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Optimization of Wheat Flour Production Process Planning in Pt Y with Linear Programming Method

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Abstract:- Growth of wheat flour industry was increasing as people in upper middle class has shifted their consumption habits from consumption rice based food to flour based food. Stability of wheat flour quality, competitive price, and product availability in market was the challenges that food industry faced. PT Y was one of national company that produce wheat flour who held 51% market share in Indonesia. The increase of market share not only raising company's revenues but also gave another challenge, which is raising company's production cost which forced the company to optimize the use of resources continuously, so it can produce at lowest cost.

This study aim to develop mathematical model using Linear Programming to optimize wheat flour production capable of lowering the production cost.

The model using Linear Programming model was shown able to produce optimal solution that meets all the constraints. Completion model was able to determine the assignment of machines and selection of raw materials in accordance with the quantity and quality expected. The results show with optimization methods, PT Y would have potential in decreasing wheat flour production cost for 20.9% compare to company recent methods.

***Keywords*:-** *Optimization, production planning, wheat flour production, Linear Programming.*

I. INTRODUCTION

Wheat flour industry is growing rapidly as a consequences of the food consumption shiftfrom rice to wheat flour. As a one of national wheat flour producer, PT Y dominate wheat flour consumptions in Indonesia with 51% share market. Their domination in market not only increasing company revenues but also increasing wheat flour production cost, so that amount of profits remained constant. This condition gave challenge to company to do some efficiency in cost area.

PT Y's production cost consist of direct cost, indirect cost, and overhead cost. Direct cost has the highest contribution to total cost with 88%, then overhead cost and indirect cost has contribute 10% and 2%, respectively. This high amount of direct cost was because of the raw material cost, which is wheat purchase has contribute 92% and both of milling cost and packaging cost contribute each 4% to total direct cost.

Currently, PT Y plan their production based on sales demand forecast from marketing plan. This planning is only see from sales view, meanwhile planning from production view is not optimally developed yet. Production planning with optimized direct production cost as the most dominant cost became the background of this study.

II. METHOD

Using Linear Programming for optimization formulation was expected to solve production planning problem in order to produce the minimum production cost while maintaining the level of quality and still meet the demand of wheat flour products.

A. *Objective Function*

Minimize Z

$$Z = \sum_{n=1}^{t} \alpha_n . T_n + \sum_{n=1}^{t}\sum_{k=1}^{q}\sum_{m=1}^{s} \varphi_{nm} . T_{nkm} + \sum_{i=1}^{o}\sum_{j=1}^{p}\sum_{k=1}^{q}\sum_{l=1}^{r} \delta_{jl} . X_{ijkl} \dots (1)$$

B. *Constraints*

1) *Demands*

Constraint for demands means the limit of amount of wheat flour to be produced to meet the demand.

$$\sum_{l=1}^{r} X_{ijkl} \geq D_{ijk}$$

$$|i = 1,..,o;\ j = 1,..,p;\ k = 1,..,q| \dots (2)$$

2) *Packaging Machines Capacities*

This constraint is the limit of machine capability to pack certain brands of wheat flour in minutes per week.

$$\sum_{i=1}^{o}\sum_{j=1}^{p}\sum_{k=1}^{q} \beta_{jl} . X_{ijkl} \leq K_l - \sum_{j=1}^{p} \tau_{jl} . Y_{jl}$$

$$|l = 1,..,r| \dots (3)$$

$$\sum_{i=1}^{o}\sum_{k=1}^{q} X_{ijkl} - M . Y_{jl} \leq 0$$

$$|l = 1,..,r;\ j = 1,..,p| \dots (4)$$

M is large positive number and andY_{jl}in this case is a binary number. Its value 1 if job packaging $j = 1$start earlier than job packaging$j = p$on machine*l*. $Y_{12}$for example showsthe use of machines to pack packaging 1 on machine 2.

