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# System Analysis of a Prawn Freezing Plant - II. Maximisation of Raw Prawn Procurement and Resource Utilisation

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A system analysis approach has been taken to study and analyse different alternatives of raw prawn procurement and resource utilisation of a prawn freezing unit. It has been found that linear programming models can be formulated for this type of process problems and effectively solved with the help of a computer software. Results of analysis have shown that quantities of variety-wise prawn procurement can be maximised with minimum of unutilised resource.

**Key words: System analysis, freezing plant, prawn procurement, resource utilization.**

In prawn freezing industry most of the freezing units are faced with problem of running at much below the installed capacity, because of fluctuations in the supply of raw prawn. Aquaculture farm produce from coastal areas is also not sufficient at present to augment the product of a prawn freezing unit. On the other hand, when there is bumper catch in peak seasons, there may arise problems of freezing the requisite stock due to non-availability of number of freezers, labourers and lack of cold store space. Moreover there may be fluctuations in the demand of a particular frozen product by the importers. Under these conditions process analysis of prawn freezing units with respect to various operations in the process flow, and scheduling of raw prawn purchase, variety-wise and quantiy-wise, may be necessary for efficient running of prawn freezing operations and optimum resource utilization in each day. Raw prawn preparation and freezing operation have been analysed in the first part of the paper (Kannan & Bandyopadhyay, 1993).

A prawn freezing plant usually procures raw prawns from marine landing, aquaculture farm produce or from both depending on the availability. Hence three alternatives of process operations may be formulated based on:

a) only marine catch,
b) marine catch and aquaculture farm produce and
c) only aquaculture farm produce

These alternatives can be analysed with the help of linear programming model with the objective of maximisation of raw prawn procurement and optimum resource utilisation. The present paper incorporates the results of analysis based on these alternatives considered under various plans.

## Materials and Methods

A linear programme is a mathematical procedure that is applicable when the objectives and requirements can be expressed as functions that are linear. Linear programming typically deals with the

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problems of allocating limited resources in a fashion that maximises return or minimises cost.

Let us suppose that there are limited resources to be allocated between competing activities. Let $x_j$ be the level of activity j; z, the numerical value of the measure of benefit; and $c_j$, the increase in z that would result in one unit increase in $x_j$. We can formulate the general programming model for allocating i resources to n activities as

$$\text{Maximise } z = \sum_{j=1}^{n} c_j x_j \qquad \ldots (1)$$

Subject to

$$a_{ij}\, x_j \le b_i, \quad i = 1, 2, \ldots m \qquad \ldots (2)$$

$$\text{with } x_j \ge 0, \quad j = 1, 2, \ldots n \qquad \ldots (3)$$

where $b_i$ denotes the amount of resource available and $a_{ij}$ represent the amount of resource i needed for one unit of activity j.

Eq. (1) is called the objective function and Eq. (2) refers to the set of constraints. $x_j$ are the decision variables and $a_{ij}$, $b_i$ and $c_j$ are the parameters of the model (Cleland & King, 1968).

## Results and Discussion

The hypothetical prawn freezing plant (Kannan & Bandyopadhyay, 1993) on which the process analysis has been carried out processes three varieties of prawn ($P_1$, $P_2$ and $P_3$) for three types of frozen products: one headless shell-on (HL), and two peeled and undeveined ($PUD_1$ and $PUD_2$) products, respectively. It is assumed that the raw prawns for PUD products are received sometimes in quantities more than the capacities of the freezers and, therefore, frozen directly after beheading and then stored for future use. This frozen stock is processed along with fresh $P_2$ and $P_3$ when they are received in less quantities. This operation is referred to as "double processing" (DP). The values of average resources ($b_i$) and resource requirement ($a_{ij}$) are given in Table 1 and 2, respectively.

Table 1. Available resources

| Resources | Values |
|---|---|
| Freezer capacity, kg day$^{-1}$ | 5808 |
| Ice plant capacity, tonnes day$^{-1}$ | 20 |
| Cold store capacity, tonnes | 10 |
| Peelers, number | 100 |
| Cleaners, number | 25 |
| Graders, number | 30 |
| Packers, number | 20 |

Table 2. Resource requirement for different products

| Resource | $P_1$ | $P_2$ | $P_3$ | $PUD_1$ (DP) | $PUD_2$ (DP) |
|---|---|---|---|---|---|
| Ice, kg kg$^{-1}$ prawn[a] | 1.5 | 2 | 2 | 2.5 | 2.5 |
| Peeling time,[b] manhour kg$^{-1}$ prawn | 0.04 | 0.018 | 0.249 | 0.088 | 0.124 |
| Cleaning time,[b] manhour kg$^{-1}$ prawn | - | 0.035 | 0.038 | - | - |
| Grading time,[b] manhour kg$^{-1}$ prawn | 0.039 | 0.029 | 0.037 | - | - |
| Packing time,[a] manhour kg$^{-1}$ prawn | 0.016 | 0.011 | 0.011 | 0.009 | 0.009 |
| Yield,[a] kg kg$^{-1}$ prawn | 0.67 | 0.45 | 0.38 | 0.73 | 0.60 |

a Assumed from practical data
b Calculated from the respective linear relations (Kannan & Bandyopadhyay, 1993)

