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THE RELIABLE SELECTION OF A RICE MILLING MACHINERY SYSTEM FOR EGYPTIAN CONDITIONS

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ABSTRACT

The milling performances of four rice milling machinery systems of different whitener units have been tested and compared. These systems include the One-Pass milling system (M1); Two-Pass milling system (M2); Three-Pass milling system (M3), and the locelly (Engelberg) milling system (M4).

The milling tests have been deduced against, three different rice varieties and at three grain moisture content levels. The milling processes of these systems have been evaluated in terms of the milled grain quality, the mill energy consumption, and the milling machinery costs.

The gained results indicated that the three-pass system (M3) produced the highest extra grade rice, and the lowest broken ratio (2 %). In addition, the minimum machinery cost (11.8 LE/ton), and the lowest specific energy consumption (28.06 kWh/ton) are accomplished the two-pass system (M2). Finally, the Engelbarg system (M4) exhibits the highest specific energy consumption (74.708 kWh/ton), the highest broken grain ratio (26.72 %), and the lowest rice quality grade (No5).

INTRODUCTION

Milling is the process of removing, and separating the silver skin and the bran layer, which are in close contact with the brown rice grain. Sabbah (1979) reported that the main objective of rice milling is to obtain the maximum possible yield of whole kernels of white rice, or head rice. He indicated that, the percentage of head rice is a major criterion in grading and pricing milled rice. Since, in many countries less head rice means lower cooking quality. He concluded that the losses during milling process in Egypt might reach a level of 10 % of the total rice production. El-Sahrigi *et al.* (1994) reported that, the losses of rice during milling equivalent to 36 million Egyptian pounds.

Three decades years ago, Koga (1972) indicated that, there was strong argument that obstructed the rice mill modernization in Africa. That is farmers said that "Even though the milling recovery percent of the traditional mills is low, they produce a mixture of bran, small broken grains, and a powdered of husk. That mixture is essential to feed cattle and/or poultry."

Later, that argument had been judged as in the following literatures. Firstly, Geripoldi (1974), reported that, if the bran is well separated from husk, it can be used for oil, and wax extraction. He indicated that rice bran contains, about 14-17 % oil, of which 3 to 9 per cent crude wax. Secondary, FAO, (1984), reported that husk is a coarse meal of low food value and may be harmful substance for both animals and poultry. Finally, Taqure and Duff (1988), revealed that the additional quantity, and the improved quality, due to the rice mill modernization in developing countries, gives more enough money to farmers for buying cattle, and poultry feed.

The traditional milling machinery systems in Egypt are one pass and the Engelbarg millers. Thosa are characterized by using fraction mill concapt. Ismail and Ramadan (1990) showed that rice mills in Egypt could ba divided into three main systems. The first is the shearing mills, which have a rubber roller husker and whitening with a horizontal abrasive and a friction whitener. The second system is the friction mills which abrasive whitenar (whitening cone). The third system is the local, small and simple machine used for hulling and whitening rice in villages.

As a result of Egyptian agricultural engineering policy, the multiple-pass rice milling technology has been introduced in Egyptian mills through vital activities of the private sectors. El-Wadey (1999) indicated that the distributing numbers of the two, and three-pass milling machinery systems allover Egypt is only about 25 mills of the two-pass system, and about 15 mills of the three-pass system.

In fact miller efficiency and milling quality vary a great deal depending upon four main variables, namely: the milling equipment techniques; the inherent quality of the rough rice when harvested; the pre-milling procedures; and variety of rice. Many scientific studies were carried out on the effect of these variables on milling characteristics of different milling machinery designs. These studies may lead to the right decision to select the proper operating parameter levels for testing the compared milling machinery system of the present study.

Ibrahim (1978) studied the effect of some mechanical factors on rice cracking during milling in Englberg milling equipment. He found that the best clearance and speed of that milling machine were 1.5 mm and 1200 r.p.m. respectively. Also, he mentioned that increasing the speed of the machine increased the broken rice grains and decreased the un-hulled paddy. Hamad *et al. (1981)* tested the above mentioned machine, and found that the highest milling efficiency and quality are obtained using the paddy with moisture content 13% (d.b.). *Matthews et al. (1982)* reported that rice separated by thickness yields of a thin fraction is subject to large endosperm losses in the bran and high breakage. They showed that in raw milling of the thin fraction rice, a minimum average of 5.1% of the milled rice was lost as endosperm chips in the bran. Also an average of 54.2% was broken rice, and an average of 25.4% of the whole-grain rice was chalky.