3) Milling Machines Capacities

Milling machines capacities constraint means the limit of machine capability to mill the wheat grain until it becomes flour.

$$\sum_{n=1}^{t}\sum_{k=1}^{q}\gamma_{nm}.T_{nkm} < K_m \,|m = 1,..,s| \ldots (5)$$

4) Raw Materials Storage Capacities

Raw materials, in this case is wheat grains storage capacities means the limit of silo capacity in storing grain before production process.

$$\sum_{k=1}^{q}\sum_{m=1}^{s}T_{nkm} \leq S_n \,|n = 1,..,t| \ldots (6)$$

5) Amount of Flour and Wheat

This constraint means the composition of particular wheat mixture to produce some brands of wheat flour.

$$\sum_{i=1}^{o}\sum_{j=1}^{p}\sum_{l=1}^{r}X_{ijkl} = \sum_{n=1}^{t}T_{nk} \,|k = 1,..,q| \ldots (7)$$

6) Nutritional Content

Nutritional content constraint means the standard composition of the various nutrient contained in each type of wheat mixture.

$$\sum_{m=1}^{s}T_{nkm} = T_{nk} \,|n = 1,..,t; k = 1,..,q| \ldots (8)$$

$$\pi_{ukmax}\sum_{n=1}^{t}T_{nk} \geq \sum_{n=1}^{t}\sigma_{nu}.T_{nk} \geq \pi_{ukmin}\sum_{n=1}^{t}T_{nk}$$

$$|u = 1,..,v\,; k = 1,..,q| \ldots (9)$$

$$T_n = \sum_{k=1}^{q}T_{nk} \,|n = 1,..,t| \ldots (10)$$

Indexing:

i : A warehouse to store finished goods stock outside home town. The warehouse is named after city according to the area location, i.e.Probolinggo, Boyolali, Malang, Kertosono, and Banjarmasin (*i*= 1,…,*o*).

j : Packaging size of flour to be sold, i.e. 25 Kg and 1 Kg (*j*= 1,..,*p*).

k :Brands of flour. Brand flour differentiated by the nutrients contained (*k*=1,..,*q*).

l : Packing machine used (*l*= 1,…,*r*).

m : Milling machine used (*m*= 1,…,*s*).

n : Type of wheat, related to supplier country (*n*= 1,…,*t*).

D_{ijk}: Demand product for warehouse*i*, packaging*j*, brand*k* (Ton/Week)

K_l : Capacity of packing machine*l* (minute/week)

β_{jl} : Time needed to pack wheat flour packaging*j*on machine*l* (minute/Ton)

τ_{jl} : Duration of machine setup time to pack packaging*j*on machine*l* (minute/week)

Y_{jl} : Binary number value 1 if packaging*j*process on machine*l*

γ_{nm} : Time needed to mill wheat grain type*n*on milling machine *m* (minute/Ton)

K_m : Capacity of milling machine *m* (minute/week)

S_n : Capacity of wheat type *n*storage (silo)(Ton/week)

T_{nk}: Amount of wheat type *n*for brand*k* (Ton/week)

u : Nutrition required on flour, e.g. protein and so on (*u* = 1,..,*v*) (%)

σ_{un} :Nutritional content*u*on wheat type*n* (%)

π_{uk}: Nutritional content*u*which is required on brand*k*, $\pi_{ukmax}$and$\pi_{ukmin}$are upper and lower limit, respectively (%).

C. Decision Variabels

The decision variables used in this formulation are as follows:

- T_n, is amount of wheat type*n* (Ton/week).
- T_{nkm}, is amount of wheat type*n*, for brand *k*, milled on milling machine*m* (Ton/week).
- X_{ijkl}, is amount of wheat flour which is delivered to warehouse *i*, on packaging*j*, with brand *k*, which is prepared on packing machine*l* (Ton/week).

III. RESULT AND DISCUSSION

A. Data Collection

Product Demand for Each Warehouse in 2nd Week of August 2017

- Warehouse has function as finished goods storage and buffer stock to prevent out of stock. Warehouse located in Probolinggo (i=1), Boyolali (i=2), Kertosono (i=3), Banjarmasin (i=4) and Malang (i=5).Table I shows data of wheat flour demand for warehouse in 2nd Week of August 2017.

