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Impact of polishing time on minimum cooking temperature of selected Indian rice varieties

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Abstract

Milling and cooking characteristics are basic properties to evaluate rice quality. Milling is an ancient processing technique to remove husk and help to increase palatability, shelf-life and meets consumer preference. The amount of bran remained on milled rice is called as Degree of Milling (DOM). An increase is in DOM, micronutrient, lipids and protein lost leads to an increase in carbohydrate content. Cooking is another significant quality aspect of rice and identifying minimum cooking temperature for each variety is important. The present study is planned to identify the minimum cooking temperature (MCT), and understand the variation in polishing time on milling yield, DOM and MCT of twenty five rice varieties. MCT was identified as 85 ºC in one variety, 95 ºC in 12 rice varieties and 100 ºC in 12 rice varieties. Milling yield and DOM were studied for polishing times i.e., 30, 60, 90, 120, and 150 sec and results indicated as that the extent of milling increased in polishing time there was decrease in milling yield and increase in DOM. At different DOM, cooking at MCT was observed and found that most of the varieties were cooked at MCT with decrease in DOM and increase in polishing time. It was evident that milled rice absorbed water at a faster rate than brown rice, which helps in cooking of rice kernel. The varieties that were completely cooked after a particular minimum DOM % indicated that there was loss of bran layer completely or partially. This study concludes that bran thickness differs among the varieties. Considering the variation of bran thickness among varieties and variation of milling capacity among rice milling machines, the minimum DOM needs to be determined for each variety.

Keywords: Milling, DOM, cooking, rice

Introduction

Rice is the major cereal staple food for nearly two-thirds of the World's population (Wynn, 2008) [24]. It has been reported that as much as 75% of the daily calorie intake of the people in some Asian countries is derived from rice (FAO, 2001) [7]. It is reported that the World's stocks of stored rice grain have been falling relative to each year's use because the consumption has surpassed the production.

The utilization of rice (*Oryza sativa* L.) as a food involves the milling of paddy to remove the hull and bran. Milled products include whole kernel rice (head rice) and partial kernels (broken rice). Head rice is grain that remains intact, completely or at least in 3/4 of the whole grain after milling. Milling quality is determined by the quantity of total milled rice and the percentage head rice that can be produced from a unit of rough rice. Head rice is a major determinant for price of rice in the paddy markets of many countries. Therefore, the value of rough rice is directly related to its milling quality and the prevailing market demands (Umadevi, *et al*., 2010) [23].

Rice consuming pattern and preferences vary in region to region. For instance, the Japanese like well milled sticky rice (Deshpande, *et al*., 1982) [5], but Americans prefer semi-milled long grain or even brown rice (BR), whereas people in the Indian sub-continent prefer well milled parboiled rice (Lyon, *et al*., 1999) [9]. Major parts of rice eating population prefer well-polished rice with little or no bran remaining on the endosperm. Rice consumers prefer white rice which is polished extensively, less percentage of broken, damaged grains and free from foreign material. The amount of bran in rice kernels varies with variety, environmental conditions and agronomic practices (Ruiten van, 1985; Sarker & Miyahara, 1984) [16, 20].

Rice in the form of grain kernel was used for consumption rather than flour like other cereals. Two methods of rice cooking are well practiced in rice consuming regions. Rice cooked in excess water and the drained off is one method, and other is rice cooked in a measured amount of water (Crowhurst & Creed, 2001) [4]. Cooking is an application of heat treatment to different produce making them edible and fit for consumption (Roy, *et al*., 2008) [15]. Cooking quality is another significant parameter generally influenced by factors such as type of cultivation, variety and post-harvest conditions, milling degree and method of cooking being employed (Park, *et al*., 2001; Perdon, *et al*., 2001) [12, 14].

Rice is said to be optimally cooked when it reaches an end point i.e. when the rice kernel has absorbed water to the maxima or the white core of rice kernels has been gelatinized during the cooking process (Kasai, *et al*., 2005) [8]. Water uptake ratio is another important characteristic which is taken into consideration during the cooking process and is influenced mainly by a variety and cooked rice yield. There is a linear relationship between the yield of cooked rice and water uptake ratio. Increase in DOM showed positive effect on water uptake and simultaneously negative effect on optimum cooking time (Mohapatra and Bal, 2006) [10]. Reduction in bran layer by milling creates facilitation of water into the endosperm easily in cooking. Water uptake and length expansion ratios are generally influenced by the degree of milling (DOM) (Saleh and Meullenet, 2007) [17]. Higher water binding capacity of milled rice results in soft textured rice.

