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Linear Programming Model for Production Planning of Cassava Crackers

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***Abstract*— Cassava crackers companies have limited availability of cassava and its availability is greatly influenced by the season. The lack of good production planning and fluctuating cracker product demand makes this company experience overproduction and also underproduction. good production planning is needed to determine the optimal amount of cassava cracker production. The objective of this study is determine the amount of cassava crackers produced in a period by developing the linear programming (LP) model. The developed LP model will maximize the total profit. The LP model has five constraints function which include raw material, man hours, machine hours, product sale and nonnegative constraint. Case studies are given for the model validation process. The results obtained indicate that the model is able to determine the optimal amount of cassava cracker production.**

***Keywords*— cassava crackers; linear programming; production planning; maximize profit**

I. Introduction

CV. X is a company that produces cassava crackers with 3 variants, namely sweet and spicy, onion and shrimp flavor. The company produces raw cassava crackers which are sold in 5 kg packages. During this time, the amount of cassava cracker production is determined by the owner of the company only based on previous requests. The make to stock system is also implemented by the company to anticipate fluctuations in demand that are varied each time. But the company still experiences a large deviation between the number of requests with the amount of production. Fluctuations in consumer demand for Cassava crackers result in companies experiencing overproduction and underproduction. This condition is exacerbated by the limitations of the main raw materials of cassava where the availability of cassava is influenced by the season.

Companies that have high efficiency and effectiveness will be able to survive in fierce and competitive market competition. Efficient and effective production can increase company productivity and profits. To achieve high company productivity, we need a good production planning. Production planning aims to allocate resources optimally. Preparation of production planning to optimize the use of resources can be done by linear programming (LP) methods.

LP model in the form of mathematical formulation is used to optimize linear objective function subject to some linear Constraints [1]. LP model is a tool used to solve constrained optimization problems [2].

The LP model has been widely applied in various fields. Model LP is used to minimize the production cost [3], LP model is used to in construction site [4], and LP technique also is used to maximize profit in food company [5]. The LP model is applied for scheduling [6,7], energy optimization [8], multiple criteria decision making problem [9], designing vehicle [10], and worker assignment problem [11].

II. RESEARCH METHODS

Development of LP model LP models begins by constructing model assumptions, model components, and model notation. The next step is to verify the model. This step aims to ensure the model is logically and mathematically consistent. then the established LP model is tested by entering the parameter data and solved by lingo software.

A. *Model Assumptions*

Some assumptions used in this LP model are as follows:

- Demand, price, and cost considered in the model are constant and known.
- There are no defective products
- The production capacity does not change.

B. *Model Components*

The component of LP model consists of index set, parameters, variable, decision variables, objective functions, and constraint functions. The following notations are used to in the LP model.

- Index Set

The index set of this model are:

i : Index of cassava crackers types, $i = 1, 2, \dots, m$
j : Index of periods, $j = 1, 2, \dots, n$

k : Index of process, $k = 1, 2, \dots, o$
l : Index of machines, $l = 1, 2, \dots, r$

- Parameters
- The parameters used in this model are:

p_{ij} : Profit of cassava crackers i in period j (rupiah/pack)

c_{ij} : The amount of cassava needed to produce crackers i in period j (kg)

CA_j : Availability of cassava in period j (kg)

t_k : Process time k (hour)

G_{kj} : Availability of man hours for process k in period j (hour)

b_l : The processing time of machine l (hour)

B_{lj} : Availability of machine hours l in period j (hour)

ls_{ij} Lowest sales of cassava crackers i in period j (pack)

hs_{ij} Highest sales of cassava crackers i in period j (pack)

- Decision Variable
The decision variable used in this model is as follows:

X_{ij} : Number of cassava crackers i produced in period j (pack)

- Objective Function

The objective function developed for this LP model is to maximize total profits. Total profits derived from product profits are multiplied by the number of crackers produced. Product profit is obtained from the selling price minus production costs. Production costs consist of raw material costs, labor costs, and overhead costs. The mathematical model of this objective function is as follow:

$Max\ Z = Total\ profits$

$$Max\ Z = \sum_{i}^{m} \sum_{j}^{j} p_{ij} X_{ij} \quad (1)$$

- Constraint Function

The constraints of LP model consist of raw material, man hours, machine hours, product sale, and nonnegative.

