    Level 3 of B    Level 2 of C	0.72	6.22	0.708	
5	Level 2 of A    Level 1 of B    Level 2 of C	0.64	3.8	0.639	
6	Level 3 of A    Level 3 of B    Level 2 of C	0.66	5.17	0.638	
7	Level 2 of A    Level 3 of B    Level 1 of C	0.63	4.1	0.606	
8	Level 1 of A    Level 2 of B    Level 2 of C	0.61	4.3	0.557	
9	Level 2 of A    Level 1 of B    Level 3 of C	0.64	7.2	0.550	
10	Level 3 of A    Level 2 of B    Level 2 of C	0.59	4.01	0.515	
11	Level 3 of A    Level 2 of B    Level 3 of C	0.63	7.45	0.514	
12	Level 2 of A    Level 2 of B    Level 1 of C	0.58	3.6	0.503	
13	Level 1 of A    Level 2 of B    Level 3 of C	0.64	8.8	0.493	
14	Level 1 of A    Level 3 of B    Level 1 of C	0.58	4.5	0.476	
15	Level 1 of A    Level 1 of B    Level 2 of C	0.57	4	0.454	
16	Level 3 of A    Level 3 of B    Level 1 of C	0.56	3.55	0.440	
17	Level 3 of A    Level 3 of B    Level 3 of C	0.69	11.85	0.415	
18	Level 1 of A    Level 1 of B    Level 3 of C	0.58	7.33	0.412	

19	Level 2 of A	Level 1 of B	Level 1 of C	0.55	3.1	0.404	
20	Level 2 of A	Level 3 of B	Level 3 of C	0.80	13.42	0.391	
21	Level 3 of A	Level 1 of B	Level 3 of C	0.56	7.03	0.374	
22	Level 3 of A	Level 1 of B	Level 2 of C	0.53	3.5	0.353	
23	Level 1 of A	Level 2 of B	Level 1 of C	0.53	3.8	0.325	
24	Level 3 of A	Level 2 of B	Level 1 of C	0.53	3.3	0.323	
25	Level 1 of A	Level 1 of B	Level 1 of C	0.51	3.5	0.222	
26	Level 3 of A	Level 1 of B	Level 1 of C	0.50	2.8	0.127	
27	Level 1 of A	Level 3 of B	Level 3 of C	0.80	15.3	0.121	

## APPENDIX-IV

### Specifications of developed fish deboner

Overall length	: 770 mm
Overall width	: 610 mm
Overall height	: 580 mm
Drum diameter (outer)	: 164 mm
Drum diameter (inner)	: 152 mm
Drum length	: 305 mm
Drum effective length	: 150 mm
Drum perforation size ( $\phi$ )	: 3 mm
Drum thickness	: 6 mm
Belt thickness (Belt A and B)	: 20 mm
Belt length (Belt A and B)	: 1315 mm
Electric motor	: 746 Watts, Single phase
Speed reduction gearbox	: 30:1
Coupling rating	: 100
Chain rating	: 12B
Main shaft diameter	: 31.75 mm
Main shaft length	: 430 mm
Secondary shaft diameter	: 25.4 mm
Secondary shaft length	: 630 mm
Number of teeth on spur gear ( $S_1$ )	: 86
Number of teeth on spur gear ( $S_2$ )	: 56
Number of bearings used	: 4

