Design and testing of small scale fish meat bone separator useful for fish processing

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Abstract The present study relates to the food processing machinery and, more specifically machine for producing boneless comminuted meat from raw fish fillet. This machine is of belt and drum type meat bone separator designed for small scale fish processing in a continuous mode. The basic principal involved in this machine is compression force. The electric geared motor consists of 1HP and the conveyor belt has a linear velocity of 19 to 22 m min⁻¹, which was sufficient to debone the fish effectively. During the meat bone separation trials an efficiency up to 75 % on dressed fish weight basis was observed and with a capacity to separate 70 kg h⁻¹ of meat from fish at the machine speed of 25 rpm. During the trials, it was demonstrated that there was no significant change in the proximate composition of comminuted fish meat when compared to unprocessed fish meat. This design has a greater emphasis on hygiene, provision for cleaning-in-place (CIP) and gives cost effective need and reliability for small scale industries to produce fish meat in turn used for their value added products.

Keywords Fish processing · Prototype specifications · Drum and conveyor belt type model · Fish meat bone separation

Introduction

Fish is an excellent source of animal protein with a wide range of essential nutrients which contributes significantly to food security and specified health benefits, which has resulted in increased positive consumer image for fish products. This increase in demand of fish and fish products resulted in increase of global supply at an average annual growth rate of 6.3 % from 34.6 million tonnes in 2001 to 59.9 million tonnes in 2010 (FAO 2012). If overall production is to keep pace with an expanding world population, and if capture fisheries are to remain stagnant, future growth will have to come from aquaculture.

In modern food processing, huge quantities of comminuted raw meat from fish are utilized in the manufacture of food products such as fish burgers, fish sticks, canned fish, fish sausage, vegetable mixes and fish dumplings or frozen in cardboard and foil containers for further use (Hall and Ahamed 1997; Demirezen and Uruc 2006). When the whole fish or fish fillets are considered, intramuscular bones are a major attribute of almost all species and these bones are found in the flesh approximately 1/3 of the depth below the body surface (Varadi 1995). The presence of these bones in the fish fillet makes it more difficult and awkward to eat. However, these bones specially in small fish are typically very fine and may not be easily noticed by the person eating the fish.

In the past, attempts have been made to remove these bones by various mechanisms such as manual method of meat bone separation, where as the tool is manually operated by gripping and pulling bones from a fish fillet. This method is laborious, time consuming and unhygienic (Newman 1981). Secondly the chemical method, which involves treating the meat samples by dilute acid, alkali and various enzymes. This method was proven to be effective, but with their own drawbacks such as treatment with acid or alkalis will also breakdown the proteins (Young 1975). The third method is enzyme treatment,

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which was effective, but improper inactivation leads to meat hydrolysis on storage (Whitehead et al. 1993). Fourth method is thermal meat bone separation, in this method meat sample are cooked. During this process flesh becomes easily separable from the bones and will also lead to change in textural properties of meat as described by Huebner et al. (1989).

Recent reports are present on small scale fish meat bone separator machines by Booman et al. (2010); Bhushan et al. (2013), which works on the basic principle of compression and shear force, the authors reported the quality profile of minced meat recovered was not influenced by the mechanical action of the machine. But, the drawback of this method lies on improper designing and selection of material for the machine, use of rubber belt has some drawbacks as it creates non-hygienic conditions, loses tensile strength on regular usage and the chances of belt to get damaged are more frequent. The second drawback of this lies in designing rotating perforated drum. Authors have used smaller diameter of drum which reduces the yield per pass and the pore size used was in range of 3–5 mm, at this size there is a tendency of small bones to pass through the perforation. Where, the yield and bone content of minced meat get affected.

In fish processing industries separation of meat is a critical step, as the above described methods either affected the quality of meat or improper mode of operation. In order to overcome these challenges the objective of this invention is to develop a small scale processing machine, which gives cost effective and reliable for small scale processors with acceptable quality of meat. Accordingly this work gives an idea for utilization of by-catch and underutilized fish species for production of meat for their value added fish products. As the use of meat bone separator machine for processing offers a perspective in production of minced meat for novel products which could gain customer appeal and gives commercial value for the market, accordingly the byproduct obtained from this processing can be utilized in traditional way for production of value added products such as fish protein concentrate, fish meal, fish oil, fish albumin, glue, gelatin, pearl essence, amino acids, non-physiological compounds, fish skin leather as described by Wasswa et al. (2007); Swapna et al. (2011).

