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Material Inventory Optimization in Bakery Supply Chain: Implications for Food Security in Nigeria

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Abstract

The study determined optimum inventory levels for various bakery resources using the bread supply chain network in Onitsha City. Structured questionnaires were administered among bakery factories. The optimum design achieved through the optimization model was compared with the existing systems. Analysis of 90 bakeries with a combined capacity of 3960 revealed that total money ₦ 564,408,477.28 is spent on energy annually. Of this amount, 66.75% is expended annually to meet diesel requirements, while firewood and petrol account for 22.57% and 10.66%, respectively. The results of the ABC analysis show that flour ranks as class A with over 78%, followed by sugar at 13%, whilst the remainder of the ingredients constitutes 9%. High operating costs was identified as a major factor militating against the growth of the sector. Consequently, baked bread is expensive and remuneration is very poor, making the industry less attractive. The implementation of optimization practice adds value leading to savings amounting to ₦ 6,957.51, thus enhancing the supply chain competiveness. The annual supply chain performance measured by inventory turnover shows a frequency of 73 inventory turns. Since the bakeries contribute to ensuring food security, these findings, if implemented, will assuage the rising food insecurity in the nation.

Keywords: Supply chain; performance evaluation; efficiency; data envelopment analysis.

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1. Introduction

Implementation of the inventory optimization technique for deciding what quantity of material to procure is critical to improving the bakery supply chain performance. The necessity to improve the chain performance through inventory optimization is strengthened by rising costs encountered across the supply chain transactions that hamper continuous production. In Nigeria, Ekechukwu, et al, (2011) have identified a number of such factors militating against the growth of the sector and have highlighted the need to minimize it. Although, bread production is a long chain process with many batches of relatively short production runs and a mixture of raw materials and ingredients resulting in high viscous dough, the cost of production increases with each processing stage of the bakery chain. The costs referred to even include the dough being transformed into finished products and then distributed to the consumers by vehicle or other means of transportation. The high cost of operating the batches, including the major constituent ingredients of bread, has been blamed on stringent importation rules that apply to bakery materials. Also, random variations in supply for locally grown materials account for part of the problem. Consequently, the bakeries suffer from adverse effects resulting from the wrong timing and sizing of inventory orders. The production of insufficient stock of these essential resources conflicts with modern inventory ethical practices and definitely leads to erroneous future business planning and decisions.

In Nigeria, according to Onwumere, Nwosu and Nmesirionye (2012), bakery firms face the challenge of inventory management that contributes to material waste in the bakery business and missed shipments to ultimate customers. Consequently, the bread production chain lacks competitiveness due to poor inventory management and profitability is grossly affected by the fluctuating cost of inputs together with rising operational and maintenance costs. Therefore, tackling insufficient resources, including energy and raw materials, requires the techno-economic decision tools of the inventory control functions.

The term inventory refers to the stocking of materials in different forms: raw, processed (finished) and semi processed (work in progress); - in addition to factors of production (energy, land); and general supplies (administrative materials etc) in order to attain the desired goods or services security for future use. For an industrial supply chain outfit such as bread baking, inventory is important for a number of reasons, including ensuring smooth operations, meeting customers' demands and avoiding production shut down occasioned by the non-availability of raw materials (Ekechukwu et al., 2011). To minimize production cost fluctuations due to unstable prices of raw materials and to avoid loss of potential customers due to plant shut down, material inventory optimization of the supply chain is a necessity.

Nwanya and Madu (2013) have argued that supply chain activity in the bakery industry involves purchasing and outsourcing functions that should focus on maximizing value to customer satisfaction. Furthermore, Lin and Ou (2011) pointed out that international business continues to outsource manufacturing to countries and regions where conditions for production are better and cost is lower and also expands product sales to where purchasing power is gradually increasing. Essentially, the supply chain connects and facilitates product development from production to delivery stages, which is aimed at ensuring customer satisfaction at minimum cost and value added can be measured from cost savings. Heizer and Render (2009) state that supply chain activity cost as much as 60% in the food industry including the bakery sector. For the vendors, it is important to keep low inventory levels and sell as fast as possible to avoid loss due to stale bread. For the baker, there is a need to minimize losses of assets in the supply chain as a means of reducing cost. In the foregoing context, inventory optimization to the baker, vendor and customer is important for the nature of bakery materials and products along the value chain.

In a contextual study on the bakery industry in Nigeria, Madu (2006) suggested short shelf-life and changing lifestyles of customers as motivation for inventory optimization. He maintains that operating with a perishable product such as bread, with low profit margins, requires accurate, timely and complete information. To meet the challenges of the constantly changing tastes of health-conscious, value-conscious customers, with a significant number of customers becoming increasingly discerning, requires a quantitative strategy as a remedy to the identified constraints. Various factors such as changing lifestyles, customer demand for new flavors and food experiences, changing dietary habits and poor compliance with external regulating standards are making the operating environment for the bakery industry difficult.

