Vol. 8 No. 2
November 2017

Print- ISSN: 1391-586X

E- ISSN: 2602-9030

JSc

Journal of Science

Eastern University, Sri Lanka

Published by Faculty of Science

JSc

Journal of Science

Eastern University, Sri Lanka

Print- ISSN: 1391-586X

E- ISSN: 2602-9030

Address: The Editor, Journal of Science, Faculty of Science, Eastern University, Sri Lanka.

Journal of Science - Eastern University, Sri Lanka

Vol. 8 No.02 **November 2017**

CONTENTS

Print- ISSN: 1391-586X

E- ISSN: 2602-9030

Published by Faculty of Science, Eastern University, Sri Lanka

JSc EUSL(2017) Vol. 8 No. 2, p 1-11,

Print- ISSN: 1391-586X, E- ISSN: 2602-9030,

STORAGE EVALUATION OF COOKIES PRODUCED FROM COMPOSITE BLENDS OF WHEAT AND SWEET POTATO FLOUR

Jemziya[1], M.B.F., and Mahendran, T[2]

[1]Department of Biosystems Technology, Faculty of Technology, South Eastern University of Sri Lanka, Oluvil.

[2]Department of Agricultural Chemistry, Faculty of Agriculture, Eastern University, Sri Lanka.

ABSTRACT

A study was conducted to develop incorporated wheat and sweet potato flour cookies and to assess the quality of cookies during storage. Different composite blends of wheat flour and sweet potato (cv. Wariapola Red) flour were mixed in the ratios of 100:00, 80:20, 60:40, 40:60, 20:80 and 00:100, were then developed. These cookies were packed in sealed laminate aluminum foil. Cookies were stored under ambient conditions of average temperature of 30+1 °C and relative humidity 75-80 % for evaluation of the shelf life. Cookies were subjected to quality assessments at two week intervals for the entire storage period of 6 months. Among the treatment, the composite superior cookies supplemented with 40 % sweet potato flour contained 1.75 % ash, 4.15 % fiber, 5.42 % fat, 6.76 % protein and 84.4 % soluble carbohydrate at the end of 12 weeks of storage. However, moisture content of these cookies increased from 1.35 to 2.01 % which is within acceptable range for long term storage. The results of organoleptic assessment revealed that there were no significant differences ($p < 0.05$) between the treatments in terms of colour, mouth feel and overall acceptability while taste and texture had significant differences ($p > 0.05$) among the tested treatments. From the results of quality assessments, 40 % composite cookies could be stored in above mentioned conditions for a minimum period of 12 weeks without any significant changes in the quality attributes.

Keywords: Cookies, nutritional quality, organoleptic evaluation, sweet potato, wheat flour

[1]*Corresponding author*: fathimajemziya@yahoo.com

1. INTRODUCTION

Sweet potatoes (*Ipomoea batatas*) are absolutely loaded with nutrition and considered to be one of nature's most perfect vegetables. Among the world's major food crops, sweet potato produces the highest amount of edible energy per hectare per day [1]. Sweet potato consists of about 70 % carbohydrates (dry basis) of which a major portion is starch, which can be utilized as a functional ingredient in certain food preparations. They are an excellent source of vitamin A (in the form of β-carotene) and also a very good source of vitamin C and manganese. In addition, sweet potatoes are a good source of dietary fiber, natural sugars, protein, niacin, vitamin B_5, vitamin B_6, vitamin E, potassium, biotin, iron, calcium and copper.

Sweet potato is commonly referred to a subsistence, food security or famine relief crop. Its uses have diversified considerably in the developing countries. Sri Lanka has a long history of sweet potato cultivation. It is considered as a crop of exotic origin, but people regard it as indigenous because it has been in cultivation in Sri Lanka as an important traditional food crop from very ancient time [2]. Options for sweet potato products are numerous, and based on recent diagnostic assessments carried out in developing countries; dried chips, starch and flour were identified as among the most promising [3], [4]. Fresh sweet potato roots are bulky and highly perishable therefore sweet potato roots can be sliced, dried and ground in order to produce flour that remains in good condition for a long time. Sweet potato, either fresh, grated, cooked and mashed, or made into flour, could with high potential for success, replace the expensive wheat flour in making buns, chapatis (flat unleavened bread) and mandazis (doughnuts).

Mixture of wheat flour and sweet potato flour could make a good baking product, which should increase its economic value [5]. Most of the technical research on sweet potato flour has been focused on the development of new products using sweet potato flour rather than on efficient methods to produce and store the flour [6], [1]. Addition of various proportion of sweet potato flour in wheat flour can increase the nutritive values in terms of fiber and carotenoids. This also helps in lowering the gluten level and prevent from coeliac disease [7]. Sweet potato based products are of high quality and could compete with existing products in the market [8]. The use of sweet potato flour for supplementing with wheat flour on the baking could substantially reduce the need for wheat being imported, reduction in the usage of sugar on the products and increase the value of sweet potato.

Our approach in the present study is to replace the wheat flour in cookies by sweet potato flour (gluten-free flours) in order to increase the fiber and other nutrients and developing cookies resembles as closely as possible to the wheat flour based product. The textural property and sensory quality of cookies are taken into consideration to improve the quality of cookies and also to reduce the postharvest losses of sweet potato by making sweet potato flour suitable for local conditions and to propose suitable sweet potato value added products and recipes that can be made from sweet potato flour.

2. MATERIALS AND METHODS

2.1 Procurement of Materials

Good qualities of sweet potatoes (cv. *Wariapola Red*) without any bruises were procured locally from the field of commercial grower after harvesting. Roots were washed, trimmed and cured to make them free from soil and other foreign materials, rotting, insect damage. Trimming was carried out manually and curing was done at 35 °C for 2-3 days, stored at 12-15 °C at 80 % relative humidity till further use. Other major ingredients that are wheat flour, sugar, baking powder, salt and margarine were purchased from a wholesale merchant from Batticaloa.

2.2 Preparation of Sweet Potato Flour

Good qualities of sweet potatoes (cv. *Wariapola Red*) were washed, peeled and cut into thin slices at around 1mm thickness. Drying of sweet potato slices was done on perforated trays in the sun until the pieces were quite brittle and then stored in air tight container till further use. The dried chips were milled into flour using electric grinder and passed through sieves (250 µ) to obtain flour of uniform size. The flour was then packed in air tight container and stored under ambient conditions until further use.

2.3 Experimental Plan

T_1 - Cookies made from 100 % wheat flour (0+100 g)
T_2 – 20 g Sweet potato flour /100 g mixture (20+80 g)
T_3 – 40 g Sweet potato flour /100 g mixture (40+60 g)
T_4 – 60 g Sweet potato flour /100 g mixture (60+40 g)
T_5 – 80 g Sweet potato flour /100 g mixture (80+20 g)
T_6 - Cookie made from 100 % sweet potato flour (100+0 g)

2.4 Development of Wheat and Sweet Potato Blend Cookies

Cookie dough was prepared according to the following formula: 100 g of flour (contain different proportion of sweet potato flour and wheat flour), 50 g of sugar, 20 g of margarine, 2 g of baking powder, 0.5 g of sodium chloride and various proportion of water to make required consistency of dough. The firm dough was rolled out to 5mm thickness in a baking tray and cut into round having 7.4 cm diameter with a cookie cutter. The cookies were placed on a greased aluminum tray and baked in a pre-heated oven at 200 °C for 10 minutes to produce cookies. These cookies were assessed for physico-chemical and organoleptic qualities.

2.5 Package, Storage and Shelf Life Evaluation

The cookies were packed in sealed laminate aluminum foil which is commercially used to pack the cookies. Cookies packs were stored under ambient conditions of average temperature of 30 °C and relative humidity 75-80 % for 6 months. The shelf life of cookies was examined based on the nutritional and sensory qualities once in two weeks.

3. RESULTS AND DISCUSSION

3.1 Nutritional Composition of the Freshly Made Sweet Potato Flour

The results of nutritional composition of sweet potato flour are closely related with the results obtained by researchers in 2008 [1]. The moisture content of sweet potato flour was 8.1 %. Sweet potato flour had fiber content 9.4 %. This high fiber increases the utility of sweet potato flour in various food products and also had lesser extent of protein content 2.3 % compared to the wheat flour 12.6 %. Most non wheat flours have less protein but higher carbohydrate content than wheat flour [9], [10].

3.2 Shelf Life Evaluation of Composite Flour Cookies

Based on the physical, nutritional and sensory analysis of freshly made wheat-sweet potato cookies, the most preferred wheat-sweet potato cookies were selected for storage studies.

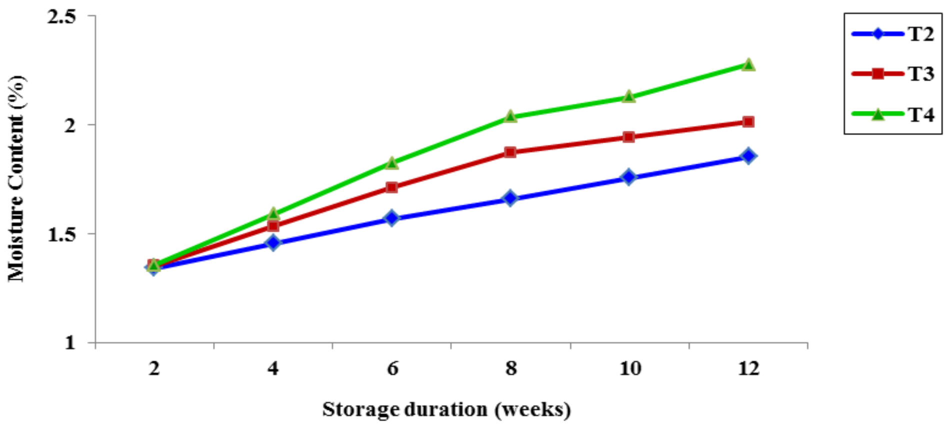
Treatment	Flour Composition
T_2	20 g Sweet potato flour / 100 g mixture
T_3	40 g Sweet potato flour / 100 g mixture
T_4	60 g Sweet potato flour / 100 g mixture

3.3 Nutritional qualities of wheat-sweet potato cookies during storage

3.3.1 Moisture Content

Nutrient content of all treatments have very little changes throughout the storage period. Certain researcher reported the moisture content in baked goods vary from 4 to 7 % [11]. According to DMRT, moisture content increased significantly (p<0.05) likewise, ash, fat, protein and fiber content decreased significantly (p<0.05) throughout the storage period (Figure 1).