JICA (1983), classified the milling machinery systems according to the whitening mechanism type into grinding and friction types. *JICA (1983)*, showed that the friction type miller is suitable for short grain rice varieties, while the grinding type mechanism is industrialized for both short and long grain rice varieties. Velupillai and Pandey (1987) showed that the approximately 65 to 73 % of the bran is removed in the first 20 seconds of milling time for any tested variety. The rate of bran removal was as much es 4 times higher in the first 20 seconds as that in the next 20seconds of milling time. They attributed that to the rapid fracture of the weak kernels and subsequent releasa of endosperm particles into the bran. Bekki and Kunze (1986) reported that the friction type miller produced many broken grains when compared to the abrasive type miller. They showed that the abrasive type miller treats the grains more gently during the milling process of the brown rice.

Yamashita *et al.* (1989) reported that when high moisture paddy is husked, some of the husked brown rice grains get their external skin damaged, and some of their embryos removed. These effects can accelerate the drying rate of brown rice and can result in the cracking of grains. *Andrews et al. (1992)* reported that moisture content is the most significant variable affecting head rice yield. As moisture content decreased, bran removal became more difficult and head rice yield increased. He concluded that the interaction effects of moisture content with milling time, weight placement, and rough rice weight are greatly influenced the degree of milling.

Ibrahim (1992) studied the effect of physicochemical and mechanical properties on milling quality of eight rice varieties. He concluded that all varieties should not be mixed during milling. Since the airiness in the length /width and starch / calcium ratios were great. *El-Sahrigi et al (1994)* found that for the whitening machine, the broken kernels, degree of whitening and the force required for whitening process is increased with increasing whitening machine speed. *Helmy (1995)* found that, increasing milling time tends to increase the percentage of broken, degree of whitening and decrease head yield and grain strength of milled rice. His best results were obtained at 50 and 40 minutes milling time for short and long grain rice variety respectively. *Shoughy (1995)* found that, the clearance between rollers, the speed of rollers and the moisture content of rough rice had highly significant effect on broken rice, un-hulled grains, hulling efficiency, broken milled kernels and degree of whitening during milling processes.

Abdelmotaleb (1998) concluded that the percentage of milled rice is affected by delay harvesting, and also related to method of drying. Also he showed that this percentage is not related to method of harvesting (by hand or by rice combine).

The aim of the present study is to evaluate the suitability of different milling equipment techniques to the Egyptian rice mills. We mainly focused on quantifying the milled grain quality, the specific energy consumption, and the machinery costs of four different milling machinery systems to determine the best system, and working conditions for the Egyptian rice mill.

MATERIALS AND METHODS

The main objective of this work was chosen to quantify and compare the milling performance of four milling machinery systems. The essential differences between these systems represent in the processing equipment of the whitening operation. They have been tested against three rice varieties (Reho, Giza171, and Giza178), and three grain moisture content levels (13, 13.5and 14%). The compared systems are the One-pass miller two-pass miller, three-pass miller, and the Engelberg miller. They will be refereed in the present study as: - (M1), (M2), (M3), and (M4) respectively.

1. Processing units of the tested systems:

The typical grain flow charts and the processing units of the four tested systems are shown in Figure (1). It can be observed that these milling systems have different numbers of the operating equipment units. The Engelberg (M4) and the one-pass (M1) systems have similar processing units namely one cleaning unit, three elevator units, and one unit for husking and whitening. The two-pass system (M2) has one cleaning unit, 5 elevator units, one husking unit, one abrasive whitening unit, and one friction-whitening unit. While the three-pass (M3) has one cleaning unit, 6 elevator units, one husking unit, two abrasive whitening units and one friction- whitening unit.

