Job Scheduling in a Small Scale Gari Processing Firm in Nigeria

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ABSTRACT

Cassava's toasted granules (Gari) has maintained an important position in the food timetable of many households in Nigeria and many African countries. The Gari processing firm has therefore occupied a significant position in the small and medium enterprises (SMEs) of these countries and has benefited from government support of its accelerated development drive. This paper develops a framework for the proper scheduling of orders (jobs) in a Gari processing firm in Nigeria. The methodology addresses this problem: suppose we have (n) customers (where n is large); in what way should customers' order be processed such that the firm's profit is maximized?

The problem is addressed by using makespan as a measure of performance with the solution methods of CDS heuristics, A1 heuristics, and serial order (SO) method utilized to solve the problem. The results show that CDS and A1 heuristics are preferred to the traditional method of SO. Accordingly, the CDS heuristic, followed by A1 heuristic, gives the best makespan results. This result is further confirmed when the number of times that CDS, A1, and SO give the best results in a set of 50 experiments was considered. The results obtained are 50, 24, and 0, respectively. Since results obtained show the feasibility of applying scheduling principles in the allocation of orders to machines, this paper presents a framework that could benefit stakeholders in the Gari processing industry towards improved customer's satisfaction, less idle time, and growth in the profit margin of the organization.

Improved operational efficiency of Gari processing firms could lead to continued sustainability of the industry and a continued support for economic growth in Nigeria and Africa.

(Keywords: Gari, order scheduling, small and medium enterprises, performance measure, Nigeria, fresh roots, CDS heuristics, A1 heuristics)

INTRODUCTION

In many developing countries of the world, cassava's toasted granules (Gari), has become an important staple food for many households. In Nigeria, Gari processing firms occupy a substantial portion of small and medium enterprises (SMEs) that has contributed significantly to national economic growth. Gari processing has been practiced for several decades, primarily on a small scale. The need to encourage the strategic development of SMEs in Africa has motivated the Nigerian government to support the development of this industry. Despite this support from the government and the increasing contributions by researchers and stakeholders in the Gari processing industry of the SMEs sectors, a myriad of problems still exist in Gari processing activities. A major problem in this industry relates to scheduling customer's orders in a way that would maximize the firm's profits.

There are relatively few reports on technical/engineering matters contained in the Gari processing literature. This is somewhat surprising, given the importance of scheduling jobs on Gari processing machines, it would be revealing to have a theoretical framework that would confirm or dispute the feasibility of applying well-known and highly successfully implemented heuristics to Gari processing. Thus, in the paragraphs that follow the authors present a vast literature review on cassava

(Gari), and many volumes that have been written to experiment and model the process.

An important thread of research in cassava processing relates to the method of reducing the cyanogens content of cassava flour. Recent reports suggest the possibility of achieving this goal using cassava processing techniques (Agbor-Egbe and Mbome, 2006), and the use of a simple wetting method (Bradbury, 2006). The re-examination of cassava processing methods to reduce cyanogens content led Cardoso et al. (2005) to develop a simple equation between the total cyanide contents of cassava root parenchyma and the processed product with the percentage retention of cyanide on processing. Despite the success recorded on this research theme, there seems to be no interaction between this study and the current work on job-machine scheduling in a Gari processing plant.

One of the central areas of research on cassava processing is the cassava characteristic during biochemical changes (Oboh and Akindahunsi, 2003). Kostinek et al. (2005) investigated the diversity of lactic acid bacteria (LAB) from a typical cassava fermentation for the preparation of Gari and their technological relevant characteristics. Oboh et al. (2002) study the nutrient and anti-nutrient contents of *Aspergillus niger*-fermented cassava products (flour and Gari). The general conclusion on these studies is that no association has been established between the results obtained and the job-machine scheduling problem addressed in this paper.

In an attempt to understand the quality of Gari from a selected processing zone in Ghana, Oduro et al. (2000) elicit compelling evidence to show that the quality of the Gari samples from the selected centers was good and many of the samples met both the national and international standards. Another class of research of recent interest is the development of a fuzzy logic-based process control system for Gari fermentation plants (Odetunji and Kehinde, 2005). Unfortunately, the scheduling problem of processing customers' orders such that the firm's profit is maximized is not addressed in these studies.

The remaining parts of this paper are sectioned as: Mathematical Framework, Data Analysis, and Conclusion. The mathematical framework consists of three heuristics that are applied to the Gari processing plants: CDS, A1, and Johnson's two-machine algorithm. The data analysis section presents the data and the results obtained from the simulated values. The concluding remarks are given in the last section of this paper.