Cookies are hygroscopic nature. In case of moisture content, T_2 and T_3 have the slow rate of increasing trend than T_4 (60 % sweet potato flour added cookie). In the T_3, there was no significant difference from 4th to 10th weeks of storage period.



Values are means of triplicates

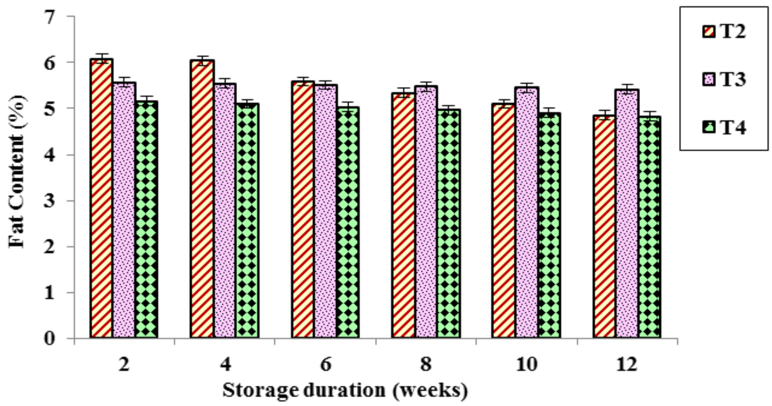
Figure 1: Changes in Moisture Content of Wheat-Sweet Potato Cookies during Storage

3.3.2 Ash Content

Ash content of T_4 has the very slow rate of decreasing trend than T_2 and T_3 and there was no significant difference in ash content of T_4 throughout the storage duration. Mineral losses may occur by heat - induced chemical reactions between reducing sugars and amino acids or proteins to form compounds that bind minerals. Considerable amounts of some soluble minerals are also dissolved in the water. This also leads to mineral loss throughout the storage period due to hygroscopic nature of the product. Likewise packaging can alter the food composition and thus influence mineral bioavailability.

3.3.3 Fat Content

Sweet potatoes are one of the limited fat content sources. Fat can help leaven a product due to incorporation of air [12]. Shortening of fat or oil contribute to the tenderization of baked products through inhibition of gluten development and starch gelatinization. This is through a water proofing effect, possibly due to the complex with the carbohydrate and/or protein. Lipid oxidation is one of the major causes of food spoilage. As shown in Figure 2, the treatment T_3 has the very slow rate of decreasing trend than all other treatments. There were no significant differences in all treatments from 4th week until the end of the study period.



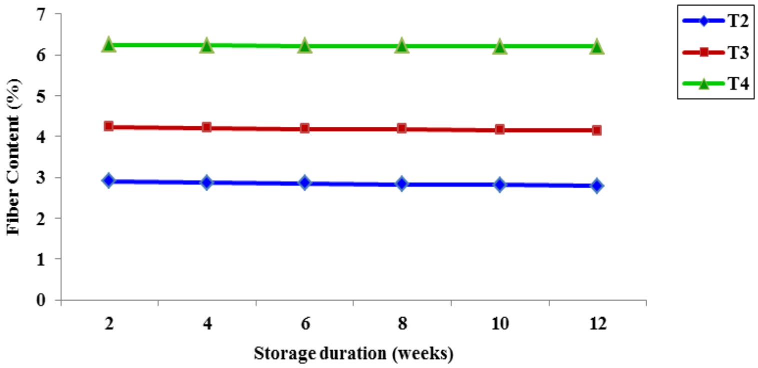
Values are means of triplicates
Vertical bars indicate the standard errors.

Figure 2: Changes in Fat Content of Wheat-Sweet Potato Cookies during the storage

3.3.4 Fiber Content

Fiber content in all treatments has very little changes during the storage period shown in Figure 3. Processes involving heat-treatment may affect the dietary fiber in different ways. An increased temperature leads to a breakage of weak bonds between polysaccharide chains.

Reactions during processing that may affect the dietary fiber content and its properties are leakage into the processing water, formation of Maillard reaction products thus adding to the lignin content and formation of resistant starch fractions. Even though, T_3 has the very slow rate of decreasing trend than all other treatments. There was no significant difference in fiber content of T_4 from 4^{th} week until the end of the study period.



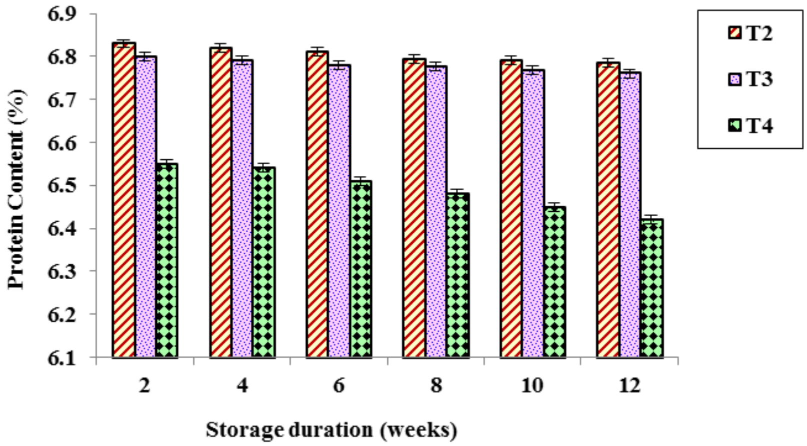
Values are means of triplicates

Figure 3: Changes in Fiber Content of Wheat-Sweet Potato Cookies during Storage

3.3.5 Protein Content

The various flour proteins present in wheat and sweet potato can undergo changes such as protein cross-linking, protein-carbohydrate interactions and protein denaturation during processing and storage of foods, non-enzymatic reaction may cause food deterioration and reduce the shelf life [13]. The changes in protein of the cookies during the storage are shown in Figure 4.

Treatment T_2 and T_3 have the very slow rate of decreasing trend than T_4. There were no significant differences in all treatments throughout the study period. This may occur due to interaction between reducing sugars and amino acids (Maillard reaction) and it is a major cause of quality change and degradation of nutritional content in many foods.



Values are means of triplicates

Vertical bars indicate the standard errors.

Figure 4: Changes in Protein Content of Wheat-Sweet Potato Cookies during Storage

3.4 Sensory Analysis of Wheat-Sweet Potato Cookies Following Storage

Organoleptic characteristics of the cookies were changed slightly following the storage period. This may be due to the non-enzymatic browning reaction (Maillard reaction) and fat oxidation. Development of off flavours as a result of oxidation, particularly fats. During the storages of food, Maillard reaction has impact on sensory qualities [14].

The 40 % sweet potato flour added cookie (T_3) has the best shelf life in based on the nutritional and organoleptic point of view compared to other combinations of wheat and sweet potato flour. Mean values of sensory attributes of stored wheat-sweet potato cookies are shown in Table 1.

Table 1: Sensory Analysis of Wheat-Sweet Potato Cookies following Storage

Treatments	Texture	Mouth feel	Taste	Colour	Overall acceptability
T_2	4.52± 0.11^{b}	4.40±0.12^{a}	4.30±0.15^{b}	4.65±0.10^{a}	4.35±0.11^{a}
T_3	4.82±0.05^{a}	4.25±0.15^{a}	4.50±0.11^{ab}	4.80±0.07^{a}	4.60±0.11^{a}
T_4	4.42±0.11^{b}	4.16±0.15^{a}	4.80±0.07^{a}	4.75±0.08^{a}	4.50±0.11^{a}

The values are means of 20 replicates ± standard error.
The means with the same letters are not significantly different from each other at 5 % level based on.

From the overall acceptance rating, the 40 % sweet potato flour added cookie has the highest mean value and no remarkable changes in organoleptic characters were observed up to three months of storage in ambient condition of average temperature 30 °C and relative humidity of 75-80 %, indicate that the 40 % sweet potato flour added cookies could be preserved up to three months. Tukey's Studentized Range (HSD) Test. The sensory attributes were analyzed in ranking test with the values from 1 to 4.9. The 40 % sweet potato flour added cookie (T_3) has the best shelf life in nutritional and organoleptical point of view compared to other combinations of wheat and sweet potato flour. From the overall acceptance rating, the 40 % sweet potato flour added cookie has the highest mean value and no remarkable changes in organoleptic characters were observed up to three months of storage in ambient condition of average temperature 30 °C and relative humidity of 75-80 %, indicate that the 40 % sweet potato flour added cookies could be preserved up to three months.

