A PILOT PLANT FOR FISH PROTEIN CONCENTRATE

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This communication deals with the design aspect and functions of individual pieces of equipment of a pilot plant of fifty kg. capacity for the production of fish protein concentrate (FPC) per day. Design is based on a solvent extraction process of wet pressed cake with an azeotropic mixture of hexane and ethyl alcohol. A flow sheet for the process and equipment layout have been indicated.

Introduction

One of the most pressing problems faced by the world to-day is the one of feeding millions in a manner as to keep them healthy. Protein undernourishment is more common in countries particularly of Asia and Africa and its prevention depends on increasing the consumption of protein. Among the various sources of protein, fish is perhaps the cheapest and readily available. Consumption of fish as such depends on its preservation and transportation to the consumer in a proper form. Out of the total catch, more than 60% is termed as trash fish which does not find any market as table fish. Conservation and processing of this source of protein for the manufacture of fish protein concentrate (FPC) for human consumption holds considerable promise to remove malnutrition. Addition of F. P. C. at less than 10% level to cereal, a staple food in many countries, can considerably improve the protein deficiency. The importance of this problem drew attention of several research organisations and world bodies like F. A. O. and U. S. A. I. D. As a result several processes were developed from time to time but only a few of them gained some commercial importance as summerised by Halliday and Disney.

Earlier attempts made on the production of F. P. C. were based on the extraction of fish meal by solvents. Moroccan (Sonafap) process involved the extraction of fish meal with a solvent mixture of hexane, ethyl acetate and iso-propanol, Chilean process involved the extraction of meal with 95% ethanol whereas in the Peruvian process fish meal was extracted with hexane. All these processes could produce F. P. C.

of Type B quality which was not completely free from fishy odour.

Next attempts were made on the development of suitable process for the extraction of fat and odour using wet material to produce Type A quality F.P.C. In Astra process iso-propanol was used whereas in Viobin process raw fish was first extracted with ethylene dichloride and finally extracted with iso-propanol. Halifax process of Fisheries Research Board of Canada used iso-propanol at elevated temperature for the extraction of fat from raw fish. Of all these methods, the process developed by U. S. Bureau of Commercial Fisheries (1966) gained considerable popularity. This method, a modification of Halifax process, consisted of the extraction of wet whole fish using iso-propanol to produce Type A F. P. C. This process ultimately gained commercial acceptance due to the support of F. A. O. and F. D. A. of U. S. A.

In India, Ismail, Madhavan & Pillai (1968) developed a process for the production of Type A F. P. C. from locally available fish by using an azeotropic mixture of hexane and ethyl alcohol. The process is much simpler and efficient compared to other processes described above for economic production of F. P. C. due to following reasons:

i) The process uses a non-toxic solvent mixture which is easy to recover by simple distillation and does not require any costly equipment like rectification column as in B. C. F. Process.

ii) Hexane alone is not efficient in deodourising fish muscle but is very efficient in removing fat, and alcohol alone is inefficient in removing fat but it is the most efficient solvent in removing odoriferous compounds and water from pressed cake. So, the azeotropic mixture is very effective in performing both these functions.

iii) Both these solvents are easily available and comparatively cheaper in India than iso-propanol. Moreover, both these solvents are inert to the material of construction.

Considering all these advantages, their process has been adopted for designing a pilot plant to study the economics and other technical aspects of production of F. P. C. on commercial scale.