Demand (Ton/Week)		Warehouse 1	Warehouse 2	Warehouse 3	Warehouse 4	Warehouse 5
Brand 1	Packaging 1	740	2,000	800	2,500	1,000
	Packaging 2	150	100	100	50	50
Brand 2	Packaging 1	730	1,500	500	500	500
	Packaging 2	1,000	1,000	200	400	100
Brand 3	Packaging 1	200	100	50	10	100
	Packaging 2	100	150	50	50	50
Brand 4	Packaging 1	1,000	2,000	1,000	3,000	500
	Packaging 2	800	200	500	50	20
Brand 5	Packaging 1	500	450	1,000	1,500	200
	Packaging 2	700	500	400	50	30

Table 1. Product Demand In 2nd Week of August 2017

- *Packing Machine Capacity*

There are 2 packaging size of wheat flour sold, 25 Kg (*j*=1) and 1 Kg (*j*=2).For packing size 25 Kg needs 3.08 minute/Ton and size 1 Kg needs 18.18 minute/Ton. PT Y has

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25 units of packing machine 1 and 15 units of packing machine 2 that each machines work for 24 hours in 7 days. All packing machines capacity shows on Table 2.

Description	Capacity (minute/week)
Packing Machine 1	252,000
Packing Machine 2	151,200

Table 2. Packing Machine Capacity

* *Milling Machine Capacity*

Wheat milling process on 3 milling machine, i.e. *Mill 1* (*m*=1), *Mill 2* (*m*=2),and*Mill 3* (*m*=3). Each machine able to mill all type of wheat but within different time duration to produce a ton of flour. Wheat from Canada (*n*=1) need 1.7 minutes, wheat from Australia (*n*=2) need 1.5 minutes, and wheat from Ukraine need 1.4 minutes.

There are 6 units of milling machine 1, 4 units of milling machine 2, and 3 units of milling machine 3 that each machines work for 24 hours in 7 days.Table 3. shows capacity for all milling machines.

Description	Capacity (minute/week)
Milling Machine 1	60,480
Milling Machine 2	50,400
Milling Machine 3	40,320

Table 3. Milling Machine Capacity

* *Raw Materials(Wheat) Storage Capacity*

Before ready to use in production, wheat grain need to be stored in silo after it unloads from carriage ship. Wheat on silo stored by its type. Silo capacity for each type of wheat shows on Table 4.

Description	Capacity (Ton/week)
Wheat Silo 1	40,000
Wheat Silo 2	62,000
Wheat Silo 3	102,000

Table4. Wheat Storage Capacity

* *Nutritional Content of Flour Brand*

Flour brand differentiated by nutritional content (*u*) required, i.e. moisture (*u*=1), protein (*u*=2), andash contain (*u*=3). Table 5. shows data of nutritional content (*u*) required for each flour brand.

Type of Nutrient	Nutrional Content Requirement (%)				
	Brand 1	Brand 2	Brand 3	Brand 4	Brand 5
Moisture	13.9-14.1	13.2-13.7	14.6-14.9	13.9-14.1	13.7-13.9
Protein	13-14	11-12	14-15	12-13	10-11
Ash	0.64-0.74	0.54-0.64	0.74-0.78	0.54-0.64	0.4-0.5

Table 5. Nutritional Content Requirement

* *Nutritional Content of Each Type of Wheat*

Wheat from different country has different characteristic and nutritional content. Wheat from Canada is hard wheat, whereas wheat from Australia and Ukraine are soft wheat. Data of nutritional content (*u*) for each type of wheat shown on Table 6.