4. CONCLUSIONS

Sweet potatoes are an excellent source of nutrition and very productive crop among other vegetable crops. In this regard, this study was carried out to reduce the wastage and improve the utilization of sweet potato through the year. The finding of the research revealed that sweet potato contains considerable amount of protein, rich in dietary fiber and carbohydrate, therefore a successful combination with wheat flour for cookies production would be nutritionally advantageous. Therefore, 20, 40 and 60 % sweet potato flour incorporated cookies were selected as the best combinations based on the nutritional and organoleptic characters. Among the tested treatments, 40 % sweet potato flour incorporated cookies have the best shelf life and have highly acceptable functional, nutritional and organoleptic quality characters compared to other combinations and no remarkable changes were observed up to 12 weeks of storage in ambient condition of average temperature 30 °C and relative humidity of 75-80 %, indicating that the 40 % sweet potato flour added cookies could be stored up to 12 weeks. Blending sweet potato flour with wheat flour up to 40 % level produced cookies which can be used for production of bakery foods with improved functional properties using innovative processing methods according to their specific and distinct functional and nutritional properties. The use of sweet potato flour for supplementing with wheat flour on the baking could substantially reduced need for wheat being imported, reduction in the usage of sugar on the products and increase the value of sweet potato. The outcome of this research could be used as valuable information for the development of high fiber-low gluten sweet cookies.

REFERENCES

[1] Sukhcharn, S., Riar, C. S., and Saxena, D. C., (2008). Effect of incorporating sweet potato flour to wheat flour on the quality characteristics of cookies. *African Journal of Food Science*. **2:** 65-72.

[2] Karunathilake, E. K., (2005). *Horticulture Vegetable Science (Vegetables, Tubers, and Spice crops)*, 120-122.

[3] Collins, M., (1989). Economic Analysis of Wholesale Demand for Sweet potatoes in Lima, Peru. M.Sc. Thesis. Department of Agricultural and Resource Economics, University of Florida, Gainesville, USA, 1-164.

[4] Okorie, S. U., and Onyeneke, E. N., (2012). Production and quality evaluation of baked cake from blend of sweet potatoes and wheat flour. Part-I: *Natural and Applied Sciences.* **3:**2-10**.**

[5] Zuraida, N., (2003). Sweet potato as an alternative food supplement during rice shortage. *Journal Lit bang Pertanian.* **22**: 4-11.

[6] Lizado, M. L. C., and Guzman, M. P., (1982). Development of new products using sweet potato flour. *Economic Journal*. **10**(1)**:** 62-69.

[7] Tilman, J. C., Colm, M. O. B., Denise, M. C., Anja, D., and Elke, K. A., (2003). Influence of gluten free flour mixes and fat powder on the quality of gluten free

biscuits. *European Journal of Food Research and Technol*ogy, **216:** 369-376.

[8] Sneha, S., Genitha, T. R., and Vrijesh, Y., (2012). Preparation and Quality Evaluation of Flour and Biscuit from Sweet Potato. *Journal of Food Processing and Technology*. **3**:12-21.

[9] Tindall, H. D., (1968). *Commercial vegetable growing*. Oxford: oxford university press, 234-279.

[10] Okorie, S. U., and Onyeneke, E. N., (2012). Production and quality evaluation of baked cake from blend of sweet potatoes and wheat flour. Part-I: *Natural and Applied Sciences*, **3:**2-11**.**

[11] Manley, D. J. R., (1998). Biscuit, Cookies and Crackers Manufacturing, Manual No VI: Packaging and Storing. 3rd Ed., Wood head Publishing Limited, England, 5-37.

[12] Brooker, B., (1998). The Role of Fat in biscuits: *Strategy for Fat reducing products.* Wood Head publishers, Cambridge, UK. 127-168.

[13] Singh, R. P., (2000). Scientific principles of shelf life evaluation. In: *Shelf life Evaluation of Foods.* 2nd ed. Man, D. and Jones, A. (Ed.). Aspen publishers. Inc., Gaithersburg, Maryland, 3-4.

[14] Fennema, O. R., (1996). *Food chemistry*. 3rd ed. CRC Press. Wisconsin, USA, 157-412.

JSc EUSL(2017), Vol. 8 No. 2, p 12-19

Print- ISSN: 1391-586X, E- ISSN: 2602-9030,

LINEAR PROGRAMMING APPROACH FOR DOCTORS SCHEDULING IN A HOSPITAL

Paramadevan, P[1]

[1]Department of Mathematics, Faculty of Science, Eastern University, Sri Lanka

---

ABSTRACT

The main objective of this study is to propose an optimization model for achieving efficient scheduling of doctors attached to any hospital. In the recent literatures, a wide variety of different methodologies and models have been developed pertaining to various scheduling problems. These include Mathematical Programming, Meta-Heuristic Methods and Constraint Satisfaction Techniques. First, an optimization model is formed by formulating the objectives and the constraints of the problem mathematically. Further, the real doctors' scheduling problem is formed as a 0-1 Integer Linear Programming problem. To solve the problem, Branch-and-Bound technique is applied by using the optimization software package LINGO. Finally, the solution to the optimization problem is converted to a regular doctors' schedule. The methodology is illustrated by preparing a weekly schedule for a private hospital in Sri Lanka which has 32 doctors of the same grade.

***Keywords*:** Doctor scheduling, Mathematical Programming, Meta Heuristic Methods, Constraint Satisfaction Techniques, Column generation, Branch-and-Bound technique.

[1]*Corresponding author*: paramdeve@yahoo.com.au

I. INTRODUCTION

Sri Lanka holds a unique position in South Asia as one of the less developed nations to provide universal health at almost free of charge. Sri Lankan government health service institutions and public hospitals have huge percentage of patients visiting every day for treatment and consultation compare to private hospitals.

In Sri Lankan hospitals, doctors try to provide tremendous service for public to solve their health-related issues in time. However, it is observed that many doctors are dissatisfied with their jobs, which is mainly due to their long working hours, and continuous night schedules without proper rest. This can affect patient care and reduce quality of the service. The main issue is that the current doctors scheduling systems in place are not intelligent enough to bring a unique scheduling solution satisfying various demands without affecting even the health and personal preferences of doctors. One of the possible mechanism to reduce the stress of the doctors may be that, prepare roster with utmost satisfaction of their preference on working day or shifts. Hence, the major objective of this study is to create a mathematical model related to the real-world problem arising from the operations of a hospital, which termed as Doctors Scheduling Problem (DSP) and propose a method to find solution in an efficient way.

A doctor schedule provides an assignment to doctors who need to perform different duties in the roster. Unlike Nurse Scheduling Problems (NSP) [1], in doctors scheduling, maximizing satisfaction only matters, since authors' retention is the most critical issue faced by hospital administrators in most of the western countries [2]. In addition, while nurse schedules must adhere to collective union agreements, doctor's schedules are more driven by personal preferences. In general, the DSP need to consider many conflicting constraints along with various preferences from doctors. In [2], the authors provide the fundamental difference between DSP and NSP. According to available literature DSP focuses primarily on a single type of duty, such as the emergency treatment unit [3], the operation theatre [4], and the physiotherapy unit [5].

This study proposes a mechanism based on 0-1 integer linear programming to prepare a roster for a group of doctors attached to a hospital for a period of one week. The proposed method is less complex compared to the existing methods since the approach Branch-and-Bound is a common technique in the scheduling field. Further, this approach does not only provide an idea to prepare a roster but it also allows the inclusion of some additional features which is more challenging in the manual roster preparation. The remainder of the paper is organized as follows. Section II, describes in detail the proposed optimization model for doctors scheduling. Section III presents the results obtained by applying our optimization model to a hospital in Sri Lanka. Section IV discusses the results and draw the conclusions.

2. THE PROPOSED MODEL

To presenting the optimization model, the notations and meanings of technical terms that are being used in the sequel is explained in this section.

1. Let $C=\{1,2,.......\hat{c}\}$ be the set of doctors. For any $c\in C, Y_c$ and Z_c be the maximum number of day shifts and maximum number of night shifts to be assigned for the doctor c within the scheduling period respectively.

2. Let $W=\{1,2,.......\hat{w}\}$ be the set of wards/units in the hospital to which doctors to be assigned.

3. Let $T=\{1(morning), 2(evening), 3(noon), 4(night)\}$ be the set of shift types. Here, all the shift types 1, 2 ,3 and 4 have equal length of 6 hours starting from morning 6 AM onwards. In this paper shift types 1,2 and 3 are mentioned as day shifts while shift type 4 is mentioned as night shift, it starts from mid night 12.00 in the particular day and ends 6 AM in the next day.

4. Let $D=\{1,2,.......\hat{d}\}$ be the days in the scheduling time horizon.

5. Let $R_{w\_d\_t}$ to be a demand for number of doctors to be at the ward $w\in W$ on a day $d\in D$ of shift type $t\in T$.

6. Let k_1 be the maximum number of consecutive day shifts, while k_2 be the maximum number of consecutive night shifts within the scheduling period respectively.

7. Let $P_{c\_w\_d\_t}$ to be a penalty occurs, if the doctor $c\in C$ is scheduled to work at the ward $w\in W$ shift type $t\in T$ on a day $d\in D$.

Here the required task is to assign doctors for different shift types to different wards according to the demand on each shift on a day in the planning time horizon. It should satisfy the following standard requirements which are common to most of the DSP.

a) Demand at any shift type on a particular day should be satisfied.

b) A doctor should be assigned for at most one shift among four available shifts on a day.

c) At most maximum number of working days/day-shift should be assigned for a doctor within the time horizon considered.

d) At least minimum number of day shifts should be assigned for a doctor within the time horizon.

e) At most maximum number of night shifts should be assigned for a doctor in the time horizon.

f) At least minimum number of night shifts should be assigned for a doctor in the time horizon.

In addition to these standard requirements following special requirements are request by the doctors:

g) Shift type 1 should not be assigned for a doctor if he/she assigned for a night shift (shift type 4) of the previous day.

h) Maximum number of consecutive working days is 3.

i) Maximum number of consecutive night shifts is 2.