As a result of these developments and other trends, bread manufacturers are confronted with a number of challenges. Prominent amongst these challenges are need for accurate and timely forecasting of customer demand, the capability to quickly respond to changing market conditions and customer tastes, the ability to maintain brand equity and increase market positions through superior quality and value added services and, the continual streamlining of operational processes to minimize production costs and losses. The foregoing plethora of concerns has influenced bakery supply chain practices and has turned inventory management into crucial strategy, most suited to offering lasting solutions towards reliable future decision-making.

The bakery raw materials and ingredients of concern in this study include wheat flour, sugar, yeast, butter (or vegetable oil), salt, bread improver, preservatives, milk and eggs. Other raw materials for bread making according to Kim and De Ruiter (1968) and He and Hoseney (1991) are flour mixtures of rice, corn and cassava. These materials are the main cost drivers throughout the supply chain and are imported, except for corn and cassava flour which are new to Nigerian bakery and sparingly used. Because of the import-based nature of these materials, shortages are often experienced in the market leading to the closure of many bakeries or production at lower capacities. The consequences include under-production and sometimes over-production, which occur as a result of inadequate planning and unreliable forecasting. Since shelf-life is a major concern for bakery products, the application of an inventory optimization technique which is unique and reduces the cost of operations is a strategic management tool for improving bakery supply chain performance. Without inventory optimization, companies commonly set inventory targets using rules of thumb or single stage calculations (Cole, 1993).

Various analytical models have been used by previous authors to address the problems of inventory levels of products to purchase, produce and ship at minimum cost. Braucer and Naadimuthu (1990) presented a goal programming model for the inventory and distribution planning of a central distribution center. Goal programming is suited to addressing competing objectives or goals in inventory management. Koteeswaran, Shayan and Rajabpour (2004) applied a mixed-model assembly line formulation to predict buffer sizes in a just-in-time manufacturing system. The mixed-model is ideal for inventory issues encompassing different shift patterns, poor line efficiencies and different production rates in the line. Carson (1997) applied simulation optimization to minimize resources spent in a system. Elwany, Shouman and Abou-Ali (2013) examined many production scheduling techniques that have a direct influence on inventory management. Okolie, Okafor and Chinwuko (2010) used linear programming in determining production mix and associated total profit for two bakeries with competing products. All these studies treated inventory cases of firms with diversified objectives, having high computational costs and time. Despite this, review of related literature shows that rural and small scale bakeries lack tools for the adaptation of basic inventory control system to practical business situations, particularly in relation to the perishable nature of bakery materials. Accordingly, it follows that material inventory optimization is a necessity for these bakeries, with a view to addressing the identified problem.

1.1 Objectives of the research study

The research study is aimed at establishing the optimal inventory for managing bakery resources, thereby ensuring food security in Nigeria. The specific objectives of the study include determining a minimal material inventory per production capacity and comparing the obtained findings with the existing system so as to determine the savings in cost. It is expected that the obtained inventory level will help rural bakeries to maximize profit by reducing unavoidable material storage costs.

1.2 Scope of the current study

The study contributes to stable production by creating a balance between having enough bakery materials to meet customer needs and not so much that cash is tied up unwisely. It is the essence of the inventory optimization technique in the bakery industry. It will provide investors with the information required to establish a bakery (facilities, costs, profits, etc).

It is of importance to shed light on choosing the bakery sector from the whole food industry for inventory optimization. An argument could be made that the reason for the choice of bakery has been addressed by a study on absorption refrigeration by Nwanya et al, (2009), which note that bakeries contribute to ensuring food availability, affordability and accessibility. There is an expected reduction in costs when applying inventory control in this sector because its products have economy of scale advantages with the active population (children and adolescents) class which forms the predominant customer base of bakery food over other food categories. Logically, the active population group severely suffers from the effects of food insecurity. The money saved by better supply chain management can be invested in customers indirectly, thus reducing their spending on bread and other bakery products.

The scope of study covered 90 bakeries, representing over 75% of the total number of registered bakeries in the Onitsha City. The current supply chain in this study is criticized for being more strategic than operational in its perspective. Hence, the raw material procurement and distribution value chain is given priority consideration.

The main contributions of this work from an inventory planning perspective are the optimum inventory algorithm and inventory turnover rate that are being used as check on impending shortages and to initiate corrective action for the Nigerian bakery industry.

2. Review of the related literature on existing inventory management of Nigerian bakery industries

Considering the seasonal food production cycle, basic stock control methods, which overcome the present inventory management challenges of the bakery industry, are strategic to ensuring food security. This is because the bakery supply chain plays a role in the transformation of excess seasonal food items into future reusable forms, thus enhancing sustainable food security as has been highlighted elsewhere (Ekechukwu et al., 2011). However, a lack of capacity, including financial and infrastructure facilities, to operate a stock control system, among other factors, affects bakery profits and competitiveness.

