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Heuristic Approach to Job Scheduling in a Small Scale Groundnut Oil Processing Firm in Nigeria

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Abstract

Groundnut is an important legume cash crop for tropical farmers and its seeds contain high amounts of edible oil (43-55%) and protein (25-28%). This paper developed a framework for the scheduling of activities (jobs) in small scale groundnut oil processing firm in Nigeria. The research problem is addressed using makespan as a measure of performance with CDS, A1 and Usual Serial Order (USO) heuristics solution methods. Findings reveal that A1 and CDS heuristics are preferred to the traditional USO methods. Also, the mean of A1 (27.11) heuristic, followed by CDS (27.22) heuristics, gives the best makespan results while the USO (31.52) gives the worst result. This paper thus presents a framework that could be beneficial to stakeholders in the Groundnut oil processing industry towards improved customer's satisfaction, less idle time, and profit optimization.

Keywords: Groundnut, small enterprises, scheduling of orders, makespans, optimum results.

1. Introduction

Groundnut (Arachis hypogeal L.) is an important oilseed crop as it contains 44-56% oil and 22-30% protein on a dry seed basis (Reddy et. al., 2003). Groundnut is grown on 19.3 million ha of land in about 82 countries. More than half of the production area is in arid and semi-arid regions. Groundnut otherwise called peanut, monkey nut, gobber pea and arachide belongs to the family leguminosea. It is originated from Latin America and the Portuguese who were responsible for its introduction into West Africa from Brazil in the 16th Century (Gibbon and Pain, 1985; Abalu and Etuk, 1986).

In Nigeria, the processing of groundnut into various products is mostly done by women either for home consumption or for commercial purposes (Ibrahim et. al., 2005). The most common commercial products of groundnut are : groundnut oil, groundnut cake and fried peanuts which are sold at markets places or hawked on the streets (Hussaini, et. al., 2010). The processing of groundnut is both the source of income and employment to a large proportion of rural women in northern Nigeria. Thus, the achievement of the Millennium Development Goal number three (promotion of gender equality and women empowerment) in northern Nigeria, requires that a study be conducted on scheduling customer's orders in a way that would maximize the firm's profits in small scale groundnut oil processing firm in Nigeria.

Scheduling is a form of decision making that plays a crucial role in manufacturing and service industries. A flowshop scheduling problem has been one of the classical problems in production scheduling since Johnson (1954) proposed the well known Johnson's rule in the two stage flowshop makespan scheduling problem. Since then a number of researchers have focused on specially structured flow shop (Smith, 1956). Smith, et. al., (1967) considered a special case in which the job processing times on the first or last machine are the longest and showed that the problem can be solved in polynomial time. Yoshida and Hitomi (1979) further considered the problem with set up times. The work was developed by Sen and Gupta (1983), Chandarsekharan (1992), Bagga and Bhambani (1997) and Gupta, et. al., (2011) by considering various parameters. In the sense of providing relative importance in the process, Chandermouli (2005) associated weight with the jobs.

Gupta, et. al., (2012) studied specially structured n x 2 flowshop scheduling under specified rental policy in which processing times were associated with probabilities. Johnson's Rule has been the basis of much flow shop scheduling heuristics (Blazewicz, et. al., 2005). The heuristic generates a slope index for jobs and sequences them in a descending order of the index. Campbell et. al., (1970) proposed Campbell, Dudek, Smith (CDS) heuristic which is a generalization of Johnson's two machine algorithm; it generates a set of m-1 artificial two-machine problems from an original m-machine problem, then each of the generated problems are solved using Johnson's algorithm. Du (1993) proposed an AIS approach for solving the permutation flow shop scheduling problem while Liaw, (2008) developed a two-phase heuristic to solve the problem of scheduling two-machine no-wait job shops to minimize makespan. This study thus proposed a framework for proper scheduling of activities (jobs) in ground oil small scale production processes.