## APPENDIX-V

### Economic analysis of developed fish deboner (as explained in Section 3.4)

#### 1. Production cost of fish deboner

Sl. No.	Material	Size	Quantity	Rates	Total (Rs.)	
1	MS C angle	76 × 64 × 6 mm	16 kg (110")	Rs. 38/kg	608.00	
2	MS angle	51 × 51 × 4 mm	30 kg (177")	Rs. 36 /kg	1080.00	
3	MS angle	38 × 38 × 4 mm	5.5 kg (52")	Rs.36 /kg	198.00	
4	MS flat	1"	1.5 kg (28")	Rs. 36/kg	54.00	
		1.5"	2.5 kg (30")	Rs. 36/kg	90.00	
		2.25"	3.2 kg (63.5")	Rs. 36/kg	115.00	
5	MS shaft	1"	7.2 kg (58")	Rs. 52/kg	390.00	
		1.25"	2.75 kg (17.5")	Rs. 53/kg	146.00	
6	Nut bolts	3/8	12 Nos.	1.25 kg	Rs. 60/kg	72.00
		½	8 Nos.			
7	Belt drum pipe	2.5 " φ	0.5 feet (6")	Rs. 36/ft	18.00	
8	Belt drum rods	6 mm φ	0.25 kg (40")	Rs. 39/kg	10.00	
9	Bush	1"	15 Nos.	1 kg	Rs. 75/kg	75.00
		1.25"	1 Nos.			
10	MS plates	12 mm thick	1 Nos.	500	500.00	
		4 mm thick	1 Nos.	250	250.00	
11	Quarter pins		3 Nos.	5	15.00	
12	Bearings	1"	2 Nos.	300	600.00	
		1.25"	2 Nos.	350	700.00	
13	Spur gears	56 teeth	1 Nos.	650	650.00	
		84 teeth	1 Nos.	800	800.00	
14	Keys	31 × 8 × 7 mm	4 Nos.	25	100.00	
15	Nylon rollers	60 mm φ	2 Nos.	280	560.00	
		80 mm φ	2 Nos.	405	810.00	
16	Coupling	100	1 Nos.	250	250.00	
17	Chain	12 B	1 Nos.	750	750.00	
18	Chain lock		2 Nos.	10	20.00	
19	Sprockets	8 teeth	1 Nos.	160	160.00	
		16 teeth	1 Nos.	220	220.00	
		20 teeth	1 Nos.	250	250.00	
		28 teeth	1 Nos.	410	410.00	
21	Electric motor	1 hp	1 Nos.	6000	6000.00	
22	Gear box	30 : 1	1 Nos.	3500	3500.00	

23	Welding rods	3 mm	1 Box	160	160.00
24	Rubber belt	1315×150×20 mm	1 Nos.	4500	4500.00
25	Paints			150	150.00
26	SS drum		1 Nos.	20000	20000.00
				<b>Total (Rs.)</b>	<b>44211.00</b>

### Calculation:

- Number of labourers used for fabrication work : Two @ Rs.150 per day
- Working hours per day : 8 h
- Number of working days : 60 days
- Cost of labour for fabrication work :  $2 \times 60 \times 150 = \text{Rs. } 18,000.00$
- Assume cost of electricity as 10 per cent of the cost of fabrication
- Cost of electricity :  $(10/100) \times 44,211 = \text{Rs. } 4,421.10$
- Assuming cost of transportation as 5 per cent of material cost
- Cost of material transportation :  $5/100 \times 44,211 = \text{Rs. } 2,210.55$

**Total production cost of the machine** = Cost of (raw material + fabrication + electricity + material transportation)

$$= 44,211.00 + 18,000.00 + 4,421.10 + 2,210.55$$

$$= \text{Rs. } 68,842.65$$

Therefore, the production cost of the machine is **Rs. 68,842.65**

### 2. Cost of operation

The parameters considered and assumptions made were listed below for computing economics of operating developed fish deboner.

- Number of working days per year - 200
- Number of working hours per day - 8 h
- Number of labours per day - 2 @ Rs.150/- per day
- Number of working hours per year - 1600 h
- Life of developed fish deboner - 5 years
- Junk value - 10% of initial investment

- vii. Insurance and Tax - 5% of initial investment
- viii. Rate of interest on fixed capital - 15% of initial investment
- ix. Housing - 1% of initial investment
- x. Repair and maintenance - 10% per annum of initial investment

Cost of production of fish deboner	= Rs. 68,842.65
Junk value of fish deboner @ 10%	= Rs. 6,884.27
Depreciation	= Rs. 15,145.38
Interest @ 15%	= Rs. 5,679.52
Insurance and Tax @ 5%	= Rs. 3,442.13
Housing @ 1%	= Rs. 688.43
Repair and maintenance @ 10%	= Rs. 6,884.27
Labour charge (2 × 200 × 150)	= Rs. 60,000.00
Electricity charge (8 × 200 @ 8/unit)	= Rs. 12,800.00

Annual fixed and operating costs were calculated using the parameters and assumption made in the above paragraph.