Quantities of raw prawn procured for the five products are the decision variables ($x_j$). The function is given by

$$z = c_1x_1+c_2x_2+c_3x_3+c_4x_4+c_5x_5 \qquad \ldots (4)$$

and the types of constraints involved are : labour hour availability, raw material availability, cold store space availability, freezer capacity, ice plant capacity and demand of the products.

In order to work out the maximum resource utilisation with the help of linear programming model, different plans were drawn within the three alternatives of resource procurement as suggested earlier.

*Procurement of only marine catch* :

Let the raw prawn available at the landing centre in a particular day be $P_1$ = 4000 kg, $P_2$ = 19000 kg, and $P_3$ = 2000 kg. Then four plans (Table 3) can be drawn on the availability of two important resources - ice and peeling hours, which can be varied according to the need.

Table 3. Available resources under different plans

| Plans | Ice, kg | Peeling hours |
|---|---|---|
| I | 20000 | 2000 |
| II | 30000 | 2000 |
| III | 25000 | 1250 |
| IV | 35000 | 2500 |

Peeling operation can be varied on hourly basis as per requirement. Ice can always be procured from the neighbouring ice plants, if the ice plant capacity is not sufficient at the freezing factory. Variety-wise procurement strategy has been worked out for the above plans through the linear programming model with the help of a computer software. The results have been shown in Figs. 1 a - c.

In plan I the freezer capacity is not fully utilised because of shortage of ice, although raw prawn is available. The result shows that we should procure $P_1$ which needs less ice and gives more yield. If $P_1$ is not available, $P_3$ which needs more peeling time should be procured. However, this has been rejected since the freezer capacity cannot be fully utilised.

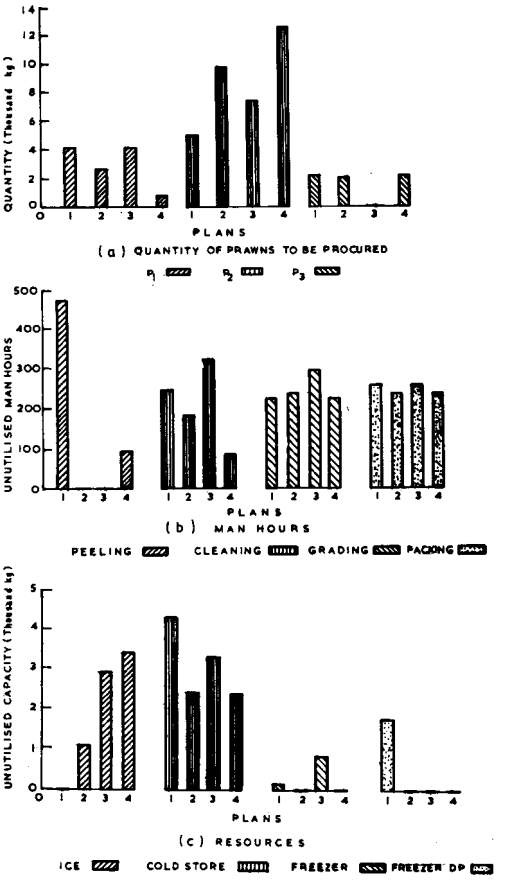


Fig. 1. Raw prawn procurement and unutilised resources when only marine prawns are procured.

Since in plan II the freezer capacity is fully utilised, $P_3$ which needs more peeling time, should be procured. If the freezer capacity were not fully utilised, the model would have indicated procurement of $P_1$ which requires less peeling hours and whose yield percentage is also more. In this plan, further increase in quantity of ice would not change the schedule of procurement, because ice is already available in excess. This plan can be accepted.