Materials and methods

General

Fish samples employed for analysis of texture and further trials during testing the developed machine were procured from the local fish market. Commercial fish species commonly used for minced meat preparation include catla (*Catla Catla*), mackerel (*Rastrelliger kanagurta*), pink perch (*Nemipterus japonica*) and sardine (*Sardinella longiceps*). For the texture studies as

well as trials using the machine, the fish were dressed in butterfly style after descaling and evisceration.

Texture analysis

As the principle of Fish meat bone separator (FMBS) design is mainly based on texture of fish. The texture analysis of different fishes mentioned above was undertaken. Before the texture measurements the dressed fish were measured for their dimensions (Table 1). For estimating the force required to compress the fish in the FMBS, detailed analysis of compressive force required for different species were also evaluated. All the texture analysis was accomplished by employing the Universal Texture Measurement system (LR5K, Lloyd Instruments, United Kingdom). Briefly, samples of fish were placed on an aluminium sample holder which is in the form of a plate. During compression tests, the sample holder was kept in a fixed position relative to the cylindrical probe (35 mm diameter), this served as the basis for the compression test. The sample was then compressed at a constant rate of 50 mm min⁻¹ from a fixed distance of 12 to 13 mm based on the size of the raw material. The maximum force attained during the test was recorded as $F_{\max}$ (Hyldig and Nielsen 2001; Chen and Opara 2013).

Equipment design, fabrication and validation

Material of fabrication

Keeping in mind the fact that product is for human consumption and hence purity is of vital importance - and that the corrosion of the material used must not occur under any circumstances (nor should germs develop on the surface of the metal which gets in contact with the sample), SS 308 grade stainless steel was used in the fabrication of FMBS. Use of SS-308 was preferred due to some of its important properties like a) It does not absorb odors and flavors and does not provide breeding grounds for microbes, b) It is resistant to most of the food materials, acidic or alkaline cleaners, disinfectants and other substances used in food processes and c) It is resistant to mechanical damage. Similarly, the other main material used in FMBS was food grade nylon. Food grade nylon was chosen based on some of its well proven properties like high tenacity, self-lubricating capacity, excellent resistance to abrasion, high resistance to infestation (by insects, fungi, molds, mildew or rot), resistance to high temperature and many commonly used food chemicals.

Design and operation

A preliminary prototype was designed and built. Some design parameters were followed as described by Avalone et al. (1996); Martin (2002); Hrishikesh et al. (2012), which were reported for other equipments. The prototype drawings were

Table 1 Average compression power required for different fish species in relation to their dimensions

Sample	Dimensions of fish (m)			Max. compression load (N)	Average stress, σ_F (Nm ⁻²)	Average tension (N)		Average power (HP) P_F
	L_F	B_F	t_F			T_{1F}	T_{2F}	
Pink Perch	0.12	0.05	0.014	290	0.406×10^6	2,639	1,205	0.54
	0.12	0.05	0.014	531				
	0.14	0.05	0.014	212				
	0.14	0.05	0.014	477				
Mackerel	0.135	0.047	0.014	161	0.293×10^6	2,077	948	0.425
	0.135	0.047	0.014	437				
	0.135	0.047	0.014	369				
	0.145	0.057	0.014	225				
Sardine	0.110	0.030	0.014	133	0.159×10^6	487	223	0.11
	0.110	0.030	0.014	149				
	0.105	0.025	0.014	178				
Catla	0.14	0.055	0.026	276	0.206×10^6	2,576	A1176	0.53
	0.15	0.1	0.02	160				
	0.15	0.1	0.02	160				