It should be denoted that, the cleaning, hulling and polishing processes are commonly, established in all tested mills. While, the abrasive whitening process is included only in M2 and M3 milling systems.

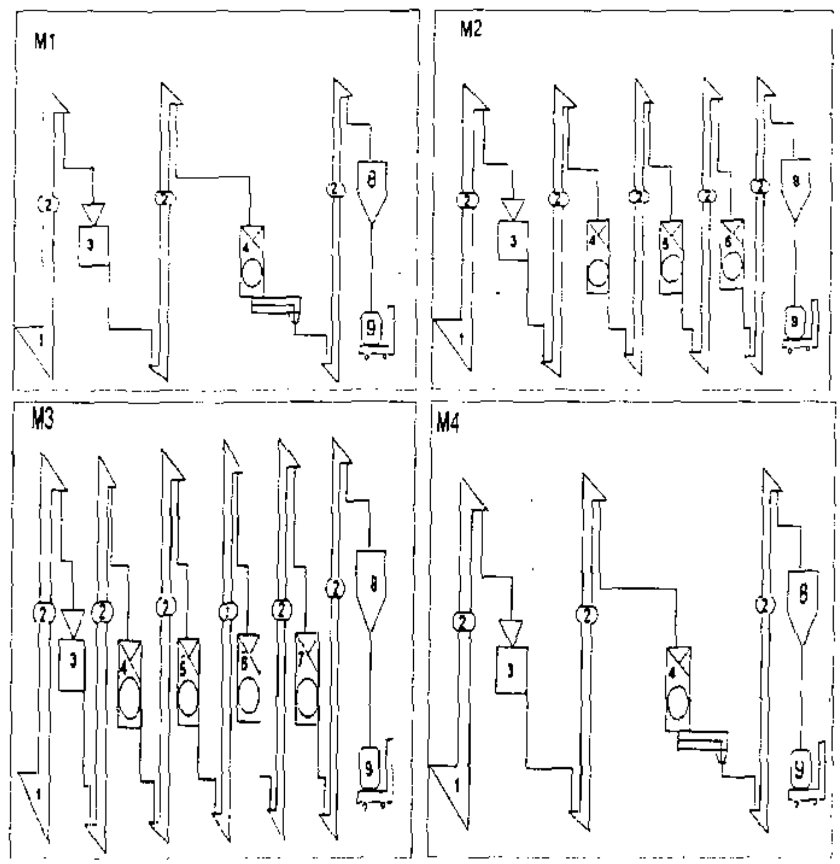


Figure (1): The seed flow charts of the four tested milling systems
1-Paddy. 2-Elevator. 3- Cleaner. 4-husker. 5- Abrasive whitener. 6-Abrasive whitener. 7-Friction whitener. 8-Control tank. 9- Scale

2.Equipment techniques of the compared system: -

Paddy as received at the mill contains about 5 percent or more of extraneous materials, such as small lumps of soil, stalk, and dust. These materials have to be separated in the cleaning equipment. In addition the bucket elevator is commonly employed for vertical conveying of rice grains. Both cleaning and elevating operations have similar equipment techniques in all compared mills. These units are often locally made in Egypt. But the essential difference of the equipment techniques of the compared systems presents in the processing equipment of the whitening operation.

However, the main technician specifications of the milling equipment in the four compared milling systems are listed in table (1).

Table (1): **The main technician specifications of the processing equipment of the four compared milling systems.**

Mill System	Processing equipment	Model	Input Cap. (Kg/h)	Motor power (kW)	Roll dimensions L*W*H(mm)	Main shaft (rpm)
One-pass (M1)	One equipment for husking and whitening	SB10D	900	14 7	10.16*22.2	950
Two-pass (M2)	Husker	HC 600A4	1800	7.35	850*700*1600	1000
	Abrasive	RBA15AL	1500	13.23	1100*530*1570	1000
	Friction	RA-125	1400	13.23	1100*530*1570	850
Three-pass (M3)	Husker	HC 600A4	1800	7.35	850*700*1600	1000
	Abrasive	RBA15AL	1500	13.23	1100*530*1570	1000
	Abrasive	RBA15AL	1500	13.23	1100*530*1570	1000
	Friction	RA-125	1400	13.23	1400*655*1320	850
Engl-Berg (M4)	One equipment husking and whitening	Local	290	19.85	10*22	950