In order to improve the cooking quality, it is important to choose a suitable DOM for each cultivar which can help in reducing losses during cooking. Milling also decreases physical aspects such as grain size and gelatinization temperature at DOM (20%) decreased cooking time for different varieties of rice. The thermal properties of rice were found to be dependent on the variety and the conditions of processing which in turn also affect its cooking quality (Marshall, 1992) [18].

Studies on rice pasting properties indicated that starch gelatinization temperature (GT) ranges roughly from 55 to 79 ºC and it may vary with amylose content. Varieties having low GT can save the energy required for cooking and can be useful in developing instant rice (Yadugiri *et al*. 2012). MCT of three rice varieties were identified using constant temperature water bath (Sanjeeva Rao, 2014) [19]. With this background, in the present investigation, MCT was determined in 25 rice varieties and the impact of polishing time on milling yield and cooking behaviour at MCT was assessed.

Material and Method

Twenty five rice varieties in the form of paddy were collected from Indian Institute of Rice Research (IIRR) and cleaned for any foreign material. The paddy samples were shelled in the Rice Sheller (Satake TH4 (No. 1012077) to obtain brown rice which contained bran and endosperm (Shobha Rani, *et al*., 2014) [21]. Brown rice samples were subjected to milling for further analysis.

Milling characteristics

Milling characteristics such as milling yield (Shobha Rani, *et al*., 2014) [21] and degree of milling were studied for selected rice varieties. A gravimetric measurement of degree of milling (DOM) was done (Mohapatra & Bal, 2007) [11]. Samples in triplicate were analyzed and average values were used for further analysis.

$$\text{Milling } \% = \frac{\text{Weight of polished grain (g)}}{\text{Weight of paddy (g)}} \times 100$$

$$\text{DOM} = \left(1 - \frac{\text{Weight of milled rice}}{\text{Weight of brown rice}}\right) \times 100$$

Estimation of minimum cooking temperature of white rice

Five grams of well-polished white rice grains were taken in a test tube to which 15 ml of distilled water was added and soaked for 10 min (Shobha Rani, *et al*., 2014) [21]. These test tubes were cooked for 15 min in a constant temperature water bath having digital display at various selected temperatures varying at every 5 ºC. After cooking at each temperature interval, sample was transferred into a petri plate and the extent of cooking was examined (Sanjeeva Rao, *et al*., 2014) [19]. Analysis was done in triplicate.

Effect of polishing time on cooking at MCT

Brown rice samples were subjected to different polishing times (30, 60, 90, 120, 150 sec) and were cooked at pre-identified minimum cooking temperature (MCT) of each rice variety. The cooked samples were transferred into a petriplate and few cooked grains were pressed between two glass slides for identifying any ungelatinzed starch granules (till no white core was left). Analysis was done in triplicate.

Statistical analysis

All experiments were carried out in triplicates and data was reported as mean ± standard deviation. The differences of mean values among selected rice varieties and among polishing times were determined by two way analysis of variance (ANOVA) using SPSS software version 16.0.

Results and Discussion

Milled rice is preferred by majority of the rice consumers due to the superior cooking quality than brown rice. Milled rice is popularly called as polished rice is obtained by processing brown rice in rice polishers and milling capacity varies among the polishers. During milling, aleurone layer of brown rice is removed in the form of bran which is used for making rice bran oil. In recent times, rice bran oil became popular among the consumers and hence, rice is subjected to more polishing than before. Since most of the nutrients of rice grain are lost along with bran some people started consuming brown rice or partially polished rice instead of white rice. Hence, some of the released varieties were selected to study their milling yield, degree of milling, minimum cooking temperature and relationship between degree of milling and minimum cooking temperature.

Milling yield

Milling is a primary processing technology, which is a combination of unit operations to obtain white rice or well milled rice. Milling technology improves eating quality and storage life which improves farmer's profit as well as meets consumer preferences. Milling yield represents the weight of rice after polishing for specific amount of time. The milling yield at different polishing times i.e. 30, 60, 90, 120 and 150 sec are presented in Table 1. The range of milling yield at 30, 60, 90, 120 and 150 sec were 90.00 to 96.06, 85.00 to 93.50, 79.33 to 90.33, 74.00 to 85.67 and 68.00 to 80.67 percentages respectively. As expected that milling yield decreased with increase in polishing time.