Equipment and their functions

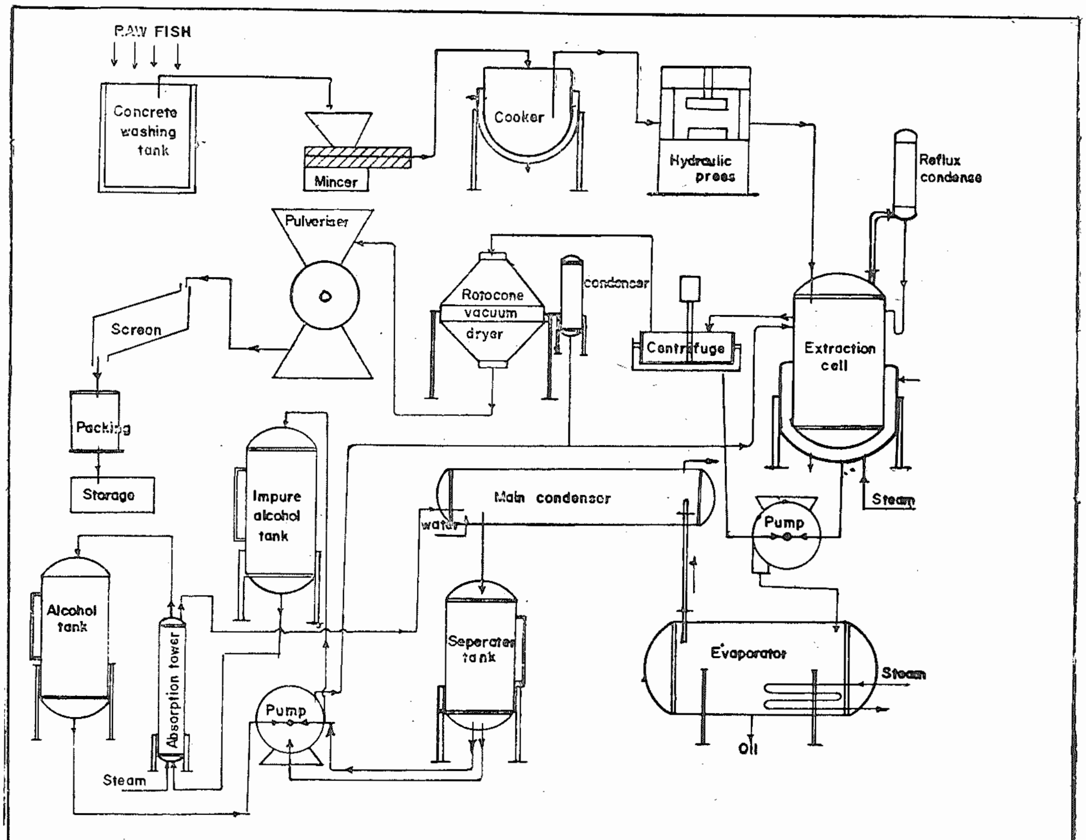
F. P. C. pilot plant comprises of the following pieces of equipment. A general arrangement of the process has been given in the flow sheet and the positions of different equipment shown in the layout.

a) Concrete washing tank:
Capacity - 300 litres.

Fish from the boat is received in this tank to remove sand, dirt and other extraneous matter using potable water. Preliminary hand sorting to remove fatty and poisonous fish is also done here. The tank is made out of concrete (1:2:4) and is provided with water inlet, false bottom and 50 mm. diameter outlet valve.

b) Meat mincer: Capacity - 100 kg./hr.

The purpose of mincing is to reduce the size of fish muscle and thereby help cooking process, mixing different sizes and types of fishes, head and tail portions, and thereby, rendering the mass homogeneous. The mincer which can reduce



FLOW SHEET FOR F.P.C PLANT

fish to 3 to 6 mm. size particles, is fitted with helical screw, reduction geared motor, reversing switch, cutter, perforated disc etc.

c) Cooker: Capacity - 100 litres.

Minced meat is taken in a hemi-spherical steam jacketed open type stainless steel kettle with tilting arrangement for cooking the mass at proper pH. The purpose of cooking is to render the mass soft and release water and fat. The vessel is fitted with steam fittings like steam joints, safety valve, pressure gauge and steam connections.

d) Hydraulic press: Capacity - 15 kg./cm^2 and 0.5 sq. m. base area.

Cooked mass is taken in a canvas bag and pressed under hydraulic press to remove substantial portion of water and fat. This amounts to a reduction in weight by 50%. The removal of water is essential as more water in cake, the less efficient is the extraction. The press has the arrangement to adjust pressure on the cake, collection of press liquor, hydraulic pump-motor set, press proper, ram, pressure gauge and basket capacity of 0.5 sq. m. × 0.5 m.

e) Extraction cell: Capacity - 450 litres

It is a stainless steel steam jacketed reaction vessel fitted with temperature controller, solenoid valve, stirring and refluxing arrangement. The vessel is fitted with anchor type agitator assembly, removable false bottom, wide charging and discharging doors, standard steam fittings on the steam jacket and dial thermometer on the vessel proper.

The function of the extraction cell is to extract oil and soluble odour bearing compounds from the press cake by a solvent mixture of hexane and ethyl alcohol at its azeotropic boiling point and the evolved solvent at the time of extraction is condensed back by reflux condenser fitted to the cell. At the end of extraction solvent is drained out from the bottom and any adhering solvent is distilled off by blowing open steam from the bottom of the cell and the evolved vapour is condensed in the reflux condenser. So, a provision is made for steam connection at the bottom of the cell. The vessel is fitted with all standard accessories, flame and explosion proof drive system and designed for 5 kg./cm^2. test pressure. In the present design, one extraction cell is used with a provision for two more in future.

f) Evaporator: Capacity-500 litres.
Heating surface: 1.5 sq.m.

Mild steel horizontal type evaporator with removable hair pin type steam coil fitted with solvent inlet and outlet connections, vapour column, pressure gauge, dial thermometer, steam fittings etc. has been designed for recovering solvent obtained from extraction cell. Solvent mixture from extraction cell is charged into the evaporator and steam is passed into the coil when solvent vapour at azeotropic composition is evolved which goes to condenser and residual oil and solid matter is removed at the bottom. As the solvent is non-corrosive, the material of construction is mild steel and the vessel has been designed for a test pressure of 5kg./cm^2.