N , Newton; m , meter; HP , horsepower; T_{1F} tension of belt in tight side; T_{2F} tension of belt in slack side; P , power; L , length; B , breadth; t , thickness

made using AutoCAD 2007 design and documentation software (Autodesk 2010). Fig. 1 depicts the drawing of front view as well as sectional view of FMBS. The FMBS designed in this study essentially consisted of the following components - (a) electric geared motor, mounted in the mainframe, (b) motor driven driver drum and idler roller drum, and (c) nylon belt driven by the drums and a thrust roller as an additional support to the conveyer belt. The electric geared motor connects to the driver drum (perforated drum) which drives the conveyor belt and the idler roller (driven drum) which is fixed to the mainframe by ball bearing system present in the housing of mainframe. The FMBS was provided with a hopper chamber for feeding the samples and a waste discharge chute. A scraper blade along with scraper rod embedded was also provided in the mainframe to scrape the waste from the outer surface of perforated drum. In addition, the idler roller was provided with the adjustment assembly for increasing/decreasing the tension of conveyor belt, this is achieved by rotating the wing nut clockwise or anticlockwise.

Selection of electric geared motor for the FMBS

The motor is a main component of the FMBS and it provides the necessary rotary motion for the equipment. The selection of electric motor was based on the basic parameters power, speed of rotation and output torque. These parameters were calculated using the following formulae -

$$P_T = P_F + P_M + P_L \quad (1)$$

where, P_T is the total power required for the machine, P_F is the power required to compress the fish, P_M is the power

requirement of the FMBS and P_L is the power to overcome gear loss. The different parameters to calculate P_T are computed using Eq. 2 through to 5.

Power required for compressing the fish (P_F) and power required for the FMBS operation (P_M) were estimated (Lingaiah 2003; Kurmi and Gupta 2005) as -

$$P_F = (T_{1F} - T_{2F}) \times v \quad (2)$$

where the tension required on the tight side (T_{1F}) and on the slack side (T_{2F}) to compress the fish are used in conjunction with the velocity of the belt (v). Similarly, the same parameters for the belt are used to calculate the power requirement of operation of FMBS (P_M) and is represented as Eq. 3 below -

$$P_M = (T_{1M} - T_{2M}) \times v \quad (3)$$

Further, belt tension to compress the fish (T_{1F}) is computed using the maximum stress required to compress the fish (σ_F), length (L_F) and breadth (B_F) of fish along with velocity of the belt (v) as shown in Eq. 4a below -

$$T_{1F} = \sigma_F \times B_F \times L_F \quad (4a)$$

Similarly, belt tension during operation of FMBS (T_{1M}) is calculated using Eq. 4b below where σ_b is the shear strength of the belt while B_b and t_b are breadth and thickness of belt respectively.

$$T_{1M} = \sigma_b \times B_b \times t_b \quad (4b)$$

Finally, the power required to overcome gear box loss during operation of FMBS (P_L) was calculated

Fig. 1 Detailed drawing of fish meat bone separator machine assembly showing various parts **a** motor, **b** perforated drum, **c** tie rod, **d** end plate, **e** cover plate, **f** wing nut, **g** waste discharge chute, **h** front plate, **i** feed hopper, **j** ball bearing, **k** bearing housing, **l** nylon belt, **m** idler roller, **n** scraper blade, **o** thrust roller and **p** main frame

assuming a gear box loss of 30 % and taking into account Eqs 2 and 3 as -

$$P_L = (P_F + P_M) \times 0.3 \quad (5)$$

Design of drums

The FMBS consists of one perforated drum (Fig. 2a) and an idler roller drum (Fig. 2b). The perforated drum is of primary importance in the deboning assembly. This drum is directly driven by the electric geared motor and carries the rotary motion and drives both the flat belt and the idler roller. As shown in Fig. 2a the outer diameter of the perforated drum is 0.212 m and the inner diameter is 0.200 m, thus providing an effective drum thickness 12 mm which was assumed to be sufficient to transfer rotary motion and accordingly bare the pressure generated during the operation. Similarly, the idler roller drum, which is connected to mainframe (Fig. 2b) by ball bearing at its end with the shaft mounted within it, has the outer and inner diameters similar to that of perforated drum i.e., 0.212 and 0.200 m to provide balanced support for perforated drum and the conveyor system. The center point distance between the two roller drums is 0.5 m and this distance is adjustable as the idler roller was provided with a provision of movement by adjusting the wing nut (Fig. 1). This increase/decrease in distance between the two rollers will increase/decrease the tension on the belt to achieve the desired compression and shear force.