At 30 sec of polishing time, highest (96.06%) and least (90%) milling yields were observed in sampada and vibhava respectively. At 60 sec of polishing time, highest (93.50%) and least (84.81%) milling yields were observed in sampada and DRR Dhan 39 respectively. At 90 sec of polishing time, highest (90.33%) and least (79.33%) milling yields were observed in Nidhi and DRR Dhan 39 respectively. At polishing time 120 seconds, least milling yield was found in rice variety vibhava (74.00%) and highest in vivekdhan82 (85.67%). At 150 seconds of polishing time, lowest milling yield found in rice variety DRR Dhan 38 (68%) and highest in Nidhi (80.67%). Among varieties, milling yields differ and noticed that there was a similar value in highest milling yields of Sampada, Nidhi and Vivekdhan 82 and least milling yields of Vibhava, DRR Dhan 39 and DRR Dhan 38 at all polishing time intervals.

In the present study, milling yield of twenty five rice varieties were statistically significant among varieties and also at each polishing times intervals (p<5%).

Variation in polishing times (10, 20, 30, and 40 sec) and polishing pressure (1, 2, 3, 4, and 5 lb) results in varied milling recovery. As increase in polishing time and pressure, it was observed that there was a decrease in milling recovery (Arshad Karim, 2002).

Degree of Milling

Results for degree of milling in selected twenty five rice varieties are presented in table 2. Degree of milling ranged from 4.64 (sampada) to 9.79 (vibhava), 6.67 (sampada) to 14.34 (DRR Dhan 39), 10.99 (vivekdhan82) to 19.39 (DRR Dhan 39), 15.00 (Vivekdhan82) to 25.74 (vibhava) and 19.00 (Vivekdhan82) to 29.89 (vibhava) at 30, 60, 90, 120, and 150 polishing time (seconds). In the present study, DOM of twenty five rice varieties were statistically significant among varieties and also at each polishing times intervals (p<5%).

It is evident from the above results that each rice variety exhibits different milling yield and degree of milling percentage at all polishing time intervals. While increasing in extent of milling in polishing time there was decrease in milling yield and increase in DOM (Figure 1). Milling yield and degree of polishing depends on the type of polisher and polishing conditions. It is an established research fact that the amount of bran varies according to variety, conditions of environment and agricultural practices in the region, requirement of milling degree varies with different rice grains (Ruiten van, 1985) [16].

Extensive polishing improves cooking quality and shelf life of milled rice. Partial milling using less polishing time than the market quality milled rice have less loss of nutrients. However, prolonged storage of brown rice or partial milled rice develops unacceptable off-flavor due to degradation of bran primary lipids triglycerols by lipases, which results oxidative rancidity. Hence, additional preventive techniques that can deactivate lipase activity or removal of fats from grain surface or adequate packaging are required (Avijit, *et al*., 2012) [2].

Effect of polishing time on cooking at MCT

MCT

The minimum cooking temperatures were identified for selected twenty five milled rice varieties (Table 3). Among these 25 rice varieties, MCT lies under 85 ºC in sugandhamati alone, MCT at 95 ºC was noticed in 12 rice varieties (vibhava, ravi, kasturi, vikramarya, govind sampada, lalat, RPBIO 226, Pusabasumathi 1121, mahsuri, DRR Dhan 38 and DRR Dhan 39) and the remaining 12 rice varieties (vivekdhan 82, Mandya vijaya, Nidhi, tellahamsa, MTU1010, IMP CM, RCM 5, BPT5204, rasi, jaya, swarnadhan and akshyadhan) were cooked at 100 ºC. MCT of selected twenty five rice varieties were statistically non-significant among varieties (p<5%).

Similar findings showed that rice can be cooked at 80 ºC (Parthasarathi and Nathi, 1953) [13] and Aghoni Bora (78 ºC), Swarna and Sambha Mahsuri rice varieties cooked at 76 ºC (Sanjeeva Rao, *et al*, 2014) [19]. However, (Yadugiri (2010) [25] reported that assamese rice variety (Aghoni Bora) can be consumed by simple soaking in water at room temperature or in luke-warm water for 15 minutes of time. The variation in the MCT on same variety can be due to variation in cultivation conditions. Varieties having MCT close to room temperature can be cooked instantaneously without any additional energy input.