Next, the decision variables are being introduced. Let

$$x_{n\_w\_d\_t} = \begin{cases} 1, \text{if doctor n is assigned } \textit{to the ward w} \text{ for the shif type t on } a \text{ day } d \\ 0, \text{other wise.} \end{cases}$$

The optimization model which incorporates both common and special requirements can be presented as:

Minimize

$$\sum_{n \in N} \sum_{w \in W} \sum_{d \in D} \sum_{t \in T} p_{c\_w\_d\_t} \, x_{c\_w\_d\_t}$$

Subject to

$$\sum_{c \in C} x_{c\_w\_d\_t} = R_{w\_d\_t} \,, \; \forall w \in W, \, d \in D, \, t \in T$$

$$\sum_{w \in W} \sum_{t \in T} x_{c\_w\_d\_t} \le 1, \quad \forall c \in C, \, d \in D$$

$$\sum_{w \in W} \sum_{d \in D} \sum_{t \in T} x_{c\_w\_d\_t} \le Y_c \,, \quad \forall c \in C$$

$$\sum_{w\in W}\sum_{d\in D}\sum_{t\in T} x_{c\_w\_d\_t} \geq y_c\,,\ \ \forall c\in C$$

$$\sum_{w\in W}\sum_{d\in D} x_{c\_w\_d\_4} \leq Z_c\,,\ \ \forall c\in C$$

$$\sum_{w\in W}\sum_{d\in D} x_{c\_w\_d\_4} \geq z_n\,,\ \ \forall c\in C$$

$$x_{c\_w\_d-1\_4} + \sum_{w\in W} x_{c\_w\_d\_1} \leq 1,\ \forall c\in C,\ w\in W,\ d\in D$$

$$\sum_{w\in W}\sum_{d=l}^{k_1+l} x_{c\_w\_d\_t} \leq k_1,\ \ \forall c\in C, l\in\{1,2,..,Y_c\}$$

$$\sum_{w\in W}\sum_{d=l}^{k_2+l} x_{c\_w\_d\_t} \leq k_2,\ \ \forall c\in C, l\in\{1,2,..,Z_c\}$$

The mathematical model described above is for preparing a work schedule for doctors in a hospital. These schedules must respect working contracts and meet the demand for a given number of doctors on a ward in each shift type, while being perceived to be fair by the doctors themselves. The objective function of our optimization model is considered as a cost function, where cost is interpreted as penalty and penalty is defined based on the undesirability of a doctor to work at a particular ward at a particular shift type on a particular day. Therefore, our attempt is to minimize the penalty subject to the given constraints. These penalties appeared as coefficients in the objective function.

3. EVALUATION, RESULTS AND DISCUSSION

The hospital that considered in this paper as a practical example for applying this mathematical model consists 32 doctors and 4 wards. The hospital administration requires only one doctor for the ward number 1 and 2 for ward numbers 2, 3 and 4 at each shift type in a day. Hence, the demands considered in the mathematical model $R_{1\_d\_t}$ is equal to 1 while $R_{2\_d\_t}$, $R_{3\_d\_t}$ and $R_{4\_d\_t}$ are uniform and is equal to 2 for all shifts throughout the time horizon. Also, the maximum number of working days and maximum number of night shifts for a doctor are required to be 5 and 3 respectively. That is, $Y_c = 5$ and $Z_c = 3$ while minimum number of working days and

minimum number of night shifts are required to be 4 and 1 respectively. Further, the maximum number of consecutive working days, k_1 and maximum number of consecutive night shifts, k_2 within the scheduling period are required to be 3 and 2 respectively.
By using the above information obtained from the hospital administration as well as the doctors attached. A 0-1 integer linear programming model is formulated, which consists of 3584, 0-1 binary decision variables and 1553 constraints. The result obtained by solving the 0-1 Integer Linear Programming problem using the LINGO software package is presented in the table 1. Here, numbers represent the shift type for corresponding days:

In this table first row, ‘Day’ represents day number and the first column ‘Ward’ represents ward number. Since the demand for the doctors in the ward number 1 is 1, the doctor number (D.No) 28, 19, 17, 29 are assigned for the available four shifts (Shift.No) respectively on the day 1. While demands are 2 for all other three wards, two doctors are assigned for each shift. For example, doctors with number 19 and 13 have duty in the shift number 1, 14, and 25 have in the shift 2, 4 and 21 have in the shift no 3 and 2,29 have night duty in the ward number 2 on day number 1. From the above table, it can be observed that this hospital runs with shortage of doctors and the doctors are working beyond the limit, when considered the number of working days. Eight of them working the whole 7 days while some working 6 days. Only 5 of them are working for the acceptable number of working days that is 5.

Table 1: Doctors' schedule

Ward	Shift. No	Day 1 D.No		Day 2 D.No		Day 3 D.No		Day 4 D.No		Day 5 D.No		Day 6 D.No		Day 7 D.No	
1	1	28		26		15		25		11		8		24	
1	2	19		28		21		20		26		22		32	
1	3	17		17		19		29		4		5		26	
1	4	29		14		6		2		22		7		10	
2	1	10	16	31	24	29	25	22	21	28	23	28	30	19	31
2	2	7	14	25	7	6	24	14	18	20	7	15	6	14	25
2	3	12	21	8	23	17	1	27	26	5	8	5	9	4	21
2	4	6	7	30	9	4	18	8	9	17	21	12	14	2	29
3	1	7	23	12	7	32	23	16	17	6	29	13	18	3	9
3	2	11	15	5	29	9	27	12	32	18	25	23	31	1	8
3	3	26	24	10	16	13	31	7	11	7	27	2	21	5	27
3	4	4	25	1	5	2	26	4	13	9	24	14	29	16	23
4	1	1	9	15	22	11	28	3	30	14	32	19	27	22	30
4	2	13	20	6	18	5	10	1	10	2	30	4	32	6	15
4	3	5	31	4	13	30	16	19	21	1	10	20	17	20	13
4	4	32	27	20	19	8	12	5	15	3	31	11	26	12	28

D.N: Doctor Number

4. CONCLUSION

An optimization model for doctors scheduling has been developed. Also a method of solution to solve the model has been proposed. This method will guide to prepare a doctor schedule more efficiently, accurately and quickly for any hospital which consists of any number of wards which satisfies the doctors' preferences and regulations provided by the hospital administrators. This method also helps the administration to study the overload situations where it requires an appointment of new doctors. In our model, all doctors are considered as same grade. In reality doctors are in different grades such as Consultant, Senior Registrar, Registrar, House Officer etc. And their demands also vary according to their qualifications/experience. One of our future works in this study will incorporate the grades in the formulation of the mathematical model and this will produce more realistic results.

REFERENCES

[1] Paramadevan, P., and Daundasekera, W.B., (2013). Nurse scheduling based on Branch-and-Bound algorithm. *International journal of Scientific and Research Publications*, **3**(7):1-7.

[2] Carter, M.W., and Lapierre, S.D., (2001). Scheduling emergency room physicians. Health Care Management Science, **4**:347-360.

[3] Beaulieu, H., Ferland, J.A., Gendron, B., and Philippe, M., (2003). A Mathematical programming approach for scheduling physicians in the emergency room, Health Care Management Science, **3**:193-200.

[4] Burke, E.K., and Riise, A., (2008). A Surgery allocation and scheduling. In proceedings of the 7th International Conference of Practice and Theory of Automated Timetabling, Montreal, Canada, 18-22.

[5] Ogulata, S.N., Koyuncu, M., .and Karakas, E., (2008). Personnel and patient scheduling in the high demanded hospital services: a case study in the physiotherapy service, *Journal of Medical Systems*, **32**(3):221-228.

JSc EUSL(2017), Vol. 8 No. 2, p 20-37
Print- ISSN: 1391-586X, E- ISSN: 2602-9030,

DETERMINING THE OPTIMUM INVENTORY LEVEL OF A PRODUCTION LINE- A CASE STUDY ON AN UMBRELLA MANUFACTURING COMPANY IN SRI LANKA

Gunawardena, S.A.B.N[1*] and Perera, S.S.N[1]

[1]Department of Mathematics, Faculty of Science, University of Colombo, Sri Lanka

ABSTRACT

The top level management often addresses the capacity, inventory, demand, and customer satisfaction as separate decisions which lead to sub optimization of financial results and conflict of interests. Therefore this study considers the above variables simultaneously. The objective is to minimize the cost of production and lost demand. Cost of loss demand was included through the service level which is the probability of not being stock out. The SKUs are grouped into three based on their revenue contribution and allocated the service level. The production capacity varies mainly due to the number of working days and working hours, therefore will be a sub problem within the model. The optimization model was developed as a linear programming model as used Excel Solver to identify the optimum solution. The developed model generates the optimum cost compared to the current level by identifying an equilibrium between the cost of production and loss demand.

Key Words: Linear Programming, Revenue contribution, Service Level, SKU

[*]*Corresponding author*: gunawardena.bhagya@gmail.com

1. INTRODUCTION

The umbrellas have a history of more than 4,000 years where the evidence of umbrella were found in ancient artifacts of Egypt, Assyria, Greece and China. The ancient umbrellas were used to provide a shade from the sun and it was developed as a product only for the women.