1. Raw material
The main raw material for producing cassava crackers is cassava. Cassava cracker production is greatly influenced by the availability of cassava. The availability of cassava itself is influenced by the season. For this reason, the amount of cassava needed to produce cassava crackers must not exceed the availability of cassava. Mathematically, the LP model for the constraints of cassava raw materials is as follows:

$$\sum_{i=1}^{m} c_{ij} X_{ij} \le CA_j, \quad \forall_j = 1, 2, \dots, n \quad (2)$$

2. Man Hours
The number of man hours needed to produce crackers in period j may not exceed the availability of human work hours in period j. There are several production processes carried out by human labor. The model equation for this constraint is as follows:

$$\sum_{i=1}^{m} t_k X_{ij} \le G_{kj}, \forall_k = 1, 2, \dots, o \quad \forall_j = 1, 2, \dots, n \quad (3)$$

3. Machine Hours
The number of machine hours needed by the machine to produce cassava crackers must not exceed the availability of the number of machines in each period. There are several types of machines for producing cassava crackers. Mathematically, the equation for machine hours constraint is as follows:

$$\sum_{i=1}^{m} b_l X_{ij} \le B_{lj}, \forall_l = 1, 2, \dots, r, \quad \forall_j = 1, 2, \dots, n \quad (4)$$

4. Product Sale
Cassava crackers production is expected to be in accordance with the sale of cassava crackers so as to minimize overproduction or under-production. Mathematically the equation for this constraint is as follows :

$$ls_{ij} \le hs_{ij}, \forall_i = 1, 2, \dots, m \quad \forall_j = 1, 2, \dots, n \quad (5)$$

5. Nonnegative
The result obtained must be positive.

$$X_{ij} \ge 0, \quad \forall i, j \quad (6)$$

III. RESULT AND DISCUSSION

CV X is a company that produces raw cassava crackers with 3 different types of flavor variants. The flavors are sweet

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spicy, onion and shrimp. Cassava crackers are packaged in the size of 5 kg (1 pack). The main raw material is cassava which is limited in number and its availability is greatly influenced by the season. The lack of good production planning and fluctuating cracker product demand makes this company experience overproduction and also underproduction. To make 1 pack of cassava crackers ready for frying (5 kg) it takes 10 kg of cassava. The company has a workforce of 20 people, divided into 4 people in the stripping, washing and grating section, 5 in the milling section, 3 in the steaming section, 5 in the forming section and 3 in the packaging section. Owned production machines are 3 units of grated machines, 3 units of grinding machines and 3 units of steam machines. The availability of cassava in the dry season is 2100 kg / week while the availability of cassava in the rainy season is 1500kg / week. Data on the profit and sale of cassava crackers per pack (5 kg) is presented in the table 1 and 2. Data on man processing time is given in the table 3. Data on machine process is given in the table 4.

TABLE I. PROFIT OF CASSAVA CRACKERS

Crackers type	Profits (IDR/pack)	Lowest sales at dry season (pack/week)
Sweet spicy	26,500	40
Onion flavor	29,000	60
shrimp flavor	31,500	40

TABLE II. SALES OF CASSAVA CRACKERS

Crackers type	Highest sales at dry season (pack/week)	Lowest sales at wet season (pack/week)	Highest sales at wetseason (pack/week)
Sweet spicy	132	80	125
Onion flavor	140	30	132
shrimp flavor	134	40	134

TABLE III. MAN PROCESS

Man Process	Time (hour/pack)	Time availability (hour/week)
Stripping	0.283	192
Washing	0.133	192
Forming	0.75	240
Packaging	0.1	144