Gelatinization temperature can be directly measured by studying the pasting properties of rice powders using rheometer. GT can be indirectly measured by ASV since these two possess inverse relationship. Among these two, most of the laboratories have adopted ASV which requires simple inputs for conducting the experiment. The GT range reported through pasting profile studies of rice powders on rheometry is comparatively lesser than the MCT and this could be due to the variation in the sample type (polished full grain instead of powders). As starch granules are packed tightly in polished grain that contains a biological barrier, more time is required for the percolation of water into the grain and to interact with the tightly packed starch granules for gelatinization. Whereas in the case of rice powders, the biological membrane is disintegrated during and the surface area of accessibility increases between water and starch granules is higher which can lead to lesser cooking time as well as gelatinization temperature.

Polishing time on cooking at MCT

MCT is the least temperature at which a rice variety is completely cooked. The effect of polishing time (30, 60, 90, 120 and 150 sec) on the cooking status of milled rice of the 25 varieties are presented in Table 3.

At 30 sec polishing time, four varieties (vikramarya, mandyavijaya, govind and jaya) were found completely cooked with an average DOM of 6.53%. Except Jaya, the other 3 varieties showed similar DOM values. At 60 sec polishing time, four more varieties (IMPCM, kasturi, mahsuri, sampada, RPBIO226) were found completely cooked with an average DOM of 9.00%. Four rice varieties showed similar DOM values except sampada. At 90 sec polishing time, three more varieties (DRR Dhan 39, Pusabasumathi 1121 and vivekdhan 82) were found completely cooked with an average of DOM 16.11%. However, these three rice varieties showed varied DOM values. At 120 sec polishing time, six more varieties (BPT 5204, MTU 1010, Nidhi, sugandhamathi, tellahamsa and vibhava) were found completely cooked, with an average of DOM 20.89%. Four varieties were showed similar except nidhi and vibhava. At 150 sec polishing time, the remaining seven varieties (akshyadhan, DRRDhan 38, lalat, ravi, RCM5, rasi and swarnadhan) were found completely cooked, with an average of DOM 25.52%.

Generally, bran layers' having protein and surface lipids reduce the water absorption rate and tends to semi-cook the rice grain when incubated in boiling water (100 ºC) for 20 minutes (Bechtel and Pomeranz, 1977) [3]. Therefore, loss of bran layers during milling makes milled rice to absorb water at faster rate than brown rice (Siebenmorgen & Meullenet, 2004) [22]. Even loss of 1% bran from kernels of brown rice increases rate of water absorption (Desikachar, *et al*., 1965) [6]. At various levels of milling, rate of water absorbed for different rice fractions were evaluated (Roy, *et al*., 2008) [15].

The varieties that were completely cooked after a particular minimum DOM % may indicate the loss of bran layer completely or partially (intactness of bran might be disturbed).

Conclusion

This study validates that bran thickness differs among the varieties. Considering the variation of bran thickness among varieties and variation of milling capacity among rice milling machines, the minimum DOM needs to be determined for each variety. However, it is worth mentioning that polishing time must be identified for each variety where nutritional and cooking qualities are maintained.