The first waterproof umbrella was developed by the Chinese. However umbrella was popularized between the men from early 1700's. [1]. At present umbrella is a global consumer product and China act as the market leader in the global umbrella manufacturing industry. Umbrella manufacturing process includes several stages; starting from raw material purchase, cutting the fabric in accordance with the style, tailoring, frame assembling, complete to quality control. Only passing through all these stages, the finished umbrella will be available for the market to be purchased by the consumers. There are several factors affecting the succession of the any industry. The developed right technology, competent employees, and conductive organizational culture can be considered as the key driving forces which are controllable by the organization. However according to PESTEL analysis, there are external factors such as political, economic, social, technological, environmental, legal which an organization has no or minimal control, and therefore need to adjust in accordance with the changes of those factors.

When considering an umbrella manufacturing organization, among the above external factors, environmental factors, specifically the weather plays a key role when considering the demand for the product. Uncertainty of weather leads to uncertain demand patterns for umbrella which leads to over stocking as well as stock out situations for the umbrella manufacturers and retailers/distributors and thereby incurring an opportunity cost as well as losing the potential market. Therefore, proper inventory management is essential in order to survive in the market by providing the required products to the consumers as well as to reduce the opportunity cost. According to INVESTOPEDIA, Inventory management is the practice overseeing and controlling of the ordering, storage and use of components that a company uses in the production of the items it sells. Inventory management is also the practice of overseeing and controlling of quantities of finished products for sale. A business's inventory is one of its major assets and represents an investment that is tied up until the item sells.

In the modern business world, customer satisfaction can be considered as a key indicator which decides the survival of an organization in the market. Therefore having sufficient stock to meet the customer demand is critical considering a manufacturing and distribution organization. However stock can be considered as a cost which ties up around 30-40 % of their working capital. In the lean environment, inventory is considered to be one of the seven wastes (*see Appendix*) [2]. Therefore most of the companies tend to move towards Just In Time (JIT) production as well as Just In Time purchasing (*See Appendix*). However proper supply chain management is a crucial element in moving towards JIT system. Even though some companies consider stock as an element of cost, some regard it as an active component of business, because it can create market value through high service levels, availability of products with the quantities requested by the customers [3].Inventory management can be considered as a financial tradeoff between inventory costs and stock out costs. Because having a higher level of stocks may result in increased cost of capital, cost of space, stock carrying out cost, cost of obsolescence, and damages due to weather, security, insurance and etc. which are generally considered to be unavoidable. On the other hand, having a lower level of stocks may lead to inventory stock outs, hence missing the potential sales, and thereby losing the customer base and interrupting the whole production process. Hence, managing these inventories effectively and efficiently is one of the competitive edges available to such organizations. Therefore, finding the appropriate balance between inventory and capacity allows to meet the performance criteria while optimizing the firm's financial criteria [4].

In this study, the focus is on an organization, which manufactures and distributes several product categories all over the island. In that, umbrella manufacturing and distribution plays a key role in the production process as well as in the financial position of the company through significantly contributing towards the performance of the company. The company is highly affected by the uncertain demand patterns for the umbrella. Because, the demand is highly affected by the factors such as weather conditions, promotional activities, new products, market developments and competition. As a result, during the peak demand seasons, the company may not have sufficient capacity to cater the demand. Therefore, the company's current policy is to fully utilize the existing capacity during the off peak seasons and build up the inventory for the peak seasons. However due to this policy, there are some periods where the organization faces the issue of building up higher stock levels and there by tightening up the working capital. However reducing the inventory by low level of production leads to the underutilization of capacity, which will eventually result in high per units cost and thereby reducing the profit margin. The organization produces several styles of umbrella (SKUs- *See* Appendix), whose demand patterns are not identical. Similarly, different SKUs consume different levels of resources in production, hence they have different levels of cost of production as well as different level of selling prices.

Therefore the management is keen to identify the optimum stock level which need to be maintained in order to satisfy the customer demand, while achieving the performance and financial targets of the company. There are several research studies have been conducted to identify the inventory optimization in a demand driven supply network. They have considered several aspects, such as optimum capacity utilization, minimum inventory holding, and etc. According to Tratar, objective of forecasting in a demand driven supply network is to identify the probable range of expected demand [5]. Supply can cover the demand by either having sufficient capacity to replenish within the lead time or having safety stock. The safety stock is defined as the amount of stock need to compensate for supply and demand inefficiencies [5]. However most of the companies consider decisions on inventory and capacity as independent decisions.

Bradley & Arntzen (1999) [4] emphasize that the optimal decision on inventory and capacity depends on the relative cost of inventory and capacity. That is if the cost of capacity investment is high, then the organization should focus on the inventory investment and vice versa. In their study, they have observed that many companies have the decision on capacity being fixed at a minimal level as capacity considered to be more expensive than the inventory and hence inventory as the only lever which can be used to overcome the uncertainty and seasonality. According to Constantin (2016) [3], safety stock must be high enough to cover vendors' delivery time variances, forecast variances of customer demands in date and quantity, and inventory variance (difference in forecasted and actual inventory), but not so high that the company loses money because of high carrying cost. Companies can increase their inventory turnover which is a key performance indicator by efficient level of inventory; that is based on the definition, low level of inventory will lead towards high level of inventory turnover. On the other hand this expose the organization to the uncertainties and risk of stock outs [2]. This may result in customer dissatisfaction which will lead to unavoidable undesired outcomes regarding the demand in longer term. Therefore safety stock is required to protect against these uncertainties.

Safety stock determinations are not intended to eliminate all stock outs, but the majority of it. [6]. According to King (2011), demand variability is the dominant influence on the safety stock requirement. According to Dialog Axiata (2016), when determining the optimum inventory level for an organization, factors such as capital available to purchase/ produce stocks, existing consumer demand quantity, demand type, past year's sales, industry averages, carrying costs and available space need to be considered [7]. Literature suggests several different approaches in determining the optimum stock level. One is the Return on Operating Assets, which is a key performance indicator and therefore easy to communicate the outcome of the model to the stake holders and the corporate managers [4]. This study assumes demand for the end product to be deterministic. But in practical situations demand is more likely to be stochastic. Some studies focus on minimization of logistic costs in determining the optimum stock level [2].

Constantin (2016), [3] suggests a statitcal model considering the specific desired service level. Service level can be explained as the expected probability of not hitting a stock out or in other words probability of not losing sales [3]. However the service level may differ from product to product. According to Tratar (2009), most safety stock calculations within ERP systems use standard calculation methods which may be suitable for stable demand situations but not in situations where demand is seasonal. In this, only the demand variability among previous years being considered. According to literature, most of the organizations as well as the research studies try to identify the optimum stock levels considering the maximum utilization of capacity or minimum level of inventory costs and do not consider the service level which may lead to customer dissatisfaction and long term reduction in profitability. Some research studies focus on having safety stock level to mitigate the risk of being stock out. But, most of the time they decide on safety factor or the service level based on their instincts without specific criteria. The knowledge and the experience of the stock controller will be the base here. This study will try to identify the optimum stock level for the considering organization considering the service level, the cost of production, and the capacity. Here, the revenue contribution of the products will take into consideration in determining the service level of each product. This study will help to identify the required monthly production considering the required optimum stock which will support to maximize the customer satisfaction by delivering the goods as they request, but not having unintended stocks which may cause damages, increased carrying costs, and working capital tightening.

In the section 2 of this study, will present the methodology used in identification of the optimum inventory as well as the required production level for the company, with regard to the considering factors. In that, the supporting basic analysis will also be presented which have been used in deciding correlation, pattern and service level and etc. for the company. The section 3 will discuss the model structure, assumptions used in model developing, and model formulation procedure. Here, the objective function as well as the constraints will be illustrated in detail. The section 4 will include the results of the developed model. Finally, in the section 5, will discuss the suitability of this model for this company and conclusion of the study.

2. METHODOLOGY

As the first step, identify the relationship between rain and sales quantities since the sales of the products are assumed to be highly correlated with the rain. For this, monthly rainfall data from 2011 to 2015 which is obtained from the Department of Metrology and the monthly sales data of the company is used.

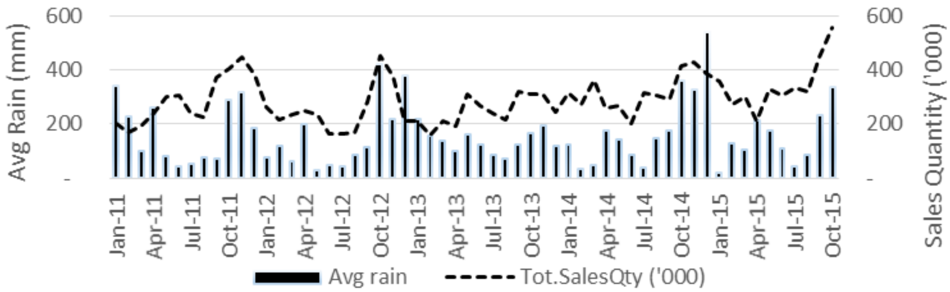


Figure 1: Rain vs. Sales comparison

Based on the Figure 1, within the period of October to December the rainfall is higher compared to the other months of a year. During the peak rain season, comparatively high sales can be observed. Even though highest sales can be observed during the beginning of the peak rain season, sales declines during the latter part of the same period in some years. The reason may be that the customers who are holding the products which they have already bought at the beginning of the period do not wish to purchase new items even though rain remains continuously. Then, to identify the overall relationship between the rain and sales, Pearson's correlation coefficient is used. To calculate the Pearson's correlation coefficient, Excel analysis tool was used.

Table 1: Pearson's correlation coefficient

	Average rain	Total sales quantity
Average rain	1	
Total sales quantity	0.44132	1

Based on the Pearson's correlation coefficient (Table 1), it is clear that there is a positive relationship between the rain and sales which means if the rain is high, sales quantity will be high and vice versa. However the significance of the relationship is low. Therefore it is clear that, even though there is a positive relationship between the rain and sales, there have to be significant impact from the factors such as promotional events, competition and etc. However, with the current situation, the impact of those factors cannot be measured.