It should be denoted that both one-pass system (M1) and Engelbarg (M4) are carrying out husking and whitening operations into two separately sections of an individual equipment. An electrical motor of 14.7 kW operates that equipment. The essential differences between M1, and M4, is presented in the operating principle of husking and in charging of the milled rice. Since the husking section of system (M1) is composed of two horizontal tangential rubber rolls, revolving in opposite directions at two different speeds. While in M4 system it is a roller revolving inside a casing, round the face of the roller are ribs. In addition the white rice in the case of M1is charging out from a white rice outlet and the brans is charging down from a bran outlet. While it is charging out with the bran rice in the case of M4

The husking of system M2 is carrying out separately in individual equipment. While, whitening is performing at two sequence stages in two sequence equipment. The first uses the abrasive concept. The second employs the friction concept. In each whitening stage about 50% of the total brans amount is accepted to be removed. By this way that system M2 can gently milled the grains. On the other hand, the milling system (M3) consists of four milling equipment. Three of them are similar in construction and dimensions to those previously described in milling system (M2). The fourth equipment is an additional abrasive whitening unit. This unit is equipped between the friction and abrasive units to provide higher whitening and polishing grains. It should be denoted that system (M3) is designed to carry out the whitening process at three sequence stages. In each stage about 33% of the total bran amount is accepted to be removed. That regular grain flow could be achieved in M2,and M3 systems by regulating flow pressure using an added weight lever. This lever controls the outlet gate opening time.

3. Experimental Procedure: -

The milling tests were carried out inside four private mills, all at Damietta Governorate. Whereas 27 pre–milling rice grain samples (each of 2 tons weight) were transported, for each mill. These samples were random collected after combine harvesting from each rice variety field at grain moisture content (Mc) of about 20-22 % (d.b.). Then, they dried using natural drying method under shade in grain layers, each of 10cm thickness until Mc is approximated 14 %. In order to accurate the evaluation of the compared rice mills, a special experimental scheme was continued for six days, and repeated three times. In the first and second days, the milling tests were conducted to illustrate the effects of both milling system and rice variety parameters at approximately Mc of 14 %. While, in the third and fourth days these effects were investigated at approximately Mc of 13.5 %. During, the fifth and six days the Mc approximated about 13 % and the effects on the milling quality were deduced. It should cleared that a sample of 1000 grains was random collected from each harvested yield and just before milling tests to measure Mc .A Satake digital grain moisture content meter (model, SS-5) was used for that purpose

4. Methods of evaluation:

Three evaluating quantities have been used to compare the performances of the four investigated milling systems. These quantities are the milled grain quality, the specific energy consumption of each mill, and the milling machinery costs.

4.1. The Milled grain quality:

Random grain samples each of five kilograms were collected from the product of each treatment. Each sample was divided manually into ten equal parts. Each part was divided into five small parts each of about 100 g. Each sample of 100 g has been distributed on a flat glass plate to sort the product into 3 main categories namely: - undesirable materials (UN),the broken grains(BR), and head rice(HR).the undesirable materials includes 6 *components. Those are* foreign materials (1), paddy (2), chalky kernel (3), yellow kernel (4), red kernel (5), and immature kernel (6). Then the percent each component in that sample could be estimated as follows:

$$\text{Component \%} = \frac{\text{Mass of that component in the milled sample}}{\text{Total mass of the sample}} \times 100$$

Finally the quality grade of the milled grain product has been determined according to the statements of GOEI (the General Organization for export and import ,1997), table (2).

Table (2): The product graduation base of the *General Organization for* Export and Import (G.O.E.I).