Table 1: Effect of polishing time on milled rice yield recovery

Name of the Rice Variety	Yield recovery (%) at different polishing time (sec)				
	30	60	90	120	150
Akshayadhan	91.50±3.04	88.00±2.65	85.67±2.08	83.00±1.73	76.33±2.08
DRR Dhan 38	92.83±3.01	87.90±1.93	81.33±2.52	75.00±1.73	68.00±2.65
Lalat	91.33±2.52	88.00±1.73	84.00±2.00	81.00±2.65	77.33±2.08
Ravi	94.50±1.32	92.17±2.02	89.33±1.15	83.00±1.73	79.67±1.53
RCM 5	91.67±2.52	92.01±3.00	87.33±1.53	83.00±1.73	75.00±1.47
Rasi	94.00±2.55	92.25±1.56	89.00±1.73	84.00±2.00	70.00±3.46
Swarnadhan	91.33±2.08	89.00±1.20	86.00±2.10	80.17±2.15	75.00±1.73
BPT 5204	92.00±1.73	88.00±0.56	82.33±1.89	79.00±0.87	74.00±3.46
MTU 1010	91.33±2.52	89.20±1.59	87.67±1.53	81.33±1.60	77.33±1.15
Nidhi	95.00±0.92	92.37±0.74	90.33±1.17	84.00±2.00	80.67±2.89
Sugandhamati	93.33±0.58	89.80±1.80	82.33±2.02	78.00±1.73	72.00±3.46
Tellahamsa	92.96±0.77	88.00±2.00	82.33±1.17	78.33±0.58	72.00±1.73
Vibhava	90.00±1.73	86.00±2.65	82.00±1.00	74.00±2.65	69.67±1.53
DRR Dhan 39	90.33±1.24	84.81±1.92	79.33±1.61	75.67±1.35	69.00±1.73
Pusabasumathi 1121	92.33±1.76	87.10±1.65	84.33±1.53	80.67±2.72	74.00±1.73
Vivekdhan 82	93.77±1.55	91.00±1.32	88.33±1.17	85.67±1.53	80.00±1.73
IMP CM	93.50±0.50	91.63±1.96	89.67±1.03	84.00±1.00	80.00±3.46
Kasturi	91.57±1.96	87.33±5.56	83.67±1.53	75.33±3.79	70.33±1.15
Mahsuri	93.17±2.02	90.90±1.65	88.33±0.58	81.67±2.47	73.00±1.73
RP BIO 226	92.67±1.76	89.70±2.31	85.33±1.37	80.33±2.36	73.33±3.21
Sampada	96.06±0.69	93.50±1.13	84.67±0.29	81.00±2.65	75.33±3.79
Vikramarya	94.17±1.04	91.33±2.09	88.33±1.53	81.00±2.71	75.00±3.46
Mandya vijaya	95.07±1.79	91.67±2.37	88.00±1.73	83.33±2.31	79.00±2.65
Govind	93.64±1.52	90.67±1.53	85.33±1.15	80.00±1.73	74.00±1.73
Jaya	91.00±0.60	88.00±1.50	85.00±2.00	78.67±1.70	72.00±3.46
Group Mean	92.76	89.61	85.60	80.45	74.48
SEM	1.56	2.25	2.97	3.11	3.67

Table 2: Effect of polishing time on Degree of Milling (DOM)

Name of the Rice Variety	DOM (%) at different polishing time (sec)				
	30	60	90	120	150
Akshayadhan	7.83±0.60	11.90±0.12	15.33±1.45	19.00±2.40	27.44±3.67
DRR Dhan 38	8.17±0.93	11.31±0.73	18.56±0.84	23.89±1.39	28.22±3.53
Lalat	7.33±1.17	11.39±0.79	14.00±1.76	17.44±1.39	22.22±1.07
Ravi	6.17±0.60	7.77±0.59	11.44±0.69	17.67±0.67	21.39±1.47
RCM 5	8.46±0.11	7.66±0.88	12.00±0.67	16.78±0.19	27.61±2.48
Rasi	6.77±0.75	8.48±1.05	12.37±1.25	17.07±1.36	28.00±2.00
Swarnadhan	8.33±0.33	11.52±0.52	15.24±1.19	20.14±0.28	24.33±0.67
BPT 5204	8.44±0.38	11.41±0.52	15.72±2.10	20.27±0.68	25.33±0.67
MTU 1010	6.76±1.84	10.17±0.93	11.42±0.87	17.80±1.28	22.33±0.33
Nidhi	5.80±0.84	8.53±0.79	11.97±2.28	18.11±2.36	22.33±3.00
Sugandhamati	6.51±0.14	10.82±1.08	18.03±0.38	21.56±0.51	27.67±0.33
Tellahamsa	8.53±1.44	12.89±0.84	17.36±0.34	22.67±1.00	28.78±0.69
Vibhava	9.79±0.39	13.71±0.51	19.06±1.18	25.74±0.36	29.89±0.38
DRR Dhan 39	8.93±0.64	14.34±0.74	19.39±1.55	23.34±1.18	29.33±1.67
Pusabasumathi 1121	7.34±0.73	12.16±1.15	14.20±1.54	17.24±1.98	24.67±1.33
Vivekdhan 82	6.12±0.20	8.38±0.67	10.99±0.60	15.00±0.58	19.00±1.00
IMP CM	6.92±0.36	11.18±2.44	12.58±2.04	18.00±2.00	23.67±3.67
Kasturi	7.85±0.68	10.59±1.86	14.56±1.68	23.72±0.92	28.67±1.00
Mahsuri	7.56±0.67	9.69±0.73	12.97±1.30	18.67±0.44	27.78±0.84
RP BIO 226	5.97±1.32	8.77±1.49	14.64±0.10	18.94±1.11	24.67±2.00
Sampada	4.64±0.66	6.67±0.15	14.39±1.00	19.67±0.91	24.89±0.19
Vikramarya	5.29±0.53	9.40±0.63	11.78±0.19	18.11±0.85	24.89±0.19
Mandya vijaya	5.31±0.37	8.39±0.10	12.78±0.84	17.67±1.00	22.44±1.50
Govind	7.29±0.85	9.83±0.60	14.78±0.19	20.40±0.44	25.67±0.33
Jaya	9.10±0.17	12.50±0.87	14.67±0.58	20.58±1.03	29.67±2.08
Group mean	7.25	10.38	14.41	19.58	25.64
SEM	1.32	1.99	2.50	2.64	2.96