There are also conflicting inventory objectives within the bakery supply chain. This factor influences such complex supply chain activities as facilities procurement, the purchase of raw materials, their transformation into dough and baking into bread and distribution of bread to final consumers. Consequently, decisions regarding inventory policies are hardly realized because of uncertainties. For example, bakers lack information on the potential size of the market. They produce excess in anticipation of demand to ensure more revenue. The vendors on the other hand act on speculation, just-in-case future demand exceeds forecast, and in the process overstock the product. The vendors mostly hold multiple brands of bread stocks and later employ a hawking strategy so as to reduce the number of days stocks are held on the shelf. This practice results in large inventories with attendant increased holding costs and health risks. Also, multiple brand selling neutralizes the expected competition among the products, since demand of popular brands when unfilled were substituted with unpopular, overstayed and stale brands by vendors. Holding multiple brands simultaneously leads to an uneconomic allocation of overheads among the different bread brands. The consequence is illusory and impacts adversely on growth of the industry.

The Nigerian bakery industry is operated predominantly by one-man business enterprises characterized by small lot-sizes and frequent stocking; by implication, low capital investments. Although raw materials and ingredients (composition of dough make-up) for bread production may be available in the market, frequent changes in prices are causing major concerns within the industry. The bakery resources most affected by these frequent price changes are wheat flour and sugar. In 1999, a bag of wheat flour and sugar would have sold for less than ₦ 1500. In 2007, they would have sold for ₦ 3000 and ₦ 5000, respectively. However today their prices, and those of other kinds of bread constituents, have increased as summarized in Table 1. It is hoped that the price of bread flour will drop down with the introduction of 10% cassava components in flour production currently taking place in the flourmill industries. The foregoing scenario of price variability for essential raw materials affects bakery production functions and necessitates inventory analysis in bread supply chain.

Table 1. Composition of dough make-up and market prices per 50kg bag

S/N	Items	Weight (kg)	%	Cost (₦)
1	Wheat flour	50 (bag)	62.50	7300
2	Sugar	5	6.25	8000/bag
3	Salt	1	1.25	1350/bag
4	Butter	1	1.25	4500/carton
5	Yeast	0.1	0.13	7000/carton
6	Bread improver	0.1	0.13	15000/20litre container
7	Preservative		2.5	25000/bag
8	Flavour	0.1 kg	0.13	1000/500g
9	Water	20 – 30 kg	23.00	

Survey conducted: July 7, 2013.

3. Methodology

Questionnaires were administered to 90 bakery factories in Onitsha City. In addition, secondary sources of information were used. Random sampling of factories categorized according to capacity based on rate of production was carried out. Using the Statistical Package for Social Sciences (SPSS) version 19, the capacity-material data collected from the 90 bakeries were analysed for eight material supply chains, namely: wheat, sugar, salt, butter, yeast, bread improver, flavor and preservatives. Also, it was observed that a selective inventory control is currently practiced in the factories. To address this anomaly, the ABC method of inventory analysis was used to classify inventory items based on cost of materials.

3.1 Assumptions

From the survey, the optimum inventory required for the bakeries is based on the following assumptions:

1. Raw materials usage is constant and the quantity is known,
2. Delivery interval or time of arrival of raw materials is known,
3. No shortage is allowed,
4. Safety stock is maintained,
5. Rural bakeries continually fill stock over time (gradual replacement of order is allowed).

3.2 Inventory model development

The inventory decision model is influenced by the following: item, holding and ordering costs. From
the total cost (TC) that affects the model and is suitable for this operation (bakery), a modified economic order quantity is derived as:
TC = (order cost, C_s)(number of orders per year) + (carrying cost, C_1)(average inventory per year) (1a)
In practice, maintaining a yearly inventory is difficult for rural and small scale bakeries because of their impecunious financial challenges. For them, inventory is continually filled or gradually replaced over time. Let us assume that q units are added monthly and the usage rate r is maintained. Here, q > r and maximum inventory is less than Q. However, average inventory = $(Q_{max} + Q_{min})/2$
where $Q_{min} = 0$.

$$Q_{\max} = \left(\frac{Q \frac{q-r}{q}}{2} \right)$$

$$= \frac{Q}{2q}(q-r) \tag{1b}$$

In the gradual replacement pattern, the optimal reorder point is zero (Everest and Ronald, 2000) and the total cost to be minimized is expressed as:

$$TC = C_s \frac{r}{Q} + C_1 \frac{Q}{2q}(q-r) \tag{2}$$

Taking the first partial derivative of TC with respect to order quantity Q and equating to zero, we have that:

$$\frac{\partial(TC)}{\partial Q} = \left(-C_s r Q^{-2}\right) + \frac{C_1}{2}\left(\frac{q-r}{q}\right)$$

The inventory decision model is a modified economic order quantity expressed as

$$EOQ = \sqrt{\frac{2C_s r}{C_1\left(1 - {r}/{q}\right)}} \tag{3}$$

The goal of optimum inventory is to minimize the cost of raw materials. The optimum method considered in equations (4) and (5) was derived based on a continual replacement pattern, where q units are added causing the inventory to grow and r units are used causing it to diminish.

$$C_{opt} = \sqrt{\left[2 \times C_s \times r \times C_1 \left\{1 - \frac{r}{q}\right\}\right]} \tag{4}$$

However, the cost of existing policy is derived as in equation 5.

$$C_{pp} = \left[\frac{C_1 \times Q}{2}\left\{1 - \frac{r}{q}\right\} + \left(\frac{C_s \times r}{Q}\right)\right] \tag{5}$$

Where r = rate of usage of raw materials per month, q = monthly plant requirement, Q = quantity ordered presently (existing policy) per month, C_s = ordering cost per order, C_1= holding cost per item per month, EOQ = production order quantity (optimum quantity), C_{opt} = optimum cost of inventory and C_{pp} = existing cost of present policy.