Type of Nutrient	Wheat Nutritional Content (%)		
	Wheat Type 1	Wheat Type 2	Wheat Type 3
Moisture	14.8	13.4	13.8
Protein	14.67	12.33	10.5
Ash	0.76	0.65	0.49

Table 6. Wheat Nutritional Content

* *Raw Materials Cost. Milling Cost. and Packing Cost*

✓ *Raw Materials Cost*

Table 7. shows cost from purchase of wheat as raw material which used on production process.

Raw Material Cost (Rp/Ton)		
Wheat Type 1	Wheat Type 2	Wheat Type 3
3,300,000	3,100,000	2,900,000

Table 7. Raw Material Cost

✓ *Milling Cost*

Milling cost consist of electricity cost, set up cost, and direct labor cost. Amount of milling cost different for each wheat type because each wheat type need different time to mill until it become flour. Data for amount of milling cost shown on Table 8.

Description	Milling Cost (Rp/Ton)		
	Wheat Type 1	Wheat Type 2	Wheat Type 3
Milling Machine 1	114,000	101,500	87,500
Milling Machine 2	116,000	99,750	72,500
Milling Machine 3	140,000	122,500	71,250

Table 8. Milling Cost

✓ *Packing Cost*

Packaging purchase cost, electricity cost, set up cost, and direct labor cost are cost that include in packing cost. Packing cost on each machine and type of package has different amount. Data of amount of packing cost shown on Table 9.

Description	Packing Cost (Rp/Ton)	
	Packaging 1	Packaging 2
Packing Machine 1	250,000	770,000
Packing Machine 2	270,000	750,000

Table 9. Packing Cost

A. *Current Production Process Planning Method*

Production cost from current method used in company is Rp 134.310.943.000. Details of amount of wheat that used in production and amount of flour that produce shown on Table 10.

B. *Result*

Production cost from optimizationis Rp 106.235.306.500.Details of amount of wheat that need to use in production and amount of flour that need to produce shown on Table 11.