MATHEMATICAL FRAMEWORK

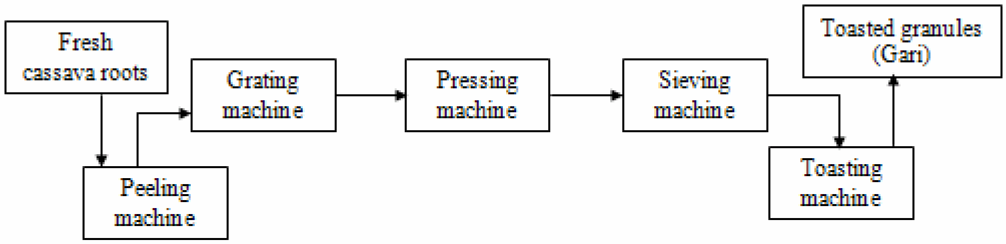
The Gari Processing System and the Scheduling Framework

The Gari processing plant (Figure 1) consists of the basic processes of peeling, grating, pressing, sieving, and toasting. The firm that processes the cassava, Dynamics Enterprises (DE), has one each of these stage-wide machines. Thus, customers from all over the city arrive at DE at different periods of the day, with varying amounts of fresh cassava roots for processing.

In order to schedule the processing of customers' orders such that maximum profit is obtained, the principles guiding flow shop scheduling are adopted in which the cassava processing plant is considered as a 5-machine flow shop system where customers are free to bring their jobs at any time. However, each customer's order (fresh roots) passes through the machines in the same order. Since different quantities are brought for processing and the fresh roots have the same surface area characteristics, each order requires different amounts of processing time. In the current work, the unit of measurement is hours.

Since we want to test methods that could handle large numbers of orders, we suppose that we have as many as 50 customers. This corresponds to 50 individual jobs. The concern is, in what way should be customers' orders be processed such that DE's profit is maximized?

In order to solve this problem, the study considers a common measure of performance utilized in the flow shop scheduling literature. This measure is the makespan. The principle here is to monitor the completion time of the last scheduled customer's order. Much work has been done in understanding this principle, as stated by Oluleye and Oyetunji (1999).



Key:

Peeling:	This involves the removal of the outer skin/back of the fresh cassava root.
Grating:	This involves grating of the peeled cassava roots into smooth pulp using a grater.
Pressing:	This involves putting the grated pulp in porous sacks which are weighted down with heavy stones for 3-4 days in order to express the excess liquid from the pulp while it is fermenting. Sometimes hydraulic jacks are used to express the water.
Sieving:	This involves sieving of the dewatered and fermented lumps of pulp into fine pulp.
Toasting:	This involves frying/toasting of the fine pulp in a pan into what is called toasted granules or Gari as it is known in West Africa.

Figure 1: Flow-Chart of Gari Processing.

There is much support for the use the makespan approach as a measure of performance, as evidenced by its extensive use in maximizing production rates and minimize the mean idle time of machines (French, 1982; Gupta, 1973). In solving the cassava processing problem considered in this work, the principles of CDS and A1 heuristics are applied and compare with the results obtained using Johnson's two machine algorithm. First, consideration is given to the CDS heuristics.

The development of the CDS heuristic is credited to Campbell et. al. (1970). The focus of the heuristic is the minimization of makespan in a flowshop situation. Despite the wide application of CDS heuristic, it seems that the current work is the first to apply the heuristic to the cassava processing firm. CDS heuristic forms a set of an m-1 artificial 2-machine sub-problems for the original m-machine problem by summing the processing times. Each of the 2-machine sub-problems are then solved using the Johnson 2-machine algorithm. The best of the m-1 artificial solution is selected as the solution to the original m-machine problem.

The second heuristic applied here is referred to as A1. The heuristic originated from the work of Oluleye and Oyetunji (1999) for the problem of minimizing makespan of the flowshop situation. Despite its relatively long period of development in the literature, researchers seem not to have explored its full potentials. A contribution is made here to apply this heuristic in the Gari processing plant.

Similar to CDS, A1 forms a set of m-1 artificial 2-machine sub-problem from the original m-machine problem by summing the processing time. However, unlike the CDS, the A1 heuristic uses a different expression to construct the processing times on the artificial machines. Also, each of the 2-machine sub-problems are then solved using the Johnson 2-machine algorithm and the best of the m-1 artificial solutions is selected as the solution to the original m-machine problem.

Now, it is important to present the Johnson's 2-machine algorithm here since it is pivotal to the development and application of the CDS and A1 heuristics.

Johnson's 2-Machine Algorithm

This algorithm supposes that we have (n) jobs to be scheduled on two machines i.e. $J_1, J_2, \ldots, J_n$. Johnson proved that the optimal solution could be obtained using the following algorithm.