Quality Grade	*Fore.* %	Paddy %	Chalky %	Yellow %	Red %	Immature %	Broken %
Super	0.02	One grain	1	0.1	0.5	0	< 2
Excellent	0.03	One grain	1.55	0.2	0.5	0.5	2-2.9
No. 1	0.05	0.01	2	0.25	1.5	0.5	3-5.9
No. 2	0.1	0.01	2.5	0.5	2	1	6-11.9
No. 3	0.2	0.03	3.5	1	2.5	1	12-19.9
No. 4	0.3	0.04	5	1.5	3	2	20-29.9
No. 5	0.6	0.1	8	2	3.5	2	30-39.9
No. 6	0.7	0.2	12	2.5	4	2	>40

According to that graduation scale the grain product has to be divided into eight *quality grades. These are super, excellent,* No.1, No.2, No.3, No.4, No.5 and No.6. The graduation categories in table (2) are dependent upon the distribution of 8 product components. In general if the product is having broken grain of less than 2 %, hence, it could be sorted as super excellent grade. And if broken grain ratio ranges from 30 to 40 %, then the product could be sorted as grade No.6. etc.

4-2. Specific energy consumption (SEC): -

To assess the energy consumption, *it was necessary to account the* electrical, and the human energy consumption in each compared mill. It *should* be denoted that the electrical energy is consumed throw five electrical motors in each of (M1) and (M4) milling systems. While it is consumed throw eight and eleven electrical motors in (M2), (M3) respectively. Furthermore, from a personal communication it was stated that the worker numbers are 5,7,8 and 5 in the four compared systems M1 M2, M3and M4 receptively.

Similar USSR electrometers model (CA4-N672T) have been used to account the electrical energy consumption for each mill. While, the average power of one worker has been considered as 0.074 kWh according to **Ezeke** (1987). The electrical energy consumption (in kWh) was accounted for each milling test. Then, the specific electrical energy (SEEE) and the specific human energy consumption *(SHEC) in kWh/ton could be estimated.* Dividing the accounted energy data on the average production rate (ton/h) did that. The total specific energy consumption (TSEC) can be estimated as follows:

$$\text{TSEC} = \text{SEEC} + \text{SHEC} \qquad ...(1)$$

4.3. Milling machinery costs: -

The cost of any of the compared milling machinery system has been determined by estimating costs of owning the equipment of that system (Cos) and cost of operating them (Cop).), In the present study the ownership cost (Cos) of each individual machine or equipment was estimated according to *Srivastava et al.(1995)*. While, the operating cost (Cop), was calculated according to Hunt (1983) and *ASAE, (1992)*.

The total milling machinery system costs was estimated as the sum of each entire equipment or machine costs. The, ownership, operating and total milling machinery costs could be calculated per-ton base. The total machinery cost per-ton has been computed by multiplying by the actual time required by the system to cover milling one ton. To judge the optimum selection of milling machinery system the annual economic save (ES) of each mill was estimated. That could be estimated as the difference between the product of multiplying the average yearly mill capacity by 50, and the total machinery system costs as follows: -

$$ES = \text{averag mill capacity} \times 50 - \sum(Coa + Cop) \cdots\cdots\cdots (2)$$

In the above equation 50 LE was assumed to be the discharge of milling one ton of rice by any system.

RESULTS AND DISCUSSION

Milled rice grain quality and mill productivity

The percentages of the milled product components and the production rates due to each investigated treatment have been determined and tabulated in table (3). The tabulated data present also the quality grade of milled grain, which accomplished the four investigated systems under the effects of rice varieties, and moisture content parameters.

Table (3) shows that the average product rates are 534.8, 1310, 1132 and 289.2 Kg/h for M1, M2, M3 and M4 respectively. Thus according the mill productivity M2 has the highest milling product rate followed by M3 and M1 came at the end M4. In addition the components of milled product is included in table (3) in three main graduation categories namely: undesirable materials percent (UM%), broken rice percent (BR%), and head rice percent (HR%).

Fig (2) shows the average data of these categories that accomplished the four tested milling systems. Analysis these data show in general that there is shortage in the design feature of the milling equipment of milling systems M1, and M4. That is because they produced high values of both UM%, and BR%.

Relating the percentages of the product components to the statements of General Organization for Export and Imports (GOEI) in table (2), the average rice quality grade for each treatment can be classified and tabulated as shown in table (3). The data reveal that product of M1 and M2 systems are almost exhibiting grain grade of No3 and No2 respectively. While the product of M3 include both extra finance and No1 grades. The worst grain grade (No5) is achieved when milling any rice variety by M4.