Determination of perforated drum parameters

The number of perforations and the maximum deflection & bending are the two basic parameters related to perforated

drum. The number of perforations required, which was calculated by using dimension of fish and by determining the diameter of perforations. The diameter of the perforation was considered as 2.5×10^{-3} m (Fig. 2c). The number of perforations (n) assuming the diameter of each perforation to be 2.5×10^{-3} m was determined using the following equation -

$$n = V_F / V_P \quad (6)$$

where V_F is the volume of fish and V_P is volume of single perforation in meter. The number of perforations were calculated by considering Eqs. 7 and 8 below followed by equating Eqs. 7 and 9 -

$$V_F = L_F \times B_F \times t_F \quad (7)$$

where L_F , B_F and t_F represent length, breadth and thickness of fish in meters, respectively. Similarly, volume of single perforation in cubic meter (V_P) is computed taking into account the diameter of perforation in meter (d_1), the thickness of drum material (i.e., 0.006 m) as follows -

$$V_P = (\pi/4) \times d_1^2 \times 0.006 \quad (8)$$

However, sum of volumes of all the perforations (V_{TP}) can be computed by Eq. 9 as -

$$V_{TP} = (\pi/4) \times d_1^2 \times 0.006 \times n \quad (9)$$

As mentioned earlier, equating Eqs. 7 and 9 will give the number of perforations (n). Likewise the maximum bending movement and deflection acting on the perforated drum was also calculated using the formulae as described in the published works (Mahadevan and Balaveera 2007; Bhandari

Fig. 2 Drawing and dimensions of (a) perforated drum (b) idler drum roller and (c) perforations

2007). The maximum bending movement (M_{Max} ; Nm) and maximum deflection (y ; m) were determined using the formulae below -

$$M_{\text{Max}} = (F_B * L_D)/4 \quad (10)$$

$$y = FL_S^3/48EI \quad (11)$$

where F_B is the maximum belt tension in Newtons acting on the drum and L_D is the length of drum in meters. The modulus of elasticity for stainless steel in Nm^{-2} (E), moment of inertia of drum shaft (I ; m^4) and L_D are used for computing maximum deflection (y).

Design of flat belt

Another major attribute in FMBS is the belt material and design of the belt. Nylon material was selected based on its supportive properties as discussed previously. The belt was designed based on following parameters - (a) center point distance between the two drum rollers, (b) curvature and diameter of both the drums. The following facts were also considered while designing the belt viz., (a) width should be sufficient to provide space for conveyor system (b) sufficient length so that space between the two drums (0.5 m) should be sufficient for feeding fish sample in the machine and dispose of wastes.

Performance parameters of FMBS

Processing yield

The whole weight, headed and gutted weights of fish was recorded, and the percentage weight loss due to heading and gutting was calculated. The minced fish meat weight obtained

per batch during trials was recorded. Yield of the machine was calculated on dressed fish weight basis (Y_d) and on whole fish weight basis (Y_w) using following formula

$$Y_d(\%, w/w) = \times 100 \quad (12)$$

$$Y_w(\%, w/w) = \times 100 \quad (13)$$

Production rate/capacity

FMBS performance was evaluated by conducting time motion studies to determine production rates for each trial. The total cycle time was determined by calculating the sum of time when the material is passing once or twice, depending on the material, plus the time used for machine cleaning. All the tests were carried out using dressed fish.

Proximate composition and bone contents of minced meat

Proximate composition was estimated as per AOAC (2000). A portion of known amount of minced meat sample was collected for finding out the moisture, fat, protein, ash content. The moisture was determined by drying the meat at 105 °C for 5–6 h to constant weight. The fat was estimated by extraction in chloroform: methanol for a period of 10–12 h or more. Nitrogen was estimated by micro-kjeldhal nitrogen estimation method and the nitrogen value was multiplied by the factor 6.25 for protein value. The ash content was estimated by igniting and subjected to muffle furnace at 550°C for 12 h.