Estimation of holding cost (C_1): using the empirical formula in equation (6).

$$C_1 = \left\{\frac{I_c \times W_c \times f}{q}\right\} \tag{6}$$

where V = annual raw material requirement, p = unit cost of raw materials, I_c = pV multiply by interest charged monthly, W_c = cost of ware house, insurance and taxes multiply by relative weight of the raw materials, in case of flour, 78%, f = factor to take care of security, spoilage, etc, and is assumed to be 0.5. Table 3contains holding cost for various capacities.

4. Analysis and Discussion

4.1 Inventory analysis and optimum values

Results of the ABC classification show that flour ranks first with over 78%, followed by sugar at 13%, whilst the remainder of the group of materials (butter, yeast, improve, salt, flavor and preservative) with a large number of items constitutes less than 10%. Hence, we rank flour as class A, sugar as class B and the remaining ingredients as class C, on the basis of total inventory cost. Details of the analysis are contained in Table 2. It should be noted that the bakeries were categorized into plant capacity such 10, 20 or more based on the number of tons of wheat flour baked per day.

Table 2. 20 ton plant capacity with corresponding annual raw material requirement

Ranking	**Items**	**Bag(s)/cts.**	**Qty (kg)**	**Price/ kg**	**Value N**	**%**
1	Flours	5760	288000	66.00	19,008,000	78.49
2	Sugar	576	28,800	110.00	3,168,000	13.08
3	Butter	384	5,760	173.33	998,400	4.12
4	Yeast	96	384	1,050.00	480,000	1.98
5	Improver	32	582	769.00	448,000	1.85
6	Salt	230	5,750	20.00	115,000	0.45
	Total	---	32,9276		24,217400	100

Using the information in Table 2, the EOQ and optimum cost of inventory for the various raw materials of production are calculated based on equations (3) and (4), respectively:

1. EOQ for wheat flour: from equation (3)
2.

r =1440, q = 1728, C_1 = 20.74, C_s = 2400 and Q = 691, i.e. 40% of q.

$$EOQ = \sqrt{\left[\frac{2 \times 2400 \times 1440}{20.74\left\{1 - \frac{1440}{1728}\right\}}\right]}$$

= 1414 bags of flour.

Similarly, EOQ for sugar, yeast, bread improver, and salt are 238 bags, 206 Cartons, 78 cartons, 23 pails, and 176 bags respectively.

2. C_{OPT} for wheat flour for different bakery capacities: from equation (4)

$$\sqrt{\left[2 \times 2400 \times 1440 \times 20.74\left\{1 - \frac{1440}{1728}\right\}\right]}$$

= ₦ 4,847.76.

Similarly, C_{opt} for sugar, butter, yeast, bread improver and salt are ₦ 1,00.69, ₦ 588.01, ₦ 395.11, ₦ 410.06 and ₦ 193.25 respectively. The pattern of behaviour C_{opt} with bakery capacity is shown in fig. 1. Details for other materials are shown in Table 3.

3. C_{PP} for wheat flour is calculated based on equation (6) as follows:

$$C_{pp} = \left[\left(\frac{20.74 \times 691}{2}\right)\left\{1 - \frac{1440}{1728}\right\} + \left(\frac{2400 \times 1440}{691}\right)\right]$$

= ₦ 6,199.93

Table 3: Plant capacity with corresponding r, q, c_1, and c_s. (based on monthly requirement)

	Plant capacity		*60*	*50*	*45*	*40*	*30*	*20*
Raw Materials	Wheat flour : r		1440	1200	1080	960	720	480
		Q	1728	1440	1296	1152	864	576
		c_1	20.74	20.74	20.74	20.74	20.74	20.74
		c_s	2400	2400	2400	2400	2400	2400
	Sugar:	r	144	120	168	96	72	48
		Q	158	144	130	115	86	58
		c_1	34.57	34.57	34.57	34.57	34.57	34.57
		c_s	600	600	600	600	600	600
	Butter	r	96	80	72	64	48	32
		Q	115	96	86	77	58	38
		c_1	16.36	16.36	16.36	16.36	16.36	16.36
		c_s	600	600	600	600	600	600
	Yeast:	r	24	20	18	16	12	8
		Q	29	24	22	19	14	10
		c_1	31.44	31.44	31.44	31.44	31.44	31.44
		c_s	600	600	600	600	600	600
	Bread improver:	r	8	7	6	5	4	3
		q	10	8	7	6	5	4
		c_1	87.58	87.58	87.58	87.58	87.58	87.58
		c_s	600	600	600	600	600	600
	Salt:	r	58	48	43	38	29	19
		Q	70	58	52	46	35	23
		c_1	13.13	13.13	13.13	13.13	13.13	13.13
		c_s	600	600	600	600	600	600

Similarly, C_{pp} for sugar, butter, yeast, bread improver and salt are ₦1, 452.10, ₦ 1, 314.34, ₦1,232.52, ₦ 1,234.03 and ₦ 1,250.33 respectively. Then, the C_{opt} was compared with the corresponding inventory cost for existing policy, C_{pp}. As illustrated in fig. 2, the value added to the chain in the different capacities is depicted by cost savings from the difference between optimum and existing policy.