Step 1: Set k=1, l=n

Step 2: Set current list of unscheduled jobs={J_1, J_2, ..., J_n}

Step 3: Find the smallest of all the processing times on first and second machines for the jobs currently unscheduled.

Step 4: If the smallest processing time obtained in step 3 for J_i is on the first machine then:
a. Schedule J_i in k^{th} position of processing sequence.
b. Delete J_i from the current list of unscheduled jobs.
c. Increment k by 1.
d. Go to step 6.

Step 5: If the smallest processing time obtained in step 3 for J_i is on the second machine then:
a. Schedule J_i in the l^{th} position of processing sequence.
b. Delete J_i from the current list of unscheduled jobs.
c. Decrease l by 1.
d. Go to step 6.

Step 6: If there are any jobs still unscheduled, then go to step 3, else go to step 7.

DATA ANALYSIS

In this section, the current practice in Dynamics Enterprises is considered as a method which is then compared with the results of the two heuristics (CDS and A1) tested here. Data are then simulated to mimic real life situation for 50 different weeks and 50 jobs (orders). Normally processed customer's orders (jobs) are on a first-come-first-serve basis. Therefore, the first customer arrives in a given serial order 1. The second customer is given serial order 2, etc.

Since the firm processes jobs using this serial order, this method is referred to as serial order (SO). The method was included in the programme written so that it can be evaluated alongside the above solution methods. The processing time, which refers to the amount of time (hours) required to process each customer's order on each machine, is considered close to reality. The scheduling period covers one week. This means that all customers' orders for a week are considered. The scheduling activities are carried out on Monday morning before processing of jobs commences. Therefore, a week represents an instance of a scheduling problem. Thus, data that mimics real life was simulated for 50 weeks, covering the second week in January to the second to the last week in December. DL has an average of 50 customers per week.

Since manual manipulation of results would be challenging, a software package was developed in order to aid computational ease of the solution to the problem. Microsoft Visual Basic® 6.0 was used to implement all three solution methods. Thus, data were generated for these solution methods (CDS, A1 and SO) in which the values of the makespan obtained using each solution method were computed. The data file generated from the program was then exported to Statistical Analysis System® (SAS® version 9.1) package for detailed analysis. SAS® is a very versatile statistical package and was employed to enable credible conclusions to be drawn from the results.

The general linear models (GLM) in SAS® was used to compute the mean value of makespan for the fifty weeks. The GLM procedure in SAS® was also used to carry out test of means (means separation) so as to determine whether the differences observed in the mean value of makespan obtained by various solution methods are significant or just due to chances. The hardware used for the experiment is a 2.4GHz Pentium® with 512MB of memory. Table 1 shows the makespan obtained from the three methods (A1, CDS and SO) for the 50-week study period. For all the three methods, the makespan obtained at the seventeenth period were the minimum, showing 23.33hrs, 23.33hrs, and 30.66hrs respectively for the A1, CDS and SO methods. The table also shows 30.62hrs, 30.51hrs and 34.56hrs as the maximum value for A1, CDS, and SO, respectively.

By considering the minimum makespan, for instance, A1 and CDS methods performed equally, while the traditional approach of SO performed poorly. This implies that if the old approach is continued the jobs for week 17 would still stay for an excess of 7.33hrs in the process before being finished. This is equivalent to about an extra day wasted. For maximum values of makespan, the CDS method performed best, followed by A1, while the worst method still remains traditional SO. So, about 4.05hrs after the job must have been completed, processing would still be on-going in the traditional approach.

Table 1: Makespan Obtained from Various Solution Methods for the 50 Weeks.

Week	Solution Methods		
	A1	CDS	SO
1	29.01	28.49	29.42
2	25.34	25.34	30.2
3	25.27	25.27	30.81
4	25.06	25.01	32.46
5	26.09	26.09	31.39
6	27.26	27.13	31.57
7	26.61	26.61	31.35
8	25.62	25.54	31.44
9	26.8	26.66	33.44
10	27.41	27.07	30.63
11	27.21	27.01	33.06
12	25.01	25.01	31.12
13	25.73	25.73	32.56
14	26.25	26.25	30.65
15	25.98	25.98	31.19
16	25.84	25.57	33.2
17	23.33	23.33	30.66
18	25.14	25.14	31.97
19	25.24	24.98	31.73
20	25.04	24.93	31.5
21	24.89	24.49	34.7
22	25.72	25.65	34.06
23	27.58	27.58	30.89
24	27.69	27.59	31.06
25	30.62	30.51	34.56
26	26.54	26.48	30.57
27	27.93	27.93	34.17
28	27.08	27.08	33.53
29	27.03	27.03	32.94
30	25	25	31.97
31	26.24	26.24	32.44
32	23.54	23.54	32.02
33	28.55	28.1	33.48
34	26.87	26.87	32.58
35	26.38	26.38	30.15
36	27.78	27.64	31.41
37	27.74	27.74	33.39
38	27.2	27.2	31.86
39	26.02	25.24	31.89
40	24.86	24.55	31.17
41	24.03	23.97	32.62
42	25.25	25.06	31.57
43	26.88	26.46	30.23
44	25.13	24.99	30.32
45	24.46	24.46	31.17
46	26.29	25.96	32.7
47	25.13	24.84	31.26
48	25.4	25.4	32.47
49	25.1	24.98	30.22
50	23.73	23.73	30.78