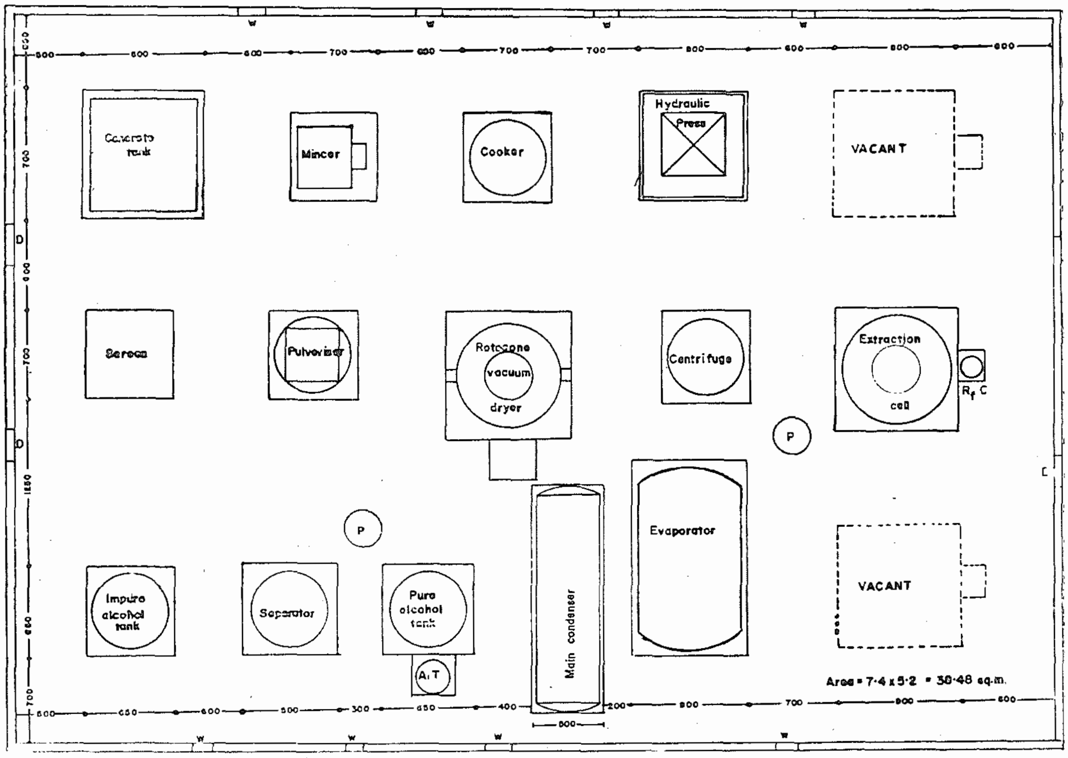
g) Main Condenser:
Cooling surface-7.0 sq.m.

This is a shell and tube type horizontal condenser with copper tube and mild steel shell designed for condensing solvent vapour evolved from evaporator by passing cooling water inside the tube. The condenser is connected to the evaporator by a 125 mm. diameter vapour column. The tube plate is fixed and tubes are fitted on 25 mm. triangular pitch. There are cooling water connections, vent cock, and vapour seal U-tube for condensate outlet.

Another condenser, called reflux condenser, is fitted to the extraction cell. This is a vertical shell and tube type condenser with copper tube and mild steel shell and cooling medium inside the tube. It has got 1.4 sq. m. cooling surface, cooling water connections, vapour pipe and vapour seal U-tube. The design pressure for shell and tube side for both the condensers is 3.5 kg./cm^2.

h) Separator tank:
Capacity: 350 litres.

This is an ordinary vertical mild steel tank fitted with level gauge to collect condensate containing two solvents and allowed to separate into two layers. The gauge glass helps in viewing the separation mark so that the bottom layer is drained out (containing alcohol) into impure alcohol tank and hexane remains in this vessel.



Layout of F. P. C. Plant

Exact quantity of hexane can also be drained to the extractor from this vessel. This cylindrical steel vessel is designed for a test pressure of 3 kg./cm^2.

i) Impure and pure alcohol tanks:
Capacity: 280 litres (each)

These are identical vessels as described above except the size and height at which they are fitted. The alcohol obtained from the separator is impure in the sense that it contains odour bearing compounds and as such cannot be used for extraction purpose without further purification. It has to be stored separately. The solvent after passing through absorption tower gets deodourised and this pure alcohol can be reused again for extraction. Pure recovered alcohol is stored in the pure alcohol tank from where it is drained to the extraction tank. Both these tanks are fitted with gauge glass, other standard fittings and designed for the pressure of 3 kg./cm^2.

j) Absorption tower:
Volume: 100 litres.