As displayed in Table 3, the difference between “Q” and “r” relative to plant capacity indicates total units of inventory carried over from one month to the next month. Fig. 3 illustrates the differences for the aforementioned various material supply chains. How this affects the chain value system is critical to maintaining food security and maximizing customer satisfaction. As shown in fig. 3, Q and r are linearly related to capacity of bakery plant such that the quantity decreases as the plant capacity decreases. This can be observed in the fig. 3 where the highest quantity values occurred at the highest plant capacity which is 60. After this every drop in plant capacity results in a drop in the quantities and this has implications for the supply chain management.

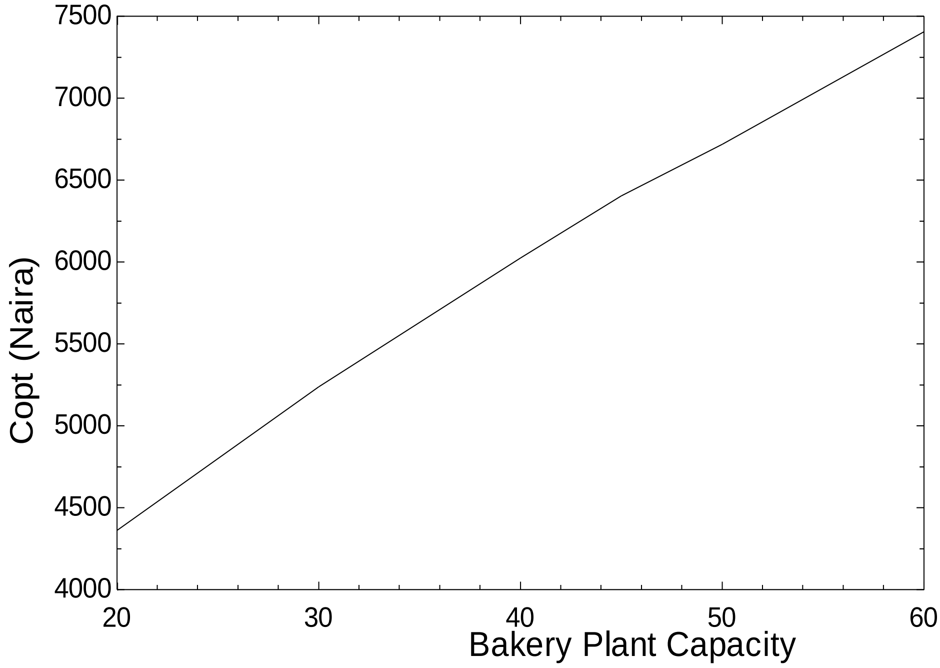

Figure 1. Inventory under optimum condition- EOQ/days/C_{opt}

Fig. 2 displays the breakdown of savings in the supply chain resulting from comparisons of optimum inventory with existing policy according to bakery plant capacity. The 25% saving is associated with the highest capacity of 60 and decreased with production capacity.

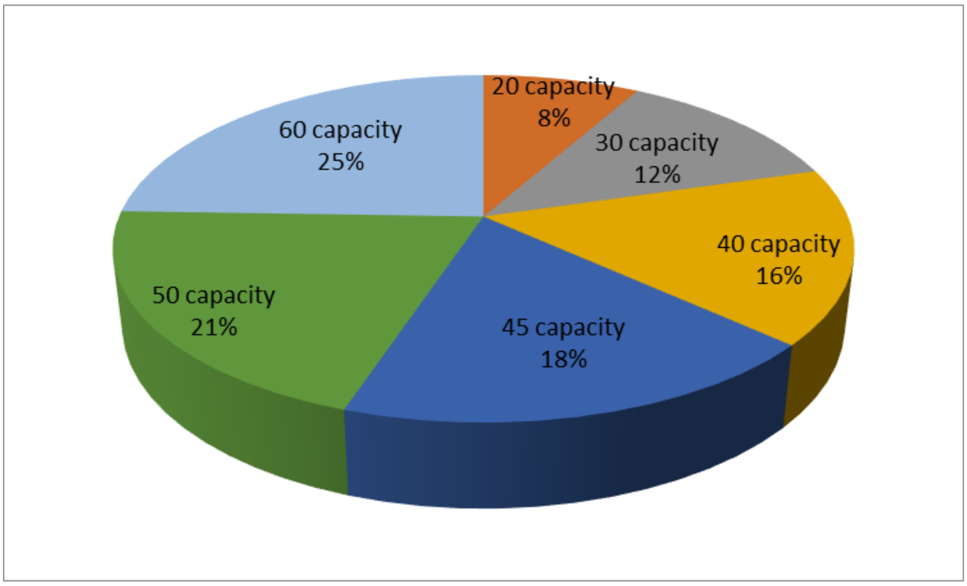

Figure 2. Savings in supply chain according to bakery plant capacity (here)

However, there is no assurance that future performance will continue to replicate this behaviour if the turnover rate for small capacity plants increases.