As the next step, the production capacity and the sales level was analyzed. The company has a requirement of at least to fully utilize the minimum capacity which is about 1,800 dozens per day for 21 days (453,600 units per month). However based on the requirement, the capacity can be stretched up to 624,000units (approx.) per month.

The production capacity and demand is indicated in the Figure 2.

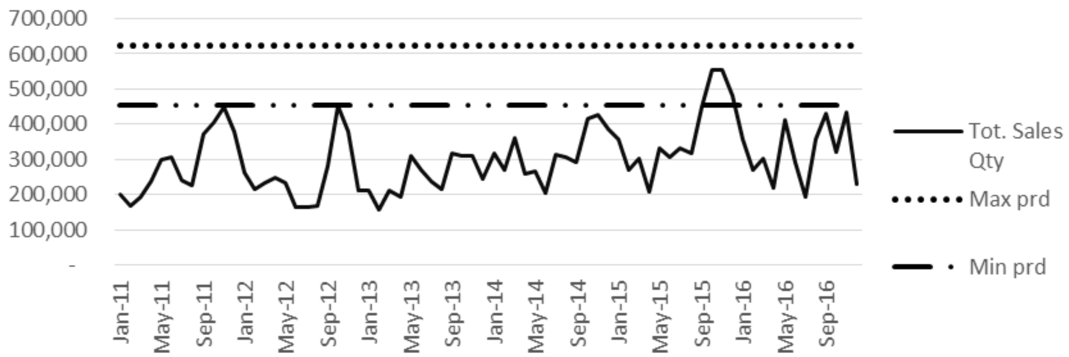


Figure 2: Sales and production levels

The production is carried out in order to full fill the currents months' sales requirement as well as to build up the closing inventory. During the peak season of sales, production may require to be at its upper limit. Even though the production is maintained at a constant level, the sales quantity varies period to period. As a result, the inventory level of the company may vary significantly. Therefore, the sales level and the behavior of the inventory level were then analyzed.

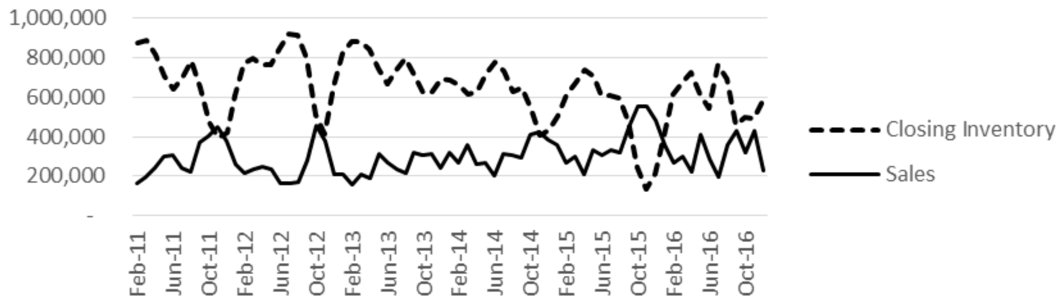


Figure 3: Sales vs. Inventory level

According to Figure 3, an opposite pattern of sales can be observed in the closing inventory level. That is, during the periods of high sales, low levels of closing inventory can be observed and vise-versa. The main reason for this pattern may be the constant level of production in order to fully utilize the capacity. In the month with higher sales, the closing inventory goes below the sales of that month, however closing inventory is always positive, indicating that at any given point the company is maintaining sufficient inventory. With the production level of the next month, again company is building up the inventory. However, it is clear that the organization is keeping a considerably higher level stock compared to the sales.

The company is manufacturing and selling several number of product styles (SKUs). All the products do not move in the same frequency, meaning some products has high sales quantities and some have low sales quantities. At the same time, the sales revenue from one sales unit varies from product to product. Therefore, an analysis on sales revenue contribution is carried out.In this analysis, the products were arranged in the descending order of their revenue contribution. The revenue from a product is calculated as;

*Revenue from a product = No. of units sold * Price per unit*

The percentage of revenue contribution is calculated as;

$$Revenue\ contribution\ of\ product = \frac{No.units\ sold\ from\ the\ product \times Unit\ selling\ price\ of\ the\ product}{\sum_{for\ all\ products}(No.units\ sold\ from\ the\ product \times Unit\ selling\ price\ of\ the\ product)} \times 100\%$$

Then, the cumulative percentage revenue contribution was calculated.

From the Figure 4, it is clear that only few products contribute more to the total revenue.

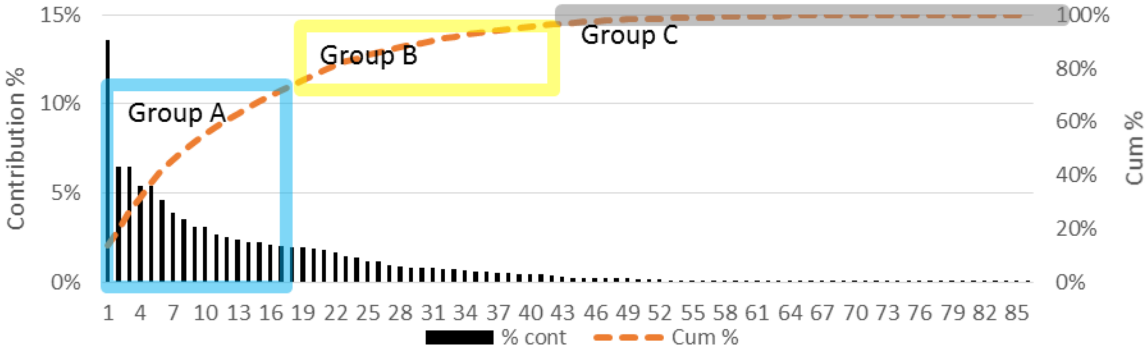


Figure 4: Percentage of Revenue contribution and cumulative % revenue contribution of the products

Based on the revenue contribution, the products are categorized into three groups. The categorization is carried out as follows.

Group A: Top 20 % of products which contribute most to the total revenue

Group B: Medium 30 % of products which contribute on average to the total revenue

Group C: Lowest 50 % of products which have the minimal contribution to the total revenue

Then, based on the product categorization, the revenue contribution is identified.

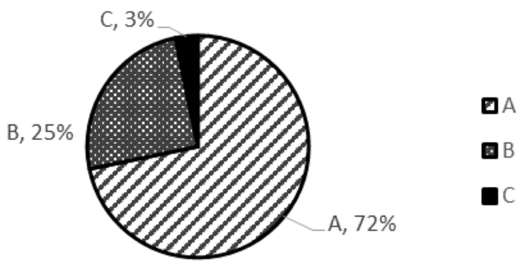


Figure 5: Category wise revenue contribution

According to figure 5, 72 % of the total revenue is generated only from the 20 % of the products, which are classified as “A”. Therefore, these products can be considered as the most important products in revenue generation for the company. Since these are the highest revenue generating products, these need to have the highest concern, and need to ensure the availability of the products when required. However 50 % of the total products, contributes only 3 % to the total revenue, therefore less important to the overall income. These products are classified as “C” and need the minimal consideration. Stock out situation of a unit in this group may have a lower impact compared to a stock out situation of a group A product on the overall performance of the organization. Their contribution is low; may be due to low profit margins or low level of sales. There are 30 % of products which contribute to 25 % of the total revenue and hence can be considered with middle importance and classified as “B”.

3. MODEL

3.1 MODEL STRUCTURE

The organization sets its monthly sales targets based on the demand variation and adding additional amount to cover the unpredictability of the demand. The production needs to be carried out in a way such that the required targets are met with the required service level during the period. According to the organization’s view, demand that cannot be satisfied in a specific period cannot be carried out for the next period. Therefore whatever required in a specific period need to be fulfilled during the required period, otherwise it will be considered as a loss sale. Some of the processes in the production process have limited capacity while the others have unlimited capacity as they can be outsourced without any additional costs.

In developing the model, following assumptions are made:

1. Raw materials are always available
2. Storage cost does not depend on the number of units stored
3. Availability of unlimited storage capacity
4. Processing time of each product in each process is deterministic
5. Loss demand during a specific period cannot be satisfied in later periods

3.2 Model Formulation

In the model formulation, the following decision variable are used.

$\boldsymbol{x_{it}}$	Number of units produced in product i in period t
$\boldsymbol{Wd_{jt}}$	Working days required in process j in period t
$\boldsymbol{OThrs_{jt}}$	Overtime hours required in process j in period t

Other data:

D_{it}	Demand for the product i in period t
c_i	Cost of production of product i
Pr_i	Profit of product i
SMV_{ji}	Standard minutes value (See appendix) to process in process j for a unit of product i
$OT\ rate_j$	OT rate in process j
Day_t	Working days available in period t
H_t	OT hours available in period t
Inv_{it}	Closing inventory of product i in period t
p_i	Service level of product i
Emp_j	Number of employees is process j

Objective Function

The sales amount varies not only due to the demand and the product availability, but also based on the sales representatives' capabilities. The main consideration in this study is to identify the optimum inventory level which facilitates the demand while minimizing the cost. Therefore the objective of this study is to minimize the directly attributable cost of production and the cost of loss demand.

The objective function considering a specific time period is to minimize:

$$Cost = Min_{t\geq 1, i\in P, j\in(Cut,Fin)}\ C(c_i, x_{it}) + L(Pr_i, D_i, x_{it}) + OT(OThrs_{jt}, rate_j) \text{ --- Eq. (1)}$$

The function $C(c_i, x_{it})$ represents the cost of production mainly considering the directly attributable manufacturing costs, excluding overtime cost where **P** is the products set.