2. Literature Review

The scheduling problem has a long history from the area of operations research where they are mainly referred to as an assignment problem. Scheduling did not receive much attention in AI community since 1980, when Fox et al. began their work on the ISIS, which was constraint-directed scheduling system for the job-shop scheduling problem (Fox, 1983 and 1984). During that period growing number of researchers started working on scheduling by using the various techniques from artificial intelligence. More recently, it has garnered the attention of a significant number of AI researchers primarily in the application areas such as manufacturing, resource allocation, military transportation and space etc. Even today there is a conceptualisation about the scheduling task that it is a special case of planning in which the actions are already chosen and leaving only the question of allocating these orders for their assignment. This is an unfortunate trivialisation of the scheduling task. As opposed to the planning task the scheduling has found its well-defined boundary line for its definition. The scheduling task can be defined from the various viewpoints such as, operations research, artificial intelligence etc. So before going on talking more about the scheduling let consider some of the few definitions that are widely accepted to describe the nature of scheduling task. “Scheduling is the problem of assigning limited resources to tasks over time in order to optimise one or more objectives” (Bartak, 2000 and Perez and Benjamins, 1999). “Scheduling deals with the exact allocation of jobs over time, i.e., finding resources that will process the job and time of processing” (Brusoni et. al., 1996). “Scheduling deals with the temporal assignment of jobs to the limited resources where a set of constraints has to be regarded” (Saucer, 1997). “Scheduling selects among the alternative plans and assigns resources and times for each job so that the assignment obey the temporal restrictions of jobs and the capacity limitations of a set of shared resources” (Fox, 1983). It is worth mentioning the OR perspective looking at the scheduling problem treats the scheduling as a class of assignment problem. The main difference between these two approaches is that scheduling normally works on the discrete time-line (Bartak, 2000) where the assignment is based on the continuous time-line. The assignment is supposed to be more specific than the scheduling problem (Poeck and Gappa, 1993). Due to standardisation of the continuous time range all the allocation problems are treated as working on the continuous time-line (Sharma, 2000). In scheduling one can jump from one time-point to another where as in the assignment problem such jumping from different time-points is not permitted. But looking from the practical point of view almost every time the time-line is discrete in its nature as the jobs may get interrupted in between its execution and can start at some other time etc. (Liu, 1988 and Lloyd, 1982). Scheduling is a process where one needs to reason about the resources and time for assigning the jobs. This lies at the very core of scheduling problems, and looking from the AI-community this issue has drawn very little attention (Silcock and Kutti, 1993). The scheduling problem frequently involves various types of choices. These choices could be ordering among the jobs (job-precedence), dependency relation between them, choosing the available resources that satisfy the need of the job, selecting the proper timeslot for the execution of jobs in order to evenly accommodate the assigned job etc. (Keng, et. al., 1988). Almost every time the scheduling problems are restricted by the various kinds of constraints that limit the space of assignment of jobs to the resources. The constraints are usually separated in two main categories such as, *hard-constraints* and *soft-constraints*. The constraints are characterised based on their nature in the scheduling process. The hard-constraints are the kind of constraints, which cannot be violated under any circumstances, where as the soft-constraints are the type of constraints, which can be relaxed if necessary during the scheduling process. There is another class of constraints called *preferences* that are usually treated as user-specific choices and they can be seen as a desirable rather than the obligatory one. The application of preferences can affect the evaluation criterion (cost-function) to the greater extent (Noronha and Sarma, 1991; Smith and Goodwin, 1995; Zweben, et. al., 1992). The examples of hard-constraints in scheduling are the capacity of a particular resource, the duration of a job etc. As the examples of soft-constraints can be meeting the due-date, usage of a particular resource for the execution of job etc. (Zweben and Fox, 1994). The preferences can be explained by the following example. For example, if job *j* chooses the use resource *r1* with preference *x* and prefers to use the resource *r2* with preference *y*. These preference specific criteria can affect the cost related issues because the alternative resources might have the different functional characteristics as compared to the original choice of the resource (Tsang, 1995). For example, different speed and feed of the milling, drilling machines, different load carrying capacity of the vehicles etc. that could affect the throughput of a schedule. Many researchers are working in job shop scheduling problem. Garey *et al.* (1976) were the first who introduced job shop scheduling problems. Some researchers like Brandimart (1993) and Paulli (1995) have used dispatching rules for solving flexible job shop scheduling problems. Attention to size proved that job shop scheduling problems are NP-Hard (Garey *et al*., 1976) and with added flexibility increase complexity more than job shop. Ram *et al.* (1996) have applied a parallel simulated annealing for job shop scheduling, but the same temperature is maintained in all the machines. Bozejko *et al.* (2009) have proposed the parallel simulated annealing for the job shop scheduling. But the same sequential algorithm is implemented more than one machine in a parallel order. Ramkumar *et al.* (2012) proposed real time fuzzy logic for job shop scheduling problem. Objective of JSP problem is to find the optimal schedule with minimum makespan, but this result is not clearly shown by author. Thamilselvan and Balasubramanie (2011; 2012) have used the various crossover strategies for genetic algorithm for JSSP and integration of Genetic algorithm with Tabu Search for the JSSP. The above two methods were efficient for the small size JSP problems. Mohamed (2011) proposed a genetic algorithm for JSSP, but this algorithm is efficient only for less number of jobs. The ratio scheduling algorithm to solve the allocation of jobs in the shop floor was proposed by Hemamalini *et al*. (2010). This algorithm is more efficient when the result for the bench mark instances when the due date is less than half of the total processing time.