4.2 Inventory analysis for a new bakery

An EOQ sensitivity analysis was conducted for the case of a new bakery. A variation of EOQ by -5 % affects the EOQ for the new bakery. Using equation (3) and calculated C_{opt}, EOQ for wheat flour is 993bags. Similarly, sugar, butter, yeast, bread improver and salt are 132bags, 143cartons, 48cartons, 17pails, and 255 bags respectively, while C_{opt} for flour, sugar, butter, yeast, bread improver and salt

are ₦3, 518.75, ₦653.22, ₦ 403.00, ₦ 300.91, ₦ 144.98 and ₦ 136.65 respectively. Table 4 compares the optimum with existing policy for a new bakery.

Table 4. Comparison of optimum cost of inventory with existing policy for the new bakery

Raw materials	EOQ	Q	C_{PP}	C_{opt}
Flour	993	351	5,599.03	3,518.75
Sugar	132	34	1,354.53	653.22
Butter	143	23	1,439.90	403.08
Yeast	48	6	1,237.73	300.91
Bread improver	17	2	1,235.03	144.98
Salt	255	14	1,248.86	136.98
Total	----	---	₦ 12,115.10	₦ 5,157.59

4.3 Discussions

The overall purpose of this study is input control of bakery materials with the specific objectives, which include determining a minimal material inventory per production capacity and comparing the computed results with the existing system so as to determine the savings in cost. Control over input materials scores a point, that is, the more input is controlled; the less output has to be controlled. Hence, this section will briefly discuss and explore any relationship that exist among the results, in particular, their food security implications.

The objective of determining a minimal material inventory per production capacity was achieved as can be shown in table 3. In this table, effort was made to show total units of inventory carried over from one month to the next month and the difference between “Q” and “r” indicates this quantity relative to plant capacity. Related studies (Ruteri and Xu, 2009; Vutete and Bobo, 2015) have been conducted in this field. The inventory solutions addressed in this paper fit into the advantages which supply chain management practice can offer the food industry as suggested by (Ruteri and Xu, 2009). Results of this work, if implemented, will also ensure stability in pricing of bread as opined by (Vutete and Bobo, 2015).

In terms of savings in cost per bakery capacity, one of the findings from the work of Oyeku, Kupoluyi, Osibanjo, Orji, Ajuebor, Ajiboshin and Asiru (2008) compared favourably with this study. They obtained 6.9 % profit per bakery capacity in their table 3, for using composite mixture, while this study obtained 3 % per capacity without composite. The difference in the profit margin is attributed to the involvement of cassava-wheat composite flour, which is a direct cost control measure.

To investigate any relationships that exist among the findings with energy and manpower requirements, a mean capacity of 44 is used and the combined capacity of the 90 bakeries studied amounts to 3960. Using the regression equation developed in equation (7), total jobs created stood at 3859 persons, while total money expended on energy amounted to ₦ 564,408, 477.28.

$$M_{est} = \sum_{1}^{n}(0.9758B_c - 4.68) \quad (7)$$

Where M_{est} = estimated manpower, B_c = bakery capacity and n = number of bakeries.

Also the optimum inventory cost increases with bakery capacity as shown in figure 1. This is significant for rural bakeries that are under pressure to expand their reach through mergers and in the process tie up scarce investment capital on stock keeping.
Optimization application using the mean capacity yielded a profit of ₦ 34,339.35 as against ₦ 33,331.07 (3 %) for existing policy (non optimization process). Sensitivity test responses were low, giving 2.60%, 2.30%, 3.60% and 4.60% for 50%, 10%, -5% and -10% variations respectively. When compared with existing inventory, savings amount to over 40%.