The content of bone fragments in minced meat was determined by two methods viz., chemical method (Yamamoto and Wong 1974) and gravity flotation method (Patashnik et al. 1974; Bhushan et al. 2013). In case of the chemical method,

100 g of minced meat from deboner was added to 2,000 ml of 3 M urea containing 0.02 M NaOH. The suspension was stirred overnight at 36 °C, using a magnetic stirrer and a hot plate. Afterwards, the bones were recovered by pouring off the basic urea solution. Likewise, in case of floatation method, a sample weighing 100 g was kept in the blender jar, and filled with cold water (5 °C). The processor was run at a lower speed for about 5 min for proper mixing, and then the blender jar was kept under the running tap water at the flow rate of approximately 4.5 L min^{-1} until the water was essentially free of floating fish muscle fibers. Some of the remaining aggregates of flesh at the bottom were removed manually to make the process of separation of bone from cartilage. After this, the bone sediment at the bottom of the jar was transferred to a petri dish for quantitative estimation after the surface drying of the bones. The residue was separated, and the total weight of the bones was weighed using digital balance.

Economic analysis of fabricating FMBS

Average cost of production of FMBS was calculated assuming a production rate of 25 machines per year. The cost of major variables (Capital and recurring) involved in fabricating the FMBS considered included raw materials (stainless steel SS-308 at Rs 250 per Kg), rent for the premises, salary for staff and cost of utilizing electricity, water, gas etc.,—apart from the applicable statutory taxes. All these were also used for determining the break even capacity of such fabrication unit and pay back period.

Results and discussion

The aim of designing and fabricating FMBS in this study was to provide a very compactly arranged group of components that complement each other to satisfy all of the requirements necessary to achieve high yield separation of fish meat from bones. The major principle followed was compression of fish flesh against perforated drum so that the fish bones, scales and skin are forced to lay flat over the perforated surface and not enter the minced flesh. This allows for the extrusion of meat through the holes, a perforated drum along with means for providing cyclic pressing and shearing action on the product and process against it. A schematic representation of the process with which the FMBS separates fish meat from bones and possible application of minced meat is presented in Fig. 3.

Texture profile, compression test & power consumption analysis

Results of the texture profile analysis of the species used in the development of FMBS are shown in Table 1. Average

Fig. 3 Schematic representation of fish processing for value added products

compressive stress from these experiments was considered for further studies. Sardine with $0.159 \times 10^6 \text{ Nm}^{-2}$ showed least power required for compression while mackerel and pink perch recorded 0.293×10^6 and $0.406 \times 10^6 \text{ Nm}^{-2}$, respectively. From this data of texture studies, the average power required to compressing different fishes in relation to their dimension was also computed (Table 1).

The compressing force as observed in the texture analysis was used to calculate the tension and power required to compress the fish samples. The compression force recorded was in the range of 133 to 531 N, corresponding average stress was in the range of 0.159×10^6 to $0.406 \times 10^6 \text{ Nm}^{-2}$ and the average power required to compress the fish sample was in range 0.11 to 0.54 horse power (HP). Accordingly, the average maximum power 0.45 HP was found to be necessary for compressing the whole fish sample to separate meat from non-edible parts (bones, skin and fins) and this was used for further theoretical calculations. The data obtained for compression force, tension and average power related each fish species is given in Table 1.

In addition to the above, the total power required for the FMBS which is to be generated by an electric geared motor was calculated by the sum of power required to compress the fish (0.45 HP), power of the FMBS (0.35 HP; calculated by considering the maximum motor speed 25 rpm, diameter 216 mm, belt thickness 0.005 m and breadth 0.165 m) and power required to overcome the gear loss (0.2325 HP; assuming gear box loss of 30 %). This theoretical calculation resulted in the total power requirement of motor at 1.0075 HP, which was rounded off to 1 HP. Based on these calculations, an electric geared motor of following specification - flange mounted two stage geared motor, power 1 HP (75 kW), speed

25–30 rpm, output torque of 174.62 Nm, electric supply of 440 V AC and frequency 50 Hz was selected for the proposed design of FMBS.