Johnson's rule is technique that manager can use to minimize the makespan for a group of jobs to be processed on two machines or at two successive work centers (2 – machine flow shop), (Johnson, 1954). It also minimizes the total idle time at the work centres. For the technique to work, the following conditions must be satisfied:

1. Job time (including setup and processing) must be known and constant for each job at each work centre.
2. Job times must be independent of the job sequence
3. All jobs must follow the same two-step work sequence
4. Job priorities cannot be used
5. All units in a job must be completed at the first work centre before the job moves on to the second work centre.

Determination of the optimum sequence involves these steps:

1. List the jobs and their times of each work centre
2. Select the job with the shortest time. If the shortest time is at first work centre, schedule that job first; if the time is at the second work centre; schedule the job last. Break ties arbitrarily.
3. Eliminate the job and its time from further consideration.
4. Repeat steps 2 and 3, working toward the centre of the sequence, until all jobs have been scheduled.

However, when significant idle time at the second work centre occurs, job splitting at the first centre just prior to the occurrence of idle time may alleviate some of it and also shorten throughput time.

Goldratt(1989) also developed and promoted another approach to scheduling. He first described it in his book. The Goal, Goldratt avoided much of the complexity often associated with scheduling problems by simply focusing on bottleneck operations (that is those for which there was insufficient capacity, in effect, a work centre with zero idle time). He reasoned the output of the system was limited by the output of the bottleneck operation(s); thus, it was essential to schedule the nonbottleneck operations in a way that minimized the idle time of the bottleneck operation(s). Therefore, idle time of nonbottleneck operations was not a factor in overall productivity of the system, as long as the bottleneck operations were used effectively. The result was a technique for scheduling intermittent production system that was simpler and less time-consuming to use. In this study the Johnson rule techniques and methodology was adopted which is in line with the Camphell et al., (1970) proposed Campbell, Dudek, Smith (CDS) heuristic; usual serial order (USO) and A1 heuristic methods.

3. Material and methods

This study was carried out on ground nut oil firm with basic operational activities as presented in figure 2

3.1: Equipment required

The equipment needed to set up a small or medium scale oil extraction enterprise falls into three main categories:

- pre-extraction equipment; eg dehullers, seed/kernel crackers, roasters, mills.
- extraction equipment; manual presses, ghanis, expellers
- equipment for basic refining of the oil; filters, settling tanks.

The specific equipment required will depend on the particular crop being processed, the final oil quality required and the scale of operation. In a small guide it is impossible to cover both the whole range of technical options and possible crops the following section concentrates on one example; the extraction of sunflower and groundnut oil by expeller.

3.1.1 Shelling or dehulling

Most oil bearing seed need to be separated from outer husk or shell. This is referred to as shelling, hulling or decortications. Shelling increases the oil extraction efficiency and reduces wear in the expeller as the husks are abrasive. In general some 10% of husk is added back prior to expelling as the fibre allows the machine to grip or bite on the material. A wide range of manual and mechanical decorticators are available and typical examples are shown in Figure 2. After decortications the shell may have to be separated from the kernels by winnowing. At small scale this can be done by throwing the material into the air and allowing the air to blow away the husk. At larger scale mechanical winnowers and seed cleaners are available

3.1.2 Heating or conditioning

Pre-heating the seeds prior to expelling speeds up the release of the oil, pre-heating is generally carried out in a steam heated kettle mounted above the expeller.