TABLE IV. MACHINE PROCESS

Machine Process	Time (hour/pack)	Time availability (hour/week)
Scarring	0.1083	192
Milling	0.1667	144
Steaming	0.15	144
Drying	0.15	96

Parameter data entered into the LP model and solved by Lingo. Complete models with data parameters are as follows:

Max Z=
$26{,}500X_{11} + 29{,}000X_{21} + 31{,}500X_{31} + 26{,}500X_{12} + 29{,}000X_{22} + 31{,}500X_{32}$

Subject to:

$10X_{11} + 10X_{21} + 10X_{31} \leq 2{,}100$
$10X_{12} + 10X_{22} + 10X_{32} \leq 1{,}500$
$0.283X_{11} + 0.283X_{21} + 0.283X_{31} \leq 192$
$0.283X_{12} + 0.283X_{22} + 0.283X_{32} \leq 192$
$0.133X_{11} + 0.133X_{21} + 0.133X_{31} \leq 192$
$0.133X_{12} + 0.133X_{22} + 0.133X_{32} \leq 192$
$0.75X_{11} + 0.75X_{21} + 0.75X_{31} \leq 240$
$0.75X_{12} + 0.75X_{22} + 0.75X_{32} \leq 240$
$0.1X_{11} + 0.1X_{21} + 0.1X_{31} \leq 144$
$0.1X_{12} + 0.1X_{22} + 0.1X_{32} \leq 144$
$0.1083X_{11} + 0.1083X_{21} + 0.1083X_{31} \leq 192$
$0.1083X_{12} + 0.1083X_{22} + 0.1083X_{32} \leq 192$
$0.1667X_{11} + 0.15X_{21} + 0.1167X_{31} \leq 144$
$0.1667X_{12} + 0.15X_{22} + 0.1167X_{32} \leq 144$
$0.15X_{11} + 0.15X_{21} + 0.15X_{31} \leq 144$
$0.15X_{12} + 0.15X_{22} + 0.15X_{32} \leq 144$
$0.15X_{11} + 0.15X_{21} + 0.15X_{31} \leq 96$
$0.15X_{12} + 0.15X_{22} + 0.15X_{32} \leq 96$
$40 \leq X_{11} \leq 132$
$60 \leq X_{21} \leq 140$
$40 \leq X_{31} \leq 134$
$80 \leq X_{12} \leq 125$
$30 \leq X_{22} \leq 132$
$40 \leq X_{32} \leq 134$
$X_{11} \geq 0$
$X_{21} \geq 0$
$X_{31} \geq 0$
$X_{12} \geq 0$
$X_{22} \geq 0$
$X_{32} \geq 0$

The Lingo solver produce global optimum output with value of the objective function, Z = 10,515,000. The value of X11 = 40 pack, X21 = 60 pack, X31 = 110 pack. X12 = 80 pack, X22= 30 pack, X32 = 40 pack.The results obtained from the lingo solver show that in the dry season the company can produce 40 packs of sweet and spicy cassava crackers, 60 packs of onion cassava crackers, and 110 packs of shrimp crackers per week. Whereas in the wet season, the company can produce 80 packs of spicy sweet cassava crackers, 30 packs of onion cassava crackers and 40 packs of shrimp flavored cassava crackers. with the amount of cassava crackers production according to the above provisions, the company will get a profit of IDR 6,265,000 / week during the dry season. While in the wet season, the company will get a profit of IDR 4,250,000 / week.

IV. CONCLUSION

The development of linear programming model in this study aims to determine the amount of cassava cracker production in the weekly period. The LP model that has been built has proven to be successful in optimally planning the production of cassava crackers that can maximize profitability and be able to reduce the deviation between the production and sale of cassava cracker products. For further research, the LP model can be developed by changing demand data to be probabilistic and considering defective products.

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