Deboning assembly and design of FMBS

The deboning assembly includes perforated drum, idler roller drum and the conveyor belt. The dimensions and design used for both the roller drums was effective for better separation of meat and for the continuous processing of the raw material. The perforation size of 2.5 mm and 3,379 numbers of perforation (holes) was sufficient to force the meat from full piece of fillet at a time to pass through and restrict non edible parts on the surface of the drum. The perforated drum used in this machine has a maximum bending moment of 83.71 Nm and maximum deflection of 1.147×10^{-7} m, this signifies that the deflection in the drum are very small and the drum designed is safe for using more amount load or tension by considering it as safe.

The idler roller was designed to provide proper equilibrium and support to perforated drum and flat belt, which is important for convenience in feeding of fish samples and continuous operation of the machine without any interference. The distance between two drums (0.5 m) was sufficient for providing provision for feeding of raw material as well as the disposal of non edible parts. The clearance gap between the mainframe body and perforated drum with flat belt is very minor (~0.01 mm) so that it retards the sample to pass through this gap into the machine. These facilities are designed for keeping the machine free of contamination and bad odor.

Flat belt used in this machine has a length 1,680 mm, breadth 165 mm and thickness of 3 mm. For this belt thickness, the efficiency of the machine was found to be around 50–70 %. In order to achieve a greater efficiency the belt thickness was to be increased. Although the belt dimensions used in our study gave a greater yield and stability. Center of gravity was determined to maintain stability and perfect balance of all the elements related to gravitational force.

Design provisions

The machine was provided with few provisions by considering the required facilities for smooth and continuous operation.

- Speed regulation of the FMBS. The rotation can be regulated by two ways, the first is gear wheel mechanism and secondly by knob regulation which is connected to the power controller of the motor.
- Conveyor belt tension adjustment. The wing nuts provided to the idler roller, by which in rotation increases or decreases the distance between the two roller drums. Simultaneously, increasing or decreasing the tension on

belt relatively. This can be adjusted depending on the sample volume.

- The provision is provided for feeding dressed fish sample (feed hopper), a conveyor system for transport of fish fillets to the perforated drum and the waste is discarded through discharge chute. Accordingly, scraper blade is provided for scraping the waste from outer surface of perforated drum and let it into waste discharge chute for free flow of raw sample without any blockage.
- Cleaning and maintenance of the equipment, as the deboning assembly is located to the outer side of machine mainframe and it facilitates for cleaning and flushing water without making any damage to the machine. The FMBS designed so as it is easy to dismantle and assembly, facilitate in quick and easy for cleaning, maintenance and parts replacement.

Performance evaluation of the fabricated FMBS

Capacity & yield

Capacity and yield are the two major parameters of determining the efficiency of the FMBS. The capacity and yield are again dependent on other factors like output speed of perforated drum, the tension generated on belt and fish species. The capacity of the machine was determined at fixed speed 25 rpm of perforated drum and the fish species used are pink perch and mackerel, which were dressed and cleaned prior to the test. As the speed of perforated drum 25 rpm was selected as it showed a maximum yield, and similar comparative studies conducted by Bhushan et al. (2013) for the meat bone separation machine at different speeds 14, 20 and 24 rpm and reported the capacity was highest at 24 rpm speed. The capacity was determined by the amount of meat separated related to time, in an average for mackerel 50.76 kg h^{-1} and pink perch 69.09 kg h^{-1} of meat was separated on a continuous basis. Capacity may also be affected by the time taken to pass the raw material in the machine and it may increase or decrease accordingly.

Yield was determined by meat recovered at the end of each batch. Yield was calculated for dressed fish weight basis and as well as for whole fish weight basis including the head, fins, scales and gut. Yield was mainly dependent on the fish species used and by keeping the other parameters speed of perforated drum and tension of flat belt as constant. Yield for dressed mackerel fish was 59.4 % and for whole fish weight basis was 36.38 %, similarly for dressed pink perch fish yield was 73.49 % and for whole fish weight basis yield was 40.66 %. The results obtained were significant on an average the yield of dressed fish was 55–75 % and similarly 35–50 % of yield showed for whole fish weight basis. The details of yield for both fish species are detailed in Table 2. This data obtained