Table 2 shows the mean values of the makespan. Thus the method with the least mean makespan is CDS, having a mean of 26.00hrs. This is closely followed by A1 with a mean makespan of 26.11. The worst method remains the traditional with a mean makespan of 31.85hrs. Thus, it is attractive to utilize the CDS method of scheduling jobs on machines for the firm being considered.

Table 2: Mean of Makespan for the 50 Weeks.

Solution methods	Mean makespan
A1	26.11
CDS	26.00
SO	31.85

Sample size = 50

Table 3 shows the result of the test of means of makespan using the three methods of A1, CDS, and SO. For the sample size of 50, pair-wise tests of means between (A1 and SO), (CDS and SO) show significant results at 5% level of significance. It therefore implies that whether SO is compared with either A1 or CDS, it performs badly relative to them.

Table 3: Test of Means of Makespan.

Solution methods	Solution methods		
	A1	CDS	SO
A1	-	0.6568	<.0001*
CDS	0.6568	-	<.0001*
SO	<.0001*	<.0001*	-

*Note * indicates significant result at 5% level*
Sample size = 50

A further analysis was carried out to find the number of times the various solution methods gives the best result (Table 4). It was found that in none of the 50 occurrences did the SO method give the best result.

The A1 method shows the best results in 24 occurrences, while for all the 50 occurrences, the CDS method showed the best results. This gives credence to the earlier conclusion of this work.

Table 5 shows the gain in scheduling length when pairwise comparison of (SO and A1) and (SO and CDS) are made. By scanning through weekly gain, it seems that the (SO – CDS) gains is more than (SO – A1) gains on the average.

Table 4: Number of Times Solution Methods Gives Best Results.

Solution methods	Number of times
A1	24
CDS	50
SO	0

CONCLUSION

In this paper, it has been demonstrated that the conventional approach in scheduling customer orders for cassava processing in a Gari firm based a serial order in which jobs are scheduled as they arrive for processing fails to satisfy the profit maximization objective of the firm. This is shown by the highest mean makespan for the traditional approach, which leads to increased expenses and decreased profit for the organization.

In particular, three methods were used to test the data simulated for the Gari processing firm. The three methods are A1, CDS, and SO, which represent methods developed by Oluleye and Oyetunji (1999), Campbell, et al. (1970) and the traditional method used by the firm, respectively. Evidently, CDS performs best, followed by A1, while the worst performance was observed with SO. By considering the results obtained here, it is suggestive that some other heuristics could be further tested on the data in the future periods. Hybrids of existing version could be used with conclusion drawn on whether they perform better or not than the two tested here when compared with the traditional method of serial order.

Table 5: Gains in Scheduling Length.

Week	Gains (hours)	
	SO-A1	SO-CDS
1	0.41	0.93
2	4.86	4.86
3	5.54	5.54
4	7.4	7.45
5	5.3	5.3
6	4.31	4.44
7	4.74	4.74
8	5.82	5.9
9	6.64	6.78
10	3.22	3.56
11	5.85	6.05
12	6.11	6.11
13	6.83	6.83
14	4.4	4.4
15	5.21	5.21
16	7.36	7.63
17	7.33	7.33
18	6.83	6.83
19	6.49	6.75
20	6.46	6.57
21	9.81	10.21
22	8.34	8.41
23	3.31	3.31
24	3.37	3.47
25	3.94	4.05
26	4.03	4.09
27	6.24	6.24
28	6.45	6.45
29	5.91	5.91
30	6.97	6.97
31	6.2	6.2
32	8.48	8.48
33	4.93	5.38
34	5.71	5.71
35	3.77	3.77
36	3.63	3.77
37	5.65	5.65
38	4.66	4.66
39	5.87	6.65
40	6.31	6.62
41	8.59	8.65
42	6.32	6.51
43	3.35	3.77
44	5.19	5.33
45	6.71	6.71
46	6.41	6.74
47	6.13	6.42
48	7.07	7.07
49	5.12	5.24
50	7.05	7.05

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