3.1.3 Expelling

A wide range of makes and sizes of expellers are available. In India in particular a number of efficient small or "baby" expellers are available. This machine has a central cylinder or cage fitted with eight separate sections or "worms". This flexible system allows single or double-reverse use and spreads wear more evenly along the screw. When the screw becomes worn only individual sections require repair thus reducing maintenance costs. As the material passes through the expeller the oil is squeezed out, exits through the perforated cage and is collected in a trough under the machine. The solid residue, oil cake, exits from the end of the expeller shaft where it is bagged.

3.1.4 Filtration

The crude expelled oil contains solid particles. These can be removed by allowing the oil to stand and then filtering the clear oil by gravity through fine cloth. A better but more expensive method is pumping the crude oil through a filter press.

3.2 Methodology

According to Blazewicz, et al., (2005), Johnson's Rule has been the basis of much flow shop scheduling heuristic. Camphell et al., (1970) proposed Campbell, Dudek, Smith (CDS) heuristic which is a generalization of Johnson's two machine algorithm; it generates a set of m-1 artificial two-machine problems from an original m-machine problem, then each of the generated problems are solved using Johnson's algorithm. Du (1993) proposed an AIS approach for solving the permutation flow shop scheduling problem, Oluleye et al., (2007) developed a three-phase heuristic to Gari processing plants and Odior, et. al., (2010) also applied Johnson 2-machine algorithm to job scheduling in a rice milling firm. This paper thus developed a heuristic job scheduling framework that could be beneficial to stakeholders in the Groundnut oil processing industry towards improved customer's satisfaction, less idle time, and profit optimization.

Sequential to the scheduling of the processing of customers' orders such that optimum profit is obtained, the principles guiding flow shop scheduling are adopted in which the groundnut processing plant is considered as a machine flow shop system where customers are free to bring their jobs at any time. The scheduling period covers one week which implies that all customers' orders for a week are considered and the scheduling activities are prepared on Monday morning before processing of jobs commences. The processing of customer's order is on a first-come-first serve basis. Hence the first customer to arrive for service is given a serial order 1; the second customer is given serial order 2, while the third is given serial order 3 and so on. We thus refer to this method as usual serial order (USO) which is traditional method being used by the Groundnut firm understudy. This method would then be used in this study in addition to the two methods: A1 and CDS mentioned above. Since we want to test methods that could handle large numbers of orders, we proposed that we have as many as 60 customers which correspond to 60 individual jobs.

4. Results and Discussion

Table 1 show the result of the simulated data when two heuristics techniques (CDS and A1) proposed was compared with the traditional USO method being practiced in the firm under study. The processing time for customer's order on each machine is assumed to be very close to reality and the scheduling period covers a period of one week. Thus data that hypothesized real life was simulated for 60 weeks covering first week in January, 2012 to second week in February 2013. The result also shows that there was an average of 60 customers per week.

Table 2 shows the gain in scheduling length when pairwise comparison of (USO and A1) and (USO and CDS) were made. Considering the week gain as depicted in the table, it reveals that the USO-CDS gains are more than that of the USO-A1 on the average. Thus, judging from this pairwise comparison, it is more reasonable to use the CDS method in a schedule of this nature. Table 3 depicts the number of times that the three solution methods gives best results and it was discovered that USO did not gives any best solution results in all the 60 occurrences which makes the USO method to be worthless when compared with A1 and CDS methods respectively

Table 4.1 reveals that the mean scores of USO result of 31.52 is the highest and the worst when compared with that of CDS (27.22) and A1 (27.11), Therefore, it is much more attractive to either use the A1 method or the CDS method with lower mean makespan. Further statistical analysis in table 4.2 also shows that a significance difference exists among the makespan results (F = 94.425, df = 179 and p = 0.00). This implies that USO result is significantly higher and less attractive when compared with A1 and CDS methods. Table 4.3 examines the level of differences among the makespan results, a multiple comparison of the items was carried out. A cursory look at the results reveals that a positive and significance difference exists between A1 over USO (p = 0.00). Similarly, positive and significance difference exists between CDS over USO (p = 0.00). Interaction produces no significance difference among the variables.