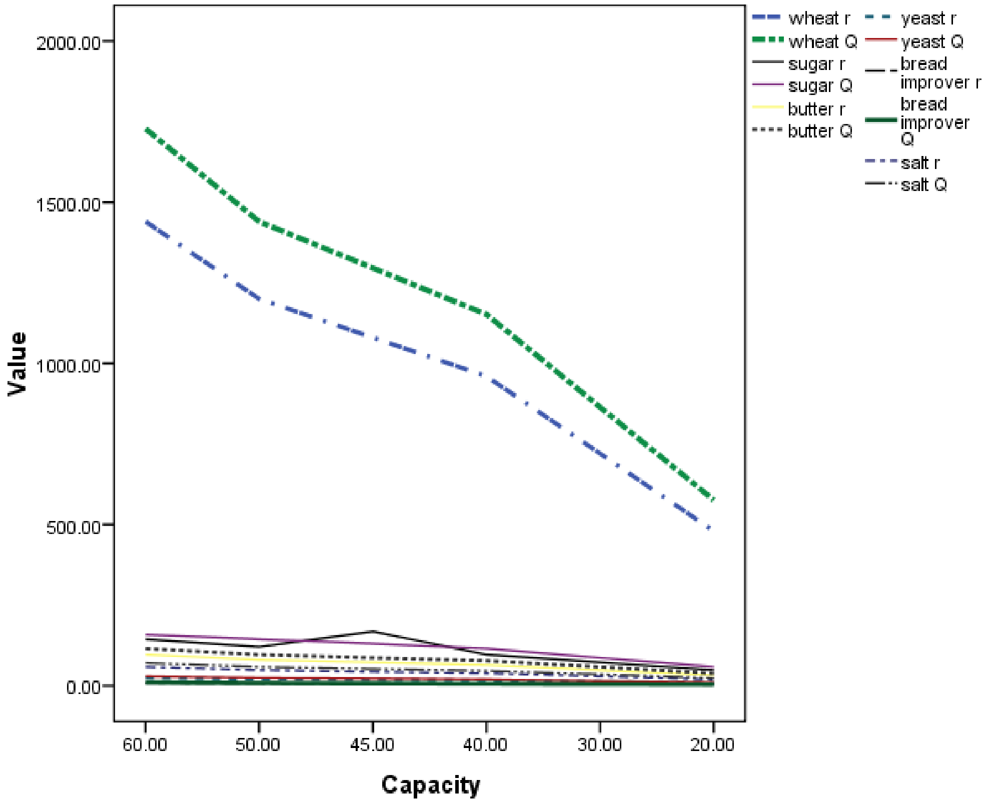

Figure 3. Total units of inventory carried over from one month to the next month

As the inventory levels change, the manpower and energy requirements will change, appropriately. With the new bakery, the manpower requirement amounts to 25 persons. Similarly, energy requirement (diesel, firewood and petrol), direct raw materials, direct labour and indirect cost stood at ₦ 16,257.00, ₦ 134,957.00, ₦ 448.00 and ₦ 767.70 respectively. Optimum product mix

stood at 846 (x_1), 1089 (x_2) and 2999 (x_3) units for 1000g, 600g and 300g loaves respectively, while profit (z) stood at ₦ 53,133.16 and savings amounted to ₦6,957.51.
The food security implications of this inventory study are many for Nigeria. For the wheat import-dependent countries, as well as countries that are highly food insecure like Nigeria, any decline in import capacity of these bread materials can have challenging food security problems. Also, the results of the study offer an opportunity for bakery operators to have knowledge of their requirements and to take advantage of bulk buying.

The economic performance of a bakery supply chain in Nigeria can be evaluated from the viewpoint of inventory turnover rate. Using a 20 capacity bakery with annual inventory data as shown table 2 for example, this performance measure can be calculated as follows:

$$P = \frac{I}{L} \qquad \text{[Payne, Chelsom and Reavill, 1996]} \qquad (8)$$

Where I= total cost of materials during a year or in a period, L= average stock or inventory in a period, P = inventory turnover. The calculated turnover index is 73 and it measures the frequency of inventory turns in a year.

In achieving the above results, this study was challenged by many factors including difficulty in the accessibility of relevant data. Considering the federal government policy on composite cassava-wheat bread and huge resources involved in the bakery industry, this paper recommends to researchers a study on integrated inventory model for lead-time variability in order to cut down safety stock requirements

5. Conclusion

The study determined optimum inventory levels for various bakery resources using the bread supply chain network in Onitsha City. The optimum design achieved through the optimization model was compared with existing systems. Analysis of 90 bakeries with a combined capacity of 3960 revealed that a total of ₦ 564,408,477.28 is spent on energy annually. Of this amount, 66.75% is expended annually to meet diesel requirements, while firewood and petrol account for 22.57% and 10.66%, respectively.

Also, the overall supply chain performance measured by inventory turnover shows a frequency of 73 inventory turns in a year. This result is worrisome for a wheat import-dependent and highly food insecure country because any decline in import capacity for these bread materials can create challenging food security implications. The results of the ABC analysis show that flour ranks as class A with over 78%, followed by sugar at 13%, whilst the remainder of the ingredients (butter, yeast, improve, salt, flavor, and preservative) constitutes less than 10%. Hence, we rank flour as A, sugar as B and the remainder as C.

High operating costs was identified as a major factor militating against the growth of the sector. The high costs are traceable to the high costs of raw materials and energy. Consequently, baked bread is expensive and remuneration is very poor, making the industry less attractive; hence the current shortage of skilled manpower ravaging the industry. The implementation of optimization practice adds value in terms of savings amounting to ₦ 6,957.51, thus enhancing the supply chain competiveness. Optimization practice is also helpful in terms of its ability to provide information to government policymakers relating production cost fluctuations and how to diminish their effects.

References

Braucer, D. C. , G. Naadimuthu (1990). A goal programming model for aggregate inventory and distribution planning. *Mathl. Comput. Modelling, Pergamon press,* Vol. 14, 1085- 1090.

Carson, Y., A. Maria (1997). Simulation optimization: methods and applications. Proceedings (S. Andradottir, K. J. Healy, D. H. Withers and B. L. Nelson ed.) of the 1997 Simulation Conference, PP 118- 125. Available www.informs-sim.org/wsc97papers/0118.pdf (accessed 15/10/2013).