**i. Annual Fixed Cost:**

Annual depreciation	= Rs. 15,145.38
Annual interest	= Rs. 5,679.52
Insurance and Taxes	= Rs. 3,442.13
Housing	= Rs. 688.43

Therefore,

$$\begin{aligned} \text{Total Annual Fixed Cost} &= 15,145.38 + 5,679.52 + 3,442.13 + 688.43 \\ &= \mathbf{Rs. 24955.55 \text{ per annum}} \end{aligned}$$

**ii. Annual operating cost**

Repair and maintenance	= Rs. 6,884.27
Labour charge	= Rs. 60,000.00
Electricity charge	= Rs. 12,800.00

Therefore,

$$\text{Total Annual Operating Cost} = 6,884.27 + 60,000.00 + 12,800.00 = \mathbf{Rs.79,684.27}$$

$$\begin{aligned}
\text{iii. Total Annual Cost of Operation} &= \text{Annual Fixed Cost} + \text{Annual Operating Cost} \\
&= 24,955.55 + 79,684.27 \\
&= \text{Rs. 1,04,639.82} \\
&\approx \text{Rs. 1,046,40.00}
\end{aligned}$$

Hence,

$$\begin{aligned}
\text{Hourly cost of operation} &= \frac{\text{Total operation cost}}{\text{Number of working days per year} \times \text{Per day working hours}} \\
&= 104640 / (200 \times 8) \\
&= \text{Rs. 65.40 per hour}
\end{aligned}$$

Considering, average capacity of fish deboner as  $\approx 50$  kg of dressed fish per hour

$$\text{Expected cost of meat separation} = 65.40 / 50 = \text{Rs. 1.31 per kg}$$

### 3. Expected Returns:

Assuming,

- Effective hours of deboning as 5 hours per day and 3 hours may be reserved for preparatory time and for proper cleaning of the machine before and after working hours. and
- Deboning charges to the customers as Rs. 5.00 per kg of dressed fish.

Therefore,

$$\text{Expected returns per day} = C_{\text{hour}} \times H_{\text{effective}} \times C_{\text{deboning}}$$

Where,

- $C_{\text{hour}}$  - Capacity of the fish deboner, kg per hour
- $H_{\text{effective}}$  - No. of effective deboning hours per day
- $C_{\text{deboning}}$  - Deboning charges, Rs. per kg of dressed fish

$$\text{Expected returns per day} = 50 \times 5 \times 5 = \text{Rs. 1,250.00 per day}$$

$$\begin{aligned}
\text{Expected Annual Returns} &= \text{No. of working days per year} \times \text{Returns per day} \\
&= 200 \times 1,250 \\
&= \text{Rs. 2,50,000.00 per annum}
\end{aligned}$$

The expected annual returns of fish deboner would be **Rs. 2,50,000.00**

Now, Expected Annual Profit = Annual Returns – Annual Cost of Operation  
= 2,50,000.00 – 1,04,640.00 = 1,45,360.00

**Expected Annual Profit = Rs. 1,45,360.00 per year**

**The expected annual profit of the fish deboner would be Rs. 1,45,360.00**

#### **4. Payback period**

$$\begin{aligned}\text{Payback period} &= \frac{\text{Investment}}{\text{Net annual return}} \\ &= \frac{68842.65}{145360.00} = 0.47 \text{ years}\end{aligned}$$

$$\text{Payback period} = 0.47 \text{ year} = 94.72 \text{ days} < 100 \text{ days}$$

The payback period for the developed fish deboner would be less than 100 days.

#### **5. Net returns**

The net returns of the developed fish deboner were computed by following the procedure explained in Section 3.4.

Cost of production of fish deboner	= Rs. 68,842.65
Cost of operation of fish deboner	= Rs. 1,04,640.00
Life of fish deboner	= 5 years
Discount rate for fish deboner	= Assumed as 12 per cent (Reddy <i>et al.</i> , 2004)

It was also assumed that, there would be two per cent increase in the operational costs of the machine due to rise in the maintenance and repair cost. The estimated cost of operation and returns were calculated based on the prevailing discount rates and are given in the following Table.

**Estimation of net returns of developed fish deboner**

<b>Life (Year)</b>	<b>Estimated cost (Rs.) (A)</b>	<b>Discounted cost @ 12% (B)</b>	<b>Estimated return (Rs.) (C)</b>	<b>Discounted return @ 12% (D)</b>	<b>Net returns (Rs.) (C-A)</b>
0	68842.65	68842.65	0	0	0
1	70219.50	62695.98	250000.00	223214.29	179780.50
2	71623.89	57098.13	255000.00	227678.57	183376.11
3	73056.37	52000.08	260100.00	232232.14	187043.63
4	74517.50	47357.22	265302.00	236876.79	190784.50
5	76007.85	43128.89	270608.04	241614.32	194600.19
<b>Total (Rs.)</b>	<b>434267.76</b>	<b>331122.96</b>	<b>1301010.04</b>	<b>1161616.11</b>	<b>935584.93</b>
<b>Mean (Rs.)</b>	<b>72377.96</b>	<b>55187.16</b>	<b>216835.01</b>	<b>193602.68</b>	<b>155930.82</b>