5. Conclusion

Manufacturing industries are the backbone in the economic structure of a nation, as they contribute to both increasing Gross Domestic Product (GDP) and Gross National Product (GNP) and providing employment. Productivity, which directly affects the growth of GDP, and benefits from a manufacturing system, can be maximized if the available resources are utilized in an optimized manner. Optimized utilization of resources can only be possible if there is proper scheduling system in place. This makes scheduling a highly important aspect of a manufacturing system. This paper presents a review of scheduling in general and Job-Shop Scheduling in particular. The approximation based approaches are broadly classified as tailored algorithms and general algorithms.

Tailored algorithms mainly consist of different types of dispatching rules and heuristics, whereas general algorithms include techniques that are based on local search and AI. The application of AI tools is considered as a comparatively recent development in this area. Recently, most of the researchers are of the view that hybrid AI tools perform better than traditional AI tools and that is the reason that trend of using hybrid AI tools to solve the JSSP is on the rise.

Three methods were used to test data simulated for the Groundnut Oil Processing Firm for a period of 60 weeks. Usually, processed customers' orders are on a first-come-first served basis, thus the first customer is giving a serial order 1, the second is giving serial order 2 and so on. This usual serial order (USO) method which is also known as the traditional method was then compared with two other methods namely CDS (developed by Campbell et. al., 1970) and A1 (as also opined by Oluleye et. al., 2007 and Odior, et. al., 2010). Using the general linear model (GLM) in SAS to compute the mean value of the makespan for the sixty weeks hypothesized, it was discovered that A1 performs best with a mean of 27.11 followed by CDS (27.22) , while the USO has a very high mean of 31.52 which make it the worst among the three methods. It is thus recommended that the firm should either adopt the A1 method or CDS method so as to enhance the firm's optimum performance as well as profitability.

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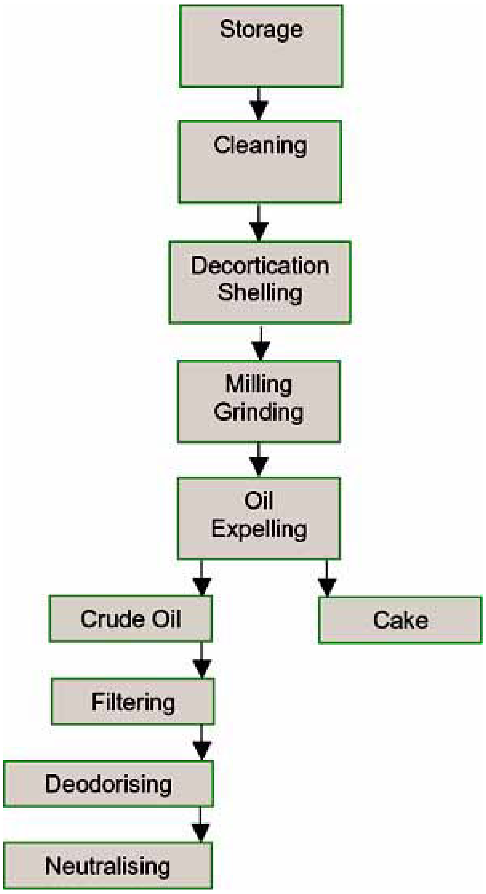

Figure 2: The basic steps involved in processing oilseeds

Table 1: Makespan results for 60 weeks.