The $L(Pr_i, D_i, x_{it})$ function indicates the lost sales due to the unsatisfied demand. The loss sales not only impact for the profit generation, but also several factors such as customer retention, reputation and competition. According to the literature [4] loss sales is worth three times of profit as if the sale is made.

The function $OT(OThrs_{jt}, rate_j)$ indicates the overtime cost in each processes.

Therefore the expanded objective function would be:

$$\textbf{Cost} = \textbf{Min}\left(\sum_{i\in P} c_i * x_{it} + 3 * \sum_{i\in P}\left(D_{i,t+1} - Inv_{it}\right) * Pr_i + \sum_{j\in Cut,Fin} OThrs_{jt} * OTrate_j\right)$$

;

$\forall t \geq 1$

Constraints

Closing Inventory:

The closing inventory of a specific product in a specific period is less than or equal to the opening inventory, plus the production, minus the sales of that period, and the closing inventory cannot be negative in any period for any product. (Eq- 2 & Eq -3).

$$Inv_{it} \leq Inv_{i,t-1} + x_{it} - D_{it} \quad \forall i \in P, t \geq 1 \qquad \text{---Eq. (2)}$$

$$Inv_{it} \geq 0,\ \forall i \in P, t \geq 1 \qquad \text{---Eq. (3)}$$

Service Level:

The service level should not be violated where this is the main indicator of the customer satisfaction. According to literature [3], group A products, which are the most critical items for the company should be assigned 96-98 % service level. That is, to ensure customer satisfaction, group A products can loss at most 2- 4 % of demand. Similarly, service level for group B products is 91-95 % and for group C products it is 85-90 %.

$$D_{it} - Inv_{i,t-1} \leq (1 - p_i)D_{it}, \forall i \in P, t \geq 1 \qquad \text{---Eq. (4)}$$

Production Capacity:

The required capacity for the production in a process cannot exceed the total capacity available in that process. The capacity is calculated based on the time required for the production and the available time which consist of normal working hours (9 hours) plus the overtime hours. Here 5 % allowance is given for the absenteeism; according to historical data, average attendance rate is 95 %.

$$\sum_{i\in P} SMV_{ji} * x_{it} \leq Emp_j * 95\% * (Wd_{jt} * 9 + OThrs_{jt}) * 60, \forall j, \forall t \qquad \text{---Eq. (5)}$$

Working Days and Overtime hours:

The required working days and the required overtime hours should be less than or equal to the available working days and overtime hours respectively. (Eq 6& 7)

$$\boldsymbol{Wd_{jt} \leq Day_t}\ ,\forall \boldsymbol{j}, \forall \boldsymbol{t} \qquad \text{---Eq. (6)}$$

$$\boldsymbol{OThrs_{jt} \leq H_t}\ ,\forall \boldsymbol{j}, \forall \boldsymbol{t} \qquad \text{---Eq. (7)}$$

Non negativity:

Any decision variable cannot be negative.

$$\boldsymbol{x_{it}, Wd_{jt}, OThrs_{jt}} \geq 0 \qquad \text{---Eq. (8)}$$

4. RESULTS AND DISCUSSION

The model formulation has begun with the actual opening inventory level. Then the arriving optimum closing inventory has used as the next period's opening inventory. Therefore at the beginning of the considering period, the required optimum production is lower due to high inventory holding at the beginning, leading to decreasing inventory till July. However according to figure 6, from July onwards, required optimum production level is comparatively higher than the actual production level, leading to increasing inventory to facilitate the seasonal impact, the variation of demand and to have the required closing inventory. However till November, the optimum inventory is lower than the actual inventory level.

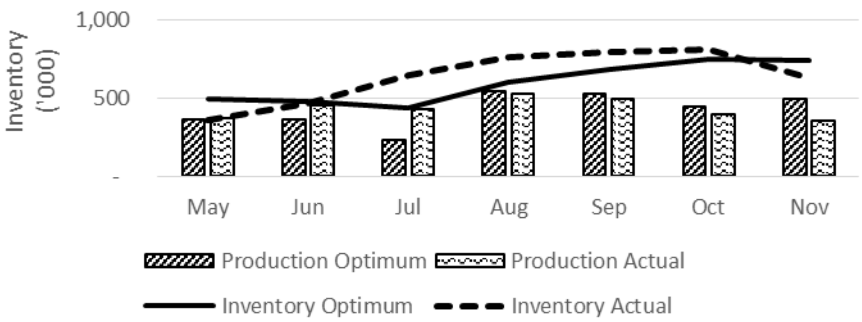


Figure 6: Optimum vs. Actual production and inventory level

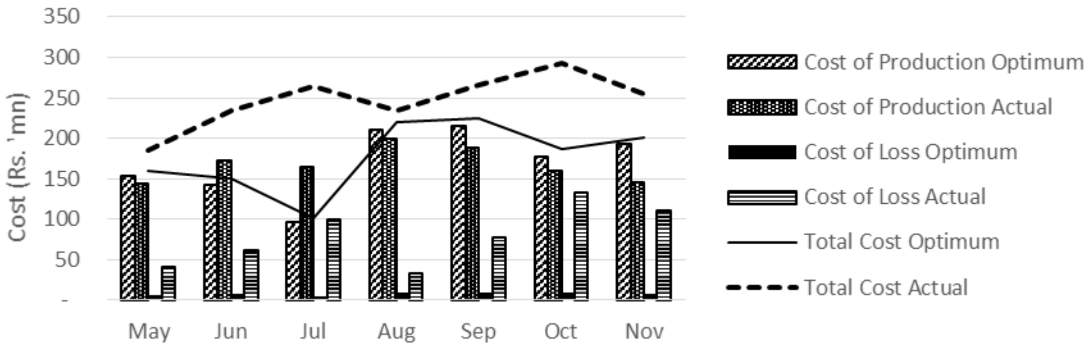


Figure 7: Optimum and actual Total cost, cost of production and cost of loss demand

The Figure 7 visualize the optimum and actual total costs, cost of productions, as well as the cost of loss demand. According to Figure 7, in both actual and optimum scenarios, the cost of production is higher than the cost of loss sales. During some periods, optimum cost of production is higher than the actual cost of production. One reason for this may be the higher optimum production levels than the actual production level as discussed under Figure 6. The other reason may be the changes in the optimum and actual production mix. Because, as the different products utilize different levels of resources, the changes in product mix lead to changes in total production cost. On the other hand, the actual and optimum product mixes change as the optimum product mix take the importance of the products based on the categorization into consideration.

The optimum cost of loss sales is significantly lower than the cost of the actual loss sales in every period. Therefore the optimum model can assure higher service level, which means the customer satisfaction achieved through the optimum inventory level will be higher than the current level. It is clear that, even though the optimum production cost is higher in some periods, the total optimum cost is always lower than the actual total cost in every period. There by the model can be validated as the optimum model.

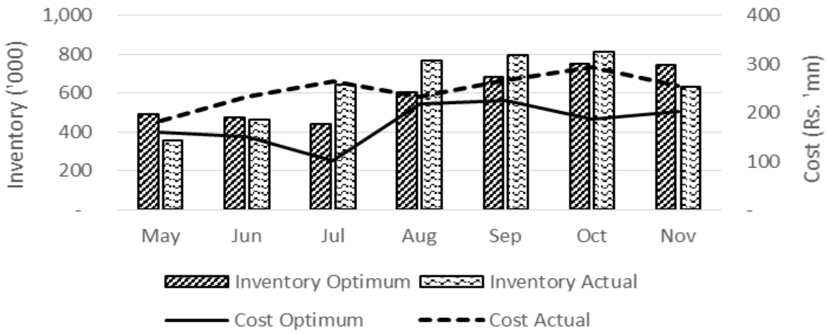


Figure 8: Optimum and actual inventory level and total cost

According to the Figure 8, the optimum inventory level may either higher or lower than the actual inventory level. Higher level of inventory may be required to maintain in order to minimize customer dissatisfaction through higher service level. In other words, higher optimum inventory level is required to minimize the cost of loss demand ensuring the availability of goods as required. However the total cost derived from the developed model is always lower than the actual total cost. Therefore the derived cost can be considered as the optimum cost.

5. CONCLUSION

In this model, each product's demand, inventory and required resources were considered simultaneously. This leads to have more than 200 constraints. When considering all products together, Excel Solver or LINGO (the software intended use in the study) do not support as their capacities are insufficient to handle the problem. Therefore as a solution, products based on their importance considered separately. That is, Group A products considered first in identifying the optimum solution for them. The available resources allocated first to the Group A products as they are the most important products based on their revenue contribution. Then the group B products considered, allocating the resources remained after allocating for the optimum result of Group A. Similarly for Group C products considered finally, allocating the remaining resources after allocating for Group A and B. A researcher, who may intend to develop this model further, can use a more powerful software to solve this problem considering all products together in arriving at a better solution. Many studies considered the cost of storage in deciding on the optimum inventory level. But in this study, it is being ignored as an addition unit of product in the inventory utilizes insignificant amount of space, and compared to the size of the product, company has unlimited capacity in warehouses. On the other hand, company do not account for storage cost separately, as they have to maintain the warehouse space regardless of the number of units being stored and the warehousing cost considered to be a fixed cost. In conclusion, the maximum utilization of capacity in order to minimize the per unit cost may lead to sub optimal financial results. The higher production levels results in high level of stock building up when the production frequency is higher than the stock moving frequency. This research identifies the optimum inventory level which minimizes the cost of production and cost of loss demand, by identifying an equilibrium between the cost of production and cost of customer dissatisfaction due to unavailability of products which leads to loss demand. The optimum results were achieved through the simultaneous consideration of production, inventory, capacity, and customer satisfaction trough service level. The optimum cost of loss demand is significantly lower than the current situation, which leads to more customer satisfaction through higher service levels. This will not only have a better impact on the top line of the business but also for the going concern of the business as the customer satisfaction is a key to survival in the industry. The proposed model always provides an optimal solution compared to the current existing situation.