Table 2 Efficiency of meat-bone separation by the Fish Meat Bone Separator in relation to dressed and whole fish weights

Fish Sample	Capacity (kg h ⁻¹) at 25 rpm	Y _d (%)	Y _w (%)
Mackerel	50.76±0.57	59.95±0.76	36.98±0.20
Pink Perch	69.09±0.82	74.39±1.27	40.98±0.44

Y_d, Yield percentage based on dressed fish; Y_w, Yield percentage based on whole fish

was related to time motion studies and the samples were passed only one time in the machine, waste was separated and this waste was not passed again for the second time for recovery of meat.

Proximate composition and bone content of the minced meat obtained

Bone content is another major performance parameter which gives quality assurance to the meat. In our study bone content is determined by two methods a chemical method and gravity floatation method, Table 3 summarizes the mean weight and standard deviation of the bone fragments recovered from minced meat of pink perch and mackerel. A chemical method was more effective and reliable than the gravity floatation method as it had effectively removed traces of meat attached to tiny bone particles. The average bone content was observed for pink perch was about 130±2.8 mg and mackerel 120±3.6 mg of bones for 100 g of minced meat sample, the maximum bone content of all the experiments was found to be less than the above mentioned values. The minced meat recovered was at fixed speed (25 rpm) of the machine.

The minced meat recovered from both fish species pink perch and mackerel was analyzed for proximate composition. The data obtained was appropriate as it was in the prescribed range described by Varadi (1995); Wong et al. (1978) on an average fish flesh contains 69–80 % water, 16–20 % protein, 3–12 % fat and 1.1–1.3 % ash. The moisture content of minced meat for pink perch and mackerel was 78.6±1.56 and 74.1±2.7 %. The other parameters were as protein 55±2.6 and 52.5±1.8 %, fat 39.9±1.8 and 34.9±3.1 % and

ash 4.2±0.13 and 4.7±0.15 %, which was estimated on dry weight basis. The obtained proximate data (Table 3) signifies that there was not much influence of the mechanical force exerted by the FMBS on proximate composition of fish meat.

Cost of production and economic analysis of FMBS

The average recurring and non-recurring expenses are estimated at Rs. 1,420,000 and Rs. 1,388,000 respectively. With this assumption, average cost of production of FMBS estimated to be Rs. 112,320 with a fabrication rate of 25 machines per year. If the machine is sold at Rs. 150,000 per unit, the industry fabricating FMBS would break even at around 59.6 % of its rated capacity and the payback period will be 2.25 years. The cost of producing FMBS as reported in this study is lower than the one reported by Booman et al. (2010); but, slightly higher than the cost reported by Bhushan et al. (2013).

Conclusion

The FMBS was designed and developed for small scale fish processing industries to increase the efficiency of production and solve labour-intensive problems. The prototype of this design was built and evaluated for its performance. Integration of processing variable, quantitative and qualitative parameter analysis has shown the benefit of the designed machine proposed for small scale processing operations. Process yield using dressed fish was in the range of 55–75 and 35–50 % for whole fish weight basis, with minimal loss of meat. Capacity of the FMBS was up to 70 kg h⁻¹ for meat which was recovered for first pass of sample, provided constant speed (25 rpm) of motor and tension on the conveyor belt. The increased number of passes achieved more amount of meat with change in insertion of bone in minced meat. The quality parameters resulted for bone content with very negligible content of bone on first pass ranged from 0.1 to 0.2 % based on the fish species and the data resulted in proximate composition showed no significant change in the quality profile of minced meat.

Table 3 Proximate composition* and bone content[#] of minced meat recovered from the fish deboner machine

Sample	Composition*, %				Bone content [#] , mg(100 g) ⁻¹	
	Moisture	Ash	Protein	Fat	Gravity	Chemical
Pink perch	78.6±1.5	4.2±0.8	55.0±3.5	39.9±3.9	210±4.3	130±7.2
Mackerel	74.1±1.6	4.7±1.1	52.5±4.8	34.9±4.5	170±3.2	120±5.8

*All the composition is on dry weight basis except Moisture; [#] content expressed per 100 g minced fish meat

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