**6. Benefit-cost (B-C) ratio**

Benefit cost ratio of the developed fish deboner was computed by considering Discounted Returns and Discounted Cost for a period of five years.

$$\text{Benefit-Cost Ratio} = \frac{\text{Discounted Returns}}{\text{Discounted Cost}} = \frac{1161616.11}{331122.96} = 3.51$$

Therefore, the benefit-cost ratio of developed fish deboner was found to be **3.51**

**5. Net present worth (NPW)**

Net Present Worth (NPW) of the developed fish deboner is the difference of discounted returns and discounted cost for a period of five years. Hence, the NPW was computed as below.

$$\begin{aligned} \text{NPW} &= \text{Discounted Returns} - \text{Discounted Cost} \\ &= 11,61,616.11 - 3,31,122.96 \\ &= 8,30,493.15 \end{aligned}$$

**The net present worth of fish deboner was Rs. 8,30,493.00**

## APPENDIX-VI

### Economics of fortified fish sausage using low value fish

The economics of production of fortified fish sausage (100 kg) using tilapia, a low value freshwater fish based on present costs of raw materials and selling price of the product were computed and the details of calculation are presented hereunder;

Production of fish sausage per batch	: 100 kg
Low value fish	: Tilapia
Dresses yield	: 80 per cent (from the results)
Meat yield from dressed fish	: 80 per cent (from the results)
Meat required for sausage @ 70 per cent	: 70 kg
Quantity of fish required	: 110 kg
Market price of Tilapia	: Rs. 40.00 per kg
Investment on purchase of fish	: Rs. 4400.00
Meat recovery charges @ Rs. 5 per kg	: Rs. 440.00 for 88 kg of fish (80 per cent of 110 kg)
Total cost of minced meat	: Rs. 4840.00

The actual cost of 100 kg of sausage was calculated by considering the recipe followed for preparation of fortified sausage in the present study and the respective unit cost of each raw material and details are given in the following Table.

Ingredients	Quantity (kg)	Rate (Rs./unit weight)	Amount (Rs.)
Minced fish meat	70.00	As calculated above	4840.00
Salt	02.50	14.00	35.00
Sugar	01.50	40.00	60.00
Poly phosphate	00.20	1000.00	200.00
Monosodium glutamate	00.20	1000.00	200.00
Potassium sorbate	00.20	1000.00	200.00
Colour solution*	00.10	1000.00	200.00
Chilli powder	00.60	140.00	84.00
Pepper powder	00.20	300.00	60.00
Coriander	00.30	200.00	60.00
Ginger paste	00.10	100.00	10.00

Garlic paste	00.10	100.00	10.00
Corn starch	10.00	60.00	600.00
Fats	05.00	100.00	500.00
Crushed ice	9.00	10.00	90.00
Fish oil	0.25	2000.00	500.00
Potassium Iodide	0.015	2000.00	30.00
<b>Total</b>	<b>100.00</b>		<b>7679.00</b>

No. of casings required @ 100 g sausage packing	: 1000 No.
Cost of casings (@ Rs. 100.00 per 100 casings)	: Rs. 1000.00
Total cost of raw materials	: Rs 8679.00
Processing cost @ 20 per cent of raw material cost	: Rs.1736.00
Packing and forwarding charges for 100 kg	: Rs.500.00
Total cost of fortified fish sausage	: Rs. 10915.00
Selling price of each sausage of 100 g	: Rs. 25.00
Total returns by selling 100 kg sausages	: Rs. 25000.00
Net Profit per batch of 100 kg sausage	: Rs. 14085.00
B:C Ratio	: 2.29

This B:C ratio of 2.29 clearly indicated that the use of low value fish in preparation of value added product like fortified fish sausage would be profitable. Large scale production of fortified sausage would not only provide solution to utilize under-utilized fishes but also make availability of nutritious product to both rural and urban consumers. Adoption of the technology would provide additional income among Indian fisher folk and might lead to generate employment opportunity for unemployed rural as well as urban youths.