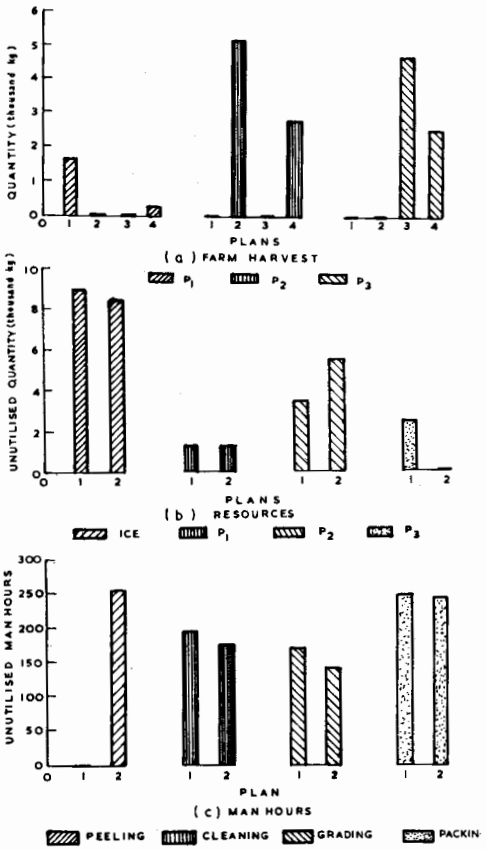


Fig. 2. Raw prawn procurement and unutilised resources when both marine and farmed prawns are procured.

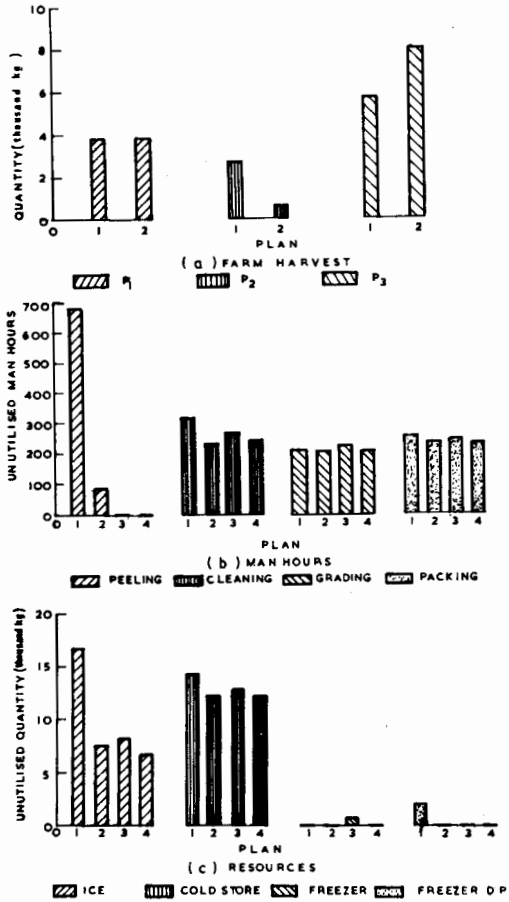


Fig. 3. Raw prawn procurement and unutilised resources when only farmed prawns are procured.

Table 4. Plans of prawn harvest

| Plan | $P_1$ | $P_2$ | $P_3$ |
|---|---|---|---|
| I | 4000 | 0 | 0 |
| II | 0 | 7000 | 0 |
| III | 0 | 0 | 7000 |
| IV | 3000 | 3500 | 2500 |

In plan III, processing of all DP products would be carried out, since here freezer capacity for regular production is not fully utilised. Further, peeling hours are not sufficient for regular production. This plan is also rejected.

In plan IV, freezer capacity is fully utilised and ice requirement and peeling hours can be reduced. This plan can be chosen as optimum plan considering maximum raw prawn purchase and resource utilisation.

*Procurement of both marine catch and farm produce* :

Assuming that the sizes of three varieties of prawn obtained from marine catch are equal to those obtained from farm produce, let in a particular day the quantities of marine catch be : $P_1$ = 4000 kg, $P_2$ = 2000 Kg and $P_3$ = 3000 kg, and the available resources are: ice 35000 kg, cold storage capacity 20000 kg, and peeling hours 2000. The other resources are the same as in the alternative 1. The freezer capacity for double processing has been assumed to be 2000 kg.

Analysis of results under the four plans, shown in Fig. 2 a - c and Table 4, indicate that out of four plans under plans I, II and IV the freezer capacity has been fully utilised. If only one variety is to be harvested, plan II is to be chosen. To harvest or purchase all three varieties, plan IV is to be chosen.

*Procurement of farm produce only* :

In this alternative, since raw prawn is to be procured from the farm only, there is no need for double processing. Only three variables for the three varieties will be considered. Ice consumption will be reduced and, therefore, has been assumed to be 1, 1.5 and 1.5 kg/kg of raw prawn, respectively. Let the available raw prawn from the farm be : $P_1$ = 5000 kg, $P_2$ = 6000 kg and $P_3$ = 8000 kg; and demand be; HL = 2500 kg and PUD = 2000 kg. Only two plans have been considered : peeling hours 2000 and 2500 with ice requirement of 25000 kg in each plan. Results are shown in Fig. 3 a - c. Since freezer capacity is fully utilised in both the plans, we can choose any plan and harvesting or procurement should be done according to the plan.

**References**

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