It is a tall cylindrical tower, filled with active carbon having size of 1528 mm. tall and 307 mm. diameter. The tower is built up of three packed beds of carbon which are fixed on flanges and the tower height can be altered by changing the number of beds. Carbon in each bed is supported on fixed support rings, removable perforated plates, screen and glass wool filter. There are two pipe connections at the bottom, three pipe connections at the top and the shell is designed for 3 kg./cm^2.

The impure alcohol passed from bottom of the tower gets purified (free from odour) by the process which is collected from the top in the pure alcohol tank. After few days operation the carbon gets deactivated and its power of removing odour is lost. At this stage the tower requires revivification which can be done by passing steam through the tower from the bottom. By this process of steam stripping, all solvent and odour is removed from the tower packing and the tower gets reactivated again. But after few months the tower becomes dead. In that case the old packing is removed and new packing added. Depending on the presence of the amount of odour bearing compounds, the height of the tower can be changed to get the desired purification.

k) Solvent pump: Centrifugal type of capacity 25-30 litres/minute

Two C. I. pumps fitted with flame proof motor are used for pumping impure alcohol from separator tank to pure alcohol tank via absorption tower and measured quantities of two solvents from separator and pure alcohol tank extractor. Other pump is used for pumping spent solvent-oil mixture to evaporator.

l) Basket type centrifuge: Basket size: 570mm. dia. and 280mm. height.

Heavy duty top suspended and bottom discharge centrifuge with perforated stainless steel basket lined with metallic filter cloth, and fitted with flame and explosion proof three phase motor having 6000 to 9000 r.p.m. has been used to remove adhearing liquid from the extracted mass. The solvent is taken to evaporator and solid to rotocone vacuum drier. It has got arrangement for slurry feeding and washing, and outer stationary basket for the collection of liquid.

m) Rotocone Vacuum drier:
Capacity: 25-30 kg./hr.

Double cone rotary vacuum drier fitted with variable flame and explosion proof motor is used for removing last traces of solvent from the extracted material from centrifuge. It has been observed that the traces of solvent from the F.P.C. can be removed only under vacuum and exposing new surfaces constantly by agitation. This drier is also used for mixing F. P. C. with other starchy material. The main body is of stainless steel with outer m. s. steam jacket heating arrangement. The drier is provided with charging and discharging doors, rotary pressure and vacuum joints, steam fittings, vacuum gauge, dial thermometer, condenser unit and structure, vacuum pump and other pipe connections for water and steam. The vessel is designed for 5 kg /cm^2. test pressure.

n) Pulveriser: Capacity 50 kg./hr.

A beater type pulveriser is used for powdering dry F. P. C. to 100 mesh particle size at temperature less than 60°C. The machine is complete with three phase motor, body and collector of powder.

o) Shaking seive:
Capacity: 50 kg./hr.

Two deck stainless steel continuous gyratory type shaking screen fitted with charging arrangement, motor and seive cleaning brush is used for seiving powder obtained from pulveriser to screen to 80 and 100 mesh sizes and separating the oversize for regrinding.

The dry F. P. C. so produced is packed in suitable container manually.

Discussion

This design has been prepared after thorough study of technical aspect of different processes developed so far for the production of F. P. C. of acceptable quality at minimum cost under Indian condition. The first consideration is the choice of solvent which is cheap, non-toxic and available in India and easy to recover. The azeotropic mixture of hexane and alcohol from extractor can be recovered by simple distillation which on cooling separate into two layers, thus avoiding costly rectification as required by B. C. F. process (1966). The process adopted for pilot plant (Ismail, *op. cit.)* is different from B. C. F. types of processes (i. e. extraction of raw meat) and Chilean types of procesess (i. e. extraction of fish meal). The first extraction stage is inefficient in B. C. F. process because of non-release of fat from raw meat whereas there is no special advantage of using fish meal as verified by Ismail *et al. (op. cit.)*. Moreover, cooked pressed cake extraction gives a better quality product by avoiding oxidation of fat. Extraction is more efficient than B. C. F. process and avoidance of one important step of drying makes it a cheaper process.

The most difficult technological problem in the preparation of F. P. C. is the complete removal of residual solvent apart from the removal of fat and odour. In this process hexane component efficiently removes fat upto 0.5% and water and odour is efficiently removed by alcohol. At the end, a wash with alcohol of the extracted mass can remove the residual hexane considerably and the rest is almost completely removed by steam stripping. Finally, the mass is dried under vacuum in a constantly agitated rotocone vacuum drier at steam temperature where practically no hexane can remain. So, the presence of residual solvent, if, any, may be alcohol (non-toxic) and practically zero percent hexane, the harmful effect of which has not been established so far (Halliday and Disney, *op. cit.)*. For purification of ethyl alcohol, an active carbon tower has been suggested.

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