Appendix

JIT System

JIT- Just In Time is an inventory strategy companies employ to reduce the waste and increase the efficiency. This included JIT purchasing; that is purchase the raw material only when required for the production. JIT manufacturing emphasize on the undertaking the production only when there is a demand.

PESTEL analysis

A PESTEL analysis is framework that used to analyze and monitor the macro environmental (external) factors that have an impact on an organization. The PESTEL stands for,

P: Political
E: Economic
S: Social
T: Technological
E: Environmental
L: Legal

Seven wastes:

1. Over production
2. Waiting
3. Transporting
4. Inappropriate processing
5. Unnecessary inventory
6. Unnecessary / excess motion
7. Defects

SKU

In the field of inventory management, a stock keeping unit (SKU) is a distinct type of item for sale, such as a product or service, and all attributes associated with the item type that distinguish it from other item types. [8]

SMV

Standard Time (also referred to as the "Standard Minute Value" or "SMV"), is the time required for a qualified worker working at "Standard Performance" to perform a given task. The SMV includes additional allowances for Rest and Relaxation, Machine Delay and anticipated Contingencies.

The SMV is the universal measurement of time and its accuracy and consistency is essential as the foundation for measurement and organization of key business processes such as Production Targets, Line Balancing, Production Planning, Incentive Schemes, and the quantification of Operator Performance and Factory Efficiency. [9]

REFERENCES

[1] Bellis, M., (2017). Who invented the Umbrella, 4 9 2016. [Online]. Available: https://www.thoughtco.com/who-invented-the-umbrella-1992592. [Accessed 24 6 2017].

[2] Amirjabbari, B., and Bhuiyan., N., (2014). Determining supply chain safey stock level and location, *Journal of Industrial Engeneering and Management,* 7(**1**):42-71.

[3] Constantin, A., (2016). Inventory Management, Service Level and Safety Stock, *Journal of Public Administration, Finance and Law,* **9**:145-153.

[4] Bradley, J. R., and Arntzen, B. C., (1999). The Simultaneous Planning of Production, Capacity, and Inventory in Seasonal Demand Environments, *Operations Research,* **47**(6):795-806.

[5] Tratar, L. F., (2009). Minimizing Inventory Cost by Properly Choosing the Level of Safety Stock, *Economic and Business Review*,**11**(2):109-117.

[6] King, P. L., (2011). *Understanding Safety Stock and Mastering its Equations*, APICS magazine.

[7] Dialog Axiata, S. L., (2017). Determine the Optimum Inventory Level for your Business, [Online]. Available: http://srilanka.smetoolkit.org/srilanka/en/content/en/53510/Determine-the-Optimum-Inventory-Level-for-your-Business. [Accessed 28 4 2017].

[8] Wikipedia, Stock Keeping Unit, 2017. [Online]. Available: https://en.wikipedia.org/wiki/Stock_keeping_unit. [Accessed 24 6 2017].

[9] GSD, defining-standard-time, [Online]. Available: http://www.gsdhq.com/defining-standard-time/. [Accessed 20 5 2017].

[10] Investopedia, Inventory Management, [Online]. Available: http://www.investopedia.com/terms/i/inventory-management.asp. [Accessed 24 6 2017].

GUIDELINES FOR AUTHORS/CONTRIBUTORS

Manuscripts for the Journal

The Journal of Science publishes the results of research in all aspects of science and technology, in the form of articles, Short communications and Correspondence. The Journal has a wide coverage of subject areas, which include Physical Science, Biological Science, Environmental Science, Computer Science and Applied Science.

Types of papers considered for publication

Articles are full- length papers presenting complete description of original research or technological achievements. Short communications are brief descriptions on new findings that are significant enough to publish without more complete description as a full paper. Correspondence about one or more article in a recent issue of the journal may also be published. All papers are subject to refereeing procedures.

Guide to preparation of manuscripts

The manuscript should be free of corrections. The language of publication is English. The style of writing should conform to acceptable English usage, Slang, jargon, unauthorized abbreviated phrasings and the like should be avoided. The length of the article is restricted to ten printed pages including figures and tables or its equivalent manuscript pages. To avoid unnecessary delays, authors should adhere strictly to the following instructions.

Manuscript Layout: Although a rigid format is not insisted, it is usually, convenient to divide the papers in to sections such as ABSTRACT, KEY WORDS, INTRODUCTION, MATERIALS AND METHODS, RESULTS, DISCUSSION, CONCLUSIONS, ACKNOWLEDGEMENTS AND REFERENCES.

Title: The title should be concise and specific. When the length of the title exceeds 45 characters, a *running title* should be indicated. The name of the institute where the research was carried out should be stated with author's name. The corresponding authors name should be underlined. If the present address is different from the given address then it should be given a foot note.

Abstract: A self-contained abstract of approximately up to 200 words should be provided, summarizing in a single paragraph the new information and the author's conclusions. For plant and animals use both common and scientific names in this section unless they are given in the title.

Materials and methods: The materials and methods should be described in sufficient detail for the protocol to be replicated. Repetition of methodological details can sometimes be avoided by referring to previous studies. If any special equipment (with details of model type/number), chemicals and reagents used then it should be included in the reference, after mentioning for the first time. Animal information should include: bred, breeder, sex, age, weight and the maintenance of conditions. For drugs, generic names should be used: trade names may be given in brackets where the drug is first mentioned. In the case of new drugs or chemicals, a full chemical description (formula) should be given. This section may also contain description of the statistics used and the activities that were recorded. *Ethical note*: where ethical considerations arise from the study, these should be addressed either in the main methods section itself (where the additional discussion is relatively minor) or in a separate subsection of the methods headed ethical note. Any ethical implication of the experimental design and procedures should be identified, and any license acquired to carry out the work specified. Procedures that were taken to minimize the welfare impact on subjects, including choice of sample sizes, use of pilot tests and predetermined rules for invention, should be described.

Key words: A list of 3 to 5 key words chosen within the paper should be provided.

Figures and Tables: Figures and Tables should be numbered consecutively and given suitable caption with reference in the text.

If you send the figures and tables in separate sheets, please label each figure and table with their numbers and the name of the author.

For the final submission it is essential to produce the figures in either in .jpg or .bmp format. This will help us to type set the final printing.

Foot notes to tables should be typed below the table and should be referred to by superscript symbols #, Ŧ and ¤ . No vertical rules should be used. Tables should not duplicate results presented elsewhere in the manuscript, (e.g., in graph)

Photographs: Photographs must be of good quality, printed on glossy paper. Photocopies and the photocopies of the photomicrographs are not acceptable. Colour photographs are accepted only when it is very essential to describe the text.

References: Special care must be taken in citing references correctly. The accuracy of the citation is entirely with the author(s). It is the author's responsibility to obtain written permission to produce material, which has appeared in another publication.

Reference in the text should be numbered (e.g. "Jones and Smith" [1] have reported that....) and listed under reference section stating the name of the author(s), year of publication (in brackets), title of the paper journal (in italic fonts), volume (in bold) and issue and the page range (e.g. 80-85).

Example:

[1] Owens, F.J., (1999). Evidence of phase transition in Cu-O chain of $LiCuO_2$,*Physica* C, **313**:65-69.

[2] Baley, N.J., (1981). *Statistical methods in Biology.* 2nd edition, London: Unibooks.

[3] Emlen, S.T., (1978). The evolution of cooperative behavior in birds, In :*Behavioral Ecology* (Ed.by J.R.Krebs and N.B.deavies) ,Oxford: Blackwell Scientific, 245-281.

[4] Rabbendran, N., (1993). Early performance of selected exotic and indigenous tree species with afforestation potential in the dry zone: Batticaloa district. M.Phil. Thesis. Eastern University, Sri Lanka.

Units: The SI system of units should be used throughout the article.

Refereeing
Every paper will be referred to at least two referees familiar with the field of research covered by the paper, who will be nominated by the editorial board.

Proofs
The corresponding author will receive galley proofs by mail for correction, which must be returned to the editor within one week of receipt. Please ensure that a full postal address and e-mail address of the corresponding author is given on the first page of manuscript so that proofs are not delayed in the mail. Please note that alterations in the text cannot be permitted during the proof reading.

Copyright
Once the paper is accepted a copyright-transfer form will be sent along with the proofs. Duly filled and signed form should be sent to the editor along with the proofs as mentioned above.

Submission of Manuscript

The manuscript should be type written using Microsoft word with double spacing on one side of A4, paper with 3 cm margin in all sides and fond size of 12 pt Times New Roman. Manuscripts in LaTex with 12pt will also be accepted. The length of the article is restricted to ten printed pages including figures and tables or its equivalent manuscript pages. **Manuscript will be accepted only in electronic format**.

Address of the corresponding author:

It should be given in a separate page as an attachment. It is important to keep the editor informed any change in your address.

Address for submission

jsc@esn.ac.lk

The Editor
'Journal of Science'
Faculty of Science
Eastern University, Sri Lanka.
Chenkalady,

Telephone:
+94 65 2240755
+94 65 2240758
Fax: +94 65 2240758
e-mail: jsc@esn.ac.lk
s_arasaretnam@esn.ac.lk