	Makespan Results		
Week	**A1**	**CDS**	**USO**
1	22.25	27.24	22.24
2	25.35	25.34	30.24
3	25.32	25.33	30.45
4	25.12	25.12	32.42
5	26.04	26.06	31.52
6	27.20	27.18	31.46
7	26.52	26.54	31.08
8	25.33	25.54	31.42
9	26.04	26.00	33.16
10	27.42	27.40	30.54
11	30.00	28.42	33.26
12	25.24	25.24	31.54
13	25.70	25.72	32.50
14	23.49	23.40	26.42
15	25.82	25.80	31.28
16	25.72	25.70	33.22
17	26.32	26.30	30.54
18	25.16	25.18	31.27
19	25.18	24.94	31.34
20	25.24	24.26	31.28
21	26.32	26.02	28.42
22	25.82	25.64	29.08
23	28.26	28.12	28.96
24	26.12	27.08	30.02
25	25	25	32
26	26.15	26.15	32.33
27	27.33	27.33	33.32
28	26.67	26.67	32.5
29	28.5	28.5	33.10
30	27.5	27.5	32.55
31	24.5	24.43	33
32	20.25	20.25	30
33	28.5	28.5	32.5
34	27.85	27.85	31.67
35	28.75	28.75	32.45
36	28.78	27.65	31.25
37	28.8	28.1	33.5
38	29.5	29	33.45
39	28.75	28	32.5
40	28.50	28	32
41	29.50	29	32.50
42	30	32	34.50
43	32	33	36.50
44	28.50	28.2	32.5
45	28	28.50	32
46	27.50	28	30
47	29.5	28.5	32
48	27	28	31
49	28.5	29.5	32
50	28.5	28.5	32
51	29.5	29.0	31
52	29	28.5	30
53	29.5	29.5	31
54	27	28.5	32.5
55	26.5	27.5	31
56	28	28	32
57	28.5	28.5	31
58	29	29.5	30
59	27	27.5	31
60	27.5	28.5	35

Table 2: Gains in Scheduling Operation for 60 weeks.

	Scheduling Gains	
Week	USO-A1	USO-CDS
1	5	0.01
2	4.89	4.9
3	5.13	5.12
4	7.3	7.3
5	5.48	5.46
6	4.26	4.28
7	4.56	4.54
8	6.09	5.88
9	7.12	7.16
10	3.12	3.14
11	3.26	4.84
12	6.3	6.3
13	6.8	6.78
14	2.93	3.02
15	5.46	5.48
16	7.5	7.52
17	4.22	4.24
18	6.11	6.09
19	6.16	6.4
20	6.04	7.02
21	2.1	2.4
22	3.26	3.44
23	0.7	0.84
24	3.9	2.94
25	7	7
26	6.18	6.18
27	5.99	5.99
28	5.83	5.83
29	4.6	4.6
30	5.05	5.05
31	8.5	8.57
32	9.75	9.75
33	4	4
34	3.82	3.82
35	3.7	3.7
36	2.47	3.6
37	4.7	5.4
38	3.95	4.45
39	3.75	4.5
40	3.5	4
41	3	3.5
42	4.5	2.5
43	4.5	3.5
44	4	4.3
45	4	3.5
46	2.5	2
47	2.5	3.5
48	4	3
49	3.5	2.5
50	3.5	3.5
51	1.5	2
52	1	1.5
53	1.5	1.5
54	5.5	4
55	4.5	3.5
56	4	4
57	2.5	2.5
58	1	0.5
59	4	3.5
60	7.5	6.5

Table 3: Number of Time Solution Methods Gives Best Results

Solution Methods	Number of Times
A1	20
CDS	24
USO	0
A1 = CDS	16

Statistical Test of Means of Makespans

Table 4.1:Descriptive Statistics
Makespans result

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
A1	60	27.1135	2.02346	.26123	26.5908	27.6362	20.25	32.00
CDS	60	27.2242	1.99458	.25750	26.7089	27.7394	20.25	33.00
USO	60	31.5213	1.99268	.25725	31.0066	32.0361	22.24	36.50
Total	180	28.6197	2.86445	.21350	28.1984	29.0410	20.25	36.50

Table 4.2: ANOVA
Makespan result

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	758.138	2	379.069	94.425	.000
Within Groups	710.567	177	4.015		
Total	1468.705	179			

Table 4.3: Multiple Comparisons
Dependent Variable: Makespans result
LSD

(I) Type	(J) Type	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
A1	CDS	-.11067	.36581	.763	-.8326	.6112
	USO	-4.40783*	.36581	.000	-5.1297	-3.6859
CDS	A1	.11067	.36581	.763	-.6112	.8326
	USO	-4.29717*	.36581	.000	-5.0191	-3.5753
USO	A1	4.40783*	.36581	.000	3.6859	5.1297
	CDS	4.29717*	.36581	.000	3.5753	5.0191

*. The mean difference is significant at the 0.05 level.

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