Cole, G. A. (1993). *Management Theory and Practice*. DP Publications Limited, 4th Edition, London, 208- 209.

Ekechukwu, O. V., S. C. Nwanya, A. C. Madu, J. C. Agunwamba (2011), Optimization of Energy and Manpower Requirement in Nigerian Bakeries. *Energy Conversion and Management, Vol. 52, pp 564- 568, 2010*.

Elwany, H., M. Shouman, M. Abou-Ali (2013). Production scheduling techniques- a review. Available at www.staff.zu.edu.eg/drshouman/userdownloads/paper (accessed 15/10/2013).

Everett, E. A., J. E. Ronald (2000). *Production and Operations Management: concepts, models and behavior*, 5th Edition, Prentice-Hall, India.

He, H., R. Hoseney (1991). Gas retention of different cereal flours. *Cereal Chemistry*, Vol. 68 (4), 334 –336.

Heizer, J., B. Render (2009). *Operations Management*. Pearson Prentice Hall (Flexible Version), 9th Edition New Jersey 07458, 362 – 380.

Kim, J.C., D. De Ruiter (1968). Bread from non- wheat flours. *Food Technology, Vol* 22, 867-878.

Koteeswaran, G. P., E. Shayan, R. Rajabpour (2004). Buffer estimation in a mixed-model assembly line.Proceedings of the fifth Asian Pacific Industrial Engineering and Management Systems(APIEMS)conference,PP14.5.1-14.5.12.Available www.apiems.net/archive/2004_14.5pdf (accessed 15/10/2013).

Lin, J. S., J. J. R. Ou (2011). A study on supply chain value-added logistics based on the great Chinese market. *International Journal of Electronic Business Management*, Vol. 9, No. 1, 58-69.

Madu, A. C. (2006), Optimization of energy, manpower and inventory requirement for the bakery industry in Nigeria. M. Eng. Degree project report submitted School of Postgraduate Studies, University of Nigeria, Nsukka.

Nwanya, S. C., A. C. Madu (2013), Inventory Optimization of Bakery Supply Chain for Food Security in Nigeria. International conference of the Nigerian Institute of Industrial Engineers: Industrial Engineering and National Transformation, November 13 – 15, 2013, Owerri, Nigeria.

Nwanya, S. C., R. Taccani, M. Reini (2009), Absorption Refrigeration for Sustainable Food Security in Remote Areas of Nigeria. [Online] available from http://www.rmrdctechnoexpo.org/.../Absorption%20Refrigeration%20sust

Okolie, P. C., E. C. Okafor, E. C. Chinwuko (2010). Optimal production mix for bread industries: a case study of selected bakery industries in eastern Nigeria. *Journal of Engineering and Applied Sciences,* Vol. 5 (6), 403- 412. Available at www.academia.edu/1376650/optimal (accessed 14/10/2013).

Onwumere, J., A. C. Nwosu, J. A. Nmesirionye (2012). Assessment of the effects of external capital mobilization on the equipment investment of bakery enterprises in South Eastern Nigeria. *Int. Journal of Economics and management sciences,* Vol. 1 (9) 83- 89.

Oyeku, O. M., C.F. Kupoluyi, A.A. Osibanjo, C.U. Orji, F.N. Ajuebor, I.O. Ajiboshin, W.B. Asiru (2008). An Economic Assessment of Commercial Production of 10% Cassava-Wheat Composite Flour Bread. Journal of Industrial Research and Technology Vol. 2 (1), pp 13-20. Available www.fiiro.org/jdownloads/Published%20Journals/fiiro_jirt03_13-20.pdf (accessed 12/11/2015).

Payne, A. C., J. C. Chelsom, L. R. P. Reavill (1996). *Management for Engineers*. John Wiley Publishers, New York, pp 409 – 430.

Ruteri, J. M., Q. Xu (2009). Supply chain management and challenges facing the food industry sector in Tanzania. *International Journal of Business and Management,* Vol. 4 (12), 70 – 80.

Vutete, C., N. Bobo (2015). The impact of bakery industry supply chain on the pricing of bread in Zimbabwe. *Greener Journal of Business and Management Studies,* V. 5(1), 1-15.

Appendix 1. Abridged Questionnaire Specimen

	Item	Nature of response
1	Bakery capacity	No of bag(s) of wheat flour baked per day…
2	Manpower requirement 1. Strength of Manpower 2. Working hours per day 3. Working days per month 4. Minimum wage and salary per worker 5. Availability of manpower (yes/No)	 No of workers… No of hours… No of days… Average monthly pay N ………… ………… shortage / surplus
3	Energy utilization 1. Sources: (Tick correctly) 2. Volume or quantity Per month (kJ/Ib/N) 3. Oven type	…………. ……………. Electricity private plant ……….etc …………… ……….. ………….. …….. electricity private plant kerosene ……. ……… ……… …….. Lpg diesel petrol etc. … …. ….. …. …. ….. ….. mud wood fired electric (local) (foreign)
4	Type of vehicle	…………. ……………. Diesel petrol
5	Problems facing the industry	…………………….