in hundreds Rupiah

Variables	Unit cost (Rp/Ton) (a)	Production Amount (Ton/Week) (b)	Total cost (Rp) (a) x (b)	Variables	Unit cost (Rp/Ton) (a)	Production Amount (Ton/Week) (b)	Total cost (Rp) (a) x (b)	Variables	Unit cost (Rp/Ton) (a)	Production Amount (Ton/Week) (b)	Total cost (Rp) (a) x (b)	Variables	Unit cost (Rp/Ton) (a)	Production Amount (Ton/Week) (b)	Total cost (Rp) (a) x (b)
T1	3,300	9,500.00	31,350,000	X1141	250	500.00	125,000	X3122	270	-	-	X4251	770	-	-
T2	3,100	12,000.00	37,200,000	X1151	250	500.00	125,000	X3132	270	50.00	13,500	X5211	770	-	-
T3	2,900	18,000.00	52,200,000	X2111	250	1,500.00	375,000	X3142	270	500.00	135,000	X5221	770	-	-
T111	114	1,000.00	114,000	X2121	250	1,500.00	375,000	X3152	270	-	-	X5231	770	-	-
T131	114	360.00	41,040	X2131	250		-	X4112	270	500.00	135,000	X5241	770	-	-
T141	114	800.00	91,200	X2141	250	1,000.00	250,000	X4122	270	-	-	X5251	770	-	-
T112	116	1,000.00	116,000	X2151	250	450.00	112,500	X4132	270	10.00	2,700	X1212	750	150.00	112,500
T132	116	-	-	X3111	250	500.00	125,000	X4142	270	1,500.00	405,000	X1222	750	1,000.00	750,000
T142	116	1,500.00	174,000	X3121	250	500.00	125,000	X4152	270	-	-	X1232	750	100.00	75,000
T113	140	675.00	94,500	X3131	250		-	X5112	270	200.00	54,000	X1242	750	500.00	375,000
T133	140	500.00	70,000	X3141	250	500.00	125,000	X5122	270	-	-	X1252	750	700.00	525,000
T143	140	679.25	95,096	X3151	250	1,000.00	250,000	X5132	270	100.00	27,000	X2212	750	100.00	75,000
T211	102	1,815.00	184,223	X4111	250	2,000.00	500,000	X5142	270	250.00	67,500	X2222	750	1,000.00	750,000
T221	102	700.00	71,050	X4121	250	500.00	125,000	X5152	270	-	-	X2232	750	150.00	112,500
T241	102	320.00	32,480	X4131	250		-	X1211	770	-	-	X2242	750	200.00	150,000
T212	100	3,000.00	299,250	X4141	250	1,500.00	375,000	X1221	770	-	-	X2252	750	500.00	375,000
T222	100	1,007.37	100,485	X4151	250	1,500.00	375,000	X1231	770	-	-	X3212	750	100.00	75,000
T242	100	325.63	32,482	X5111	250	800.00	200,000	X1241	770	300.00	231,000	X3222	750	200.00	150,000
T213	123	-	-	X5121	250	500.00	125,000	X1251	770	-	-	X3232	750	50.00	37,500
T223	123	1,000.00	122,500	X5131	250		-	X2211	770	-	-	X3242	750	500.00	375,000
T243	123	-	-	X5141	250	250.00	62,500	X2221	770	-	-	X3252	750	400.00	300,000
T321	88	1,000.00	87,500	X5151	250	200.00	50,000	X2231	770	-	-	X4212	750	50.00	37,500
T341	88	945.11	82,697	X1112	270	140.00	37,800	X2241	770	-	-	X4222	750	400.00	300,000
T351	88	2,000.00	175,000	X1122	270	-	-	X2251	770	-	-	X4232	750	50.00	37,500
T322	73	1,722.63	124,891	X1132	270	200.00	54,000	X3211	770	-	-	X4242	750	50.00	37,500
T342	73	2,000.00	145,000	X1142	270	500.00	135,000	X3221	770	-	-	X4252	750	50.00	37,500
T352	73	2,330.00	168,925	X1152	270	-	-	X3231	770	-	-	X5212	750	50.00	37,500
T323	71	1,000.00	71,250	X2112	270	500.00	135,000	X3241	770	-	-	X5222	750	100.00	75,000
T343	71	2,500.00	178,125	X2122	270	-	-	X3251	770	-	-	X5232	750	50.00	37,500
T353	71	1,000.00	71,250	X2132	270	100.00	27,000	X4211	770	-	-	X5242	750	20.00	15,000
X1111	250	600.00	150,000	X2142	270	1,000.00	270,000	X4221	770	-	-	X5252	750	30.00	22,500
X1121	250	730.00	182,500	X2152	270	-	-	X4231	770	-	-	**Total**			**134,310,943**
X1131	250	-	-	X3112	270	300.00	81,000	X4241	770	-	-				