Table 3: Effect of polishing time on cooking at MCT

Name of the Rice Variety	Identified MCT (ºC)	Polishing times (sec) on cooking at MCT				
		30	60	90	120	150
Akshayadhan	100	-ve	-ve	-ve	-ve	+ve
DRR Dhan 38	95	-ve	-ve	-ve	-ve	+ve
Lalat	95	-ve	-ve	-ve	-ve	+ve
Ravi	95	-ve	-ve	-ve	-ve	+ve
RCM 5	100	-ve	-ve	-ve	-ve	+ve
Rasi	100	-ve	-ve	-ve	-ve	+ve
Swarnadhan	100	-ve	-ve	-ve	-ve	+ve
BPT 5204	100	-ve	-ve	-ve	+ve	+ve
MTU 1010	100	-ve	-ve	-ve	+ve	+ve
Nidhi	100	-ve	-ve	-ve	+ve	+ve
Sugandhamati	85	-ve	-ve	-ve	+ve	+ve
Tellahamsa	100	-ve	-ve	-ve	+ve	+ve
Vibhava	95	-ve	-ve	-ve	+ve	+ve
DRR Dhan 39	95	-ve	-ve	+ve	+ve	+ve
Pusabasumathi 1121	95	-ve	-ve	+ve	+ve	+ve
Vivekdhan 82	100	-ve	-ve	+ve	+ve	+ve
IMP CM	100	-ve	+ve	+ve	+ve	+ve
Kasturi	95	-ve	+ve	+ve	+ve	+ve
Mahsuri	95	-ve	+ve	+ve	+ve	+ve
RP BIO 226	95	-ve	+ve	+ve	+ve	+ve
Sampada	95	-ve	+ve	+ve	+ve	+ve
Vikramarya	95	+ve	+ve	+ve	+ve	+ve
Mandya vijaya	100	+ve	+ve	+ve	+ve	+ve
Govind	95	+ve	+ve	+ve	+ve	+ve
Jaya	100	+ve	+ve	+ve	+ve	+ve

+ve and –ve indicates cooked and uncooked rice at MCT respectively

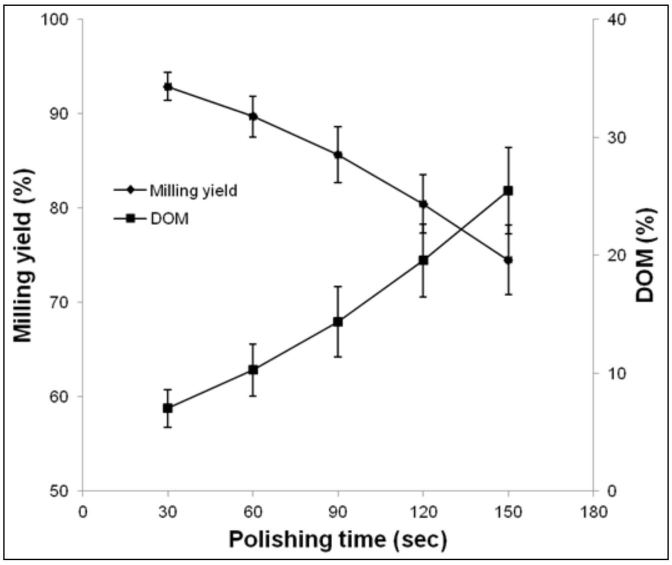

Fig 1: Impact of polishing times (sec) on means of Milling yiled and DOM

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