Table 10. Current Company Production Process Planning Method

in hundreds Rupiah

Variables	Unit cost (Rp/Ton) (a)	Production Amount (Ton/Week) (b)	Total cost (Rp) (a) x (b)	Variables	Unit cost (Rp/Ton) (a)	Production Amount (Ton/Week) (b)	Total cost (Rp) (a) x (b)	Variables	Unit cost (Rp/Ton) (a)	Production Amount (Ton/Week) (b)	Total cost (Rp) (a) x (b)	Variables	Unit cost (Rp/Ton) (a)	Production Amount (Ton/Week) (b)	Total cost (Rp) (a) x (b)
T1	3,300	7,000.00	23,100,000	X1141	250	1,000.00	250,000	X3122	270	-	-	X4251	770	-	-
T2	3,100	8,500.00	26,350,000	X1151	250	500.00	125,000	X3132	270	-	-	X5211	770	-	-
T3	2,900	15,000.00	43,500,000	X2111	250	2,000.00	500,000	X3142	270	-	-	X5221	770	-	-
T111	114	2,675.00	304,950	X2121	250	1,500.00	375,000	X3152	270	-	-	X5231	770	-	-
T131	114	860.00	98,040	X2131	250	100.00	25,000	X4112	270	-	-	X5241	770	-	-
T141	114	2,979.25	339,635	X2141	250	2,000.00	500,000	X4122	270	-	-	X5251	770	-	-
T112	116	-	-	X2151	250	450.00	112,500	X4132	270	-	-	X1212	750	150.00	112,500
T132	116	-	-	X3111	250	800.00	200,000	X4142	270	-	-	X1222	750	1,000.00	750,000
T142	116	-	-	X3121	250	500.00	125,000	X4152	270	-	-	X1232	750	100.00	75,000
T113	140	-	-	X3131	250	50.00	12,500	X5112	270	-	-	X1242	750	800.00	600,000
T133	140	-	-	X3141	250	1,000.00	250,000	X5122	270	-	-	X1252	750	700.00	525,000
T143	140	-	-	X3151	250	1,000.00	250,000	X5132	270	-	-	X2212	750	100.00	75,000
T211	102	-	-	X4111	250	2,500.00	625,000	X5142	270	-	-	X2222	750	1,000.00	750,000
T221	102	-	-	X4121	250	500.00	125,000	X5152	270	-	-	X2232	750	150.00	112,500
T241	102	-	-	X4131	250	10.00	2,500	X1211	770	-	-	X2242	750	200.00	150,000
T212	100	4,815.00	480,296	X4141	250	3,000.00	750,000	X1221	770	-	-	X2252	750	500.00	375,000
T222	100	2,707.37	270,060	X4151	250	1,500.00	375,000	X1231	770	-	-	X3212	750	100.00	75,000
T242	100	645.63	64,402	X5111	250	1,000.00	250,000	X1241	770	-	-	X3222	750	200.00	150,000
T213	123	-	-	X5121	250	500.00	125,000	X1251	770	-	-	X3232	750	50.00	37,500
T223	123	-	-	X5131	250	100.00	25,000	X2211	770	-	-	X3242	750	500.00	375,000
T243	123	-	-	X5141	250	500.00	125,000	X2221	770	-	-	X3252	750	400.00	300,000
T321	88	-	-	X5151	250	200.00	50,000	X2231	770	-	-	X4212	750	50.00	37,500
T341	88	-	-	X1112	270	-	-	X2241	770	-	-	X4222	750	400.00	300,000
T351	88	-	-	X1122	270	-	-	X2251	770	-	-	X4232	750	50.00	37,500
T322	73	-	-	X1132	270	-	-	X3211	770	-	-	X4242	750	50.00	37,500
T342	73	-	-	X1142	270	-	-	X3221	770	-	-	X4252	750	50.00	37,500
T352	73	-	-	X1152	270	-	-	X3231	770	-	-	X5212	750	50.00	37,500
T323	71	3,722.63	265,238	X2112	270	-	-	X3241	770	-	-	X5222	750	100.00	75,000
T343	71	5,445.11	387,964	X2122	270	-	-	X3251	770	-	-	X5232	750	50.00	37,500
T353	71	5,330.00	379,763	X2132	270	-	-	X4211	770	-	-	X5242	750	20.00	15,000
X1111	250	740.00	185,000	X2142	270	-	-	X4221	770	-	-	X5252	750	30.00	22,500
X1121	250	730.00	182,500	X2152	270	-	-	X4231	770	-	-	**Total**			**106,235,307**
X1131	250	200.00	50,000	X3112	270	-	-	X4241	770	-	-				

Table 11. Result From Optimization Method

IV. CONCLUSION AND SUGGESTION

A. Conclusion

- Using Linear Programming to determine amount of products to be produced for each stock point is capable to deliver optimal solution that meets all constraints.
- The completion model is able to determine the assignment of machines and selection of raw materials in accordance with the quantity and quality expected.
- The results of optimization method show that company has potential to decrease production cost by 20.9%.

B. Suggestion

- Need to be given a minimum level of machine hours to allocate the work hours of machine more balanced.
- Wheat import prices as a commodities are very fluctuate which is affected by tariffs, so the application of this model requires more adjustment.

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