Table (3) and fig (2) show that the average of undesirable material percentages are about 9.08, 5.49,3.60,and14.29 % for M1, M2, M3, andM4 respectively. These results indicated that higher separation efficiencies (less undesirable material percent) have been achieved by the Satake miller designs, compared to the Engelbarg one.

It can be stated that the three systems M1, M2 and M3 reduced the undesirable materials in the milled product, by about 36.46, 61.58, and 74.81 % respectively compared to the traditional system. That result trend may be attributed to the number of separation outlets in each system. Whereas, the Satake designs have four separation outlets for the individual passing of husk, extraneous, bran and the head rice.

While there is only one outlet orifice in the milling equipment unit of the Engelbarg system.

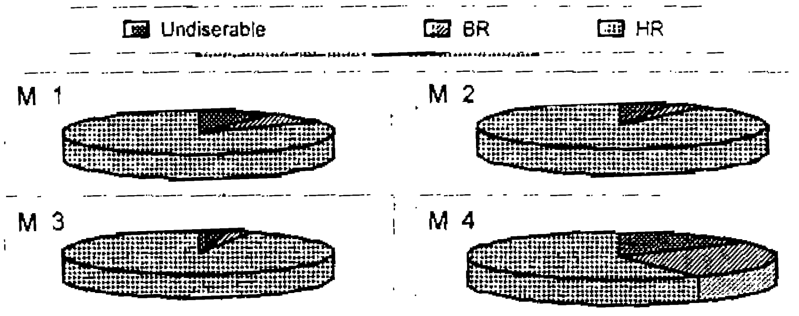


Fig. (2) The effect of the milling equipment systems on: the undesirable materials (UM), the broken rice (BR), and the head rice (HR) percentages

Furthermore the data of table (3) shows that, the separation efficiency was not affected by the moisture content parameter (Mc%) and slightly affected by rice variety (R) parameter.

Fig (3) provides a useful insights on the percentages of both milled grain broken (BR%), and head rice (HR%) as they affected by the used milling system parameter and both grain parameters (variety and moisture content Mc%). This figure presents 12 relationships between Mc% and BR%, in doted lines, which can be estimated by the left hand Y-axis. While other 12 relationships between Mc% and HR%, are presented in whole lines that can be estimated by the right hand Y-axis. Furthermore each of BR%, and HR% relationships is presented in three groups with respect to the variety. Each group involves four relationships with respect to the machinery system type.

From fig (3) it can be seen in general that both BR%, and HR% are strongly influenced by the used milling equipment parameter and slightly influenced by paddy variety, and moisture content parameters.

Table (3) Average grain *quality and mill productivity* performed by the four compared milling systems

Studied parameters			Evaluating parameters of the milled product									
Sys.	Variety.	Mc. %	Product component percentages %								Productivity	
			Undesirable materials %						BR	HR	grade	Kg/h
			1	2	3	4	5	6	%	%		
(M1)	Giza 178	13.0	0.19	0.03	2.90	1.25	3.00	1.90	10.00	80.73	3	518.0
		13.5	0.19	0.03	3.00	1.30	2.26	1.80	11.00	80.42	3	518.0
		14.0	0.18	0.04	3.20	1.40	2.20	1.80	12.00	79.38	4	516 0
	Aver.	13.5	0.18	0.03	3.03	1.31	2.48	1 76	11.00	80.17	3	517.0
	Giza 171	13.0	0.21	0.03	3.50	1 10	2.29	2.00	9.00	81.87	3	538 0
		13.5	0.20	0.03	4 10	1.30	2.22	1.50	9.00	81.64	3	535.0
		14.0	0.19	0.03	4.10	1 35	2.20	1.50	10 00	80.62	3	534.0
	Aver	13.5	0.20	0.03	3.90	1.25	2.23	1.66	9.33	81.37	3	535.6
	Reho	13.0	0.18	0.03	3.50	1.20	2.50	2.00	7.00	83.59	3	582.0
		13.5	0.18	0.03	3 80	1.25	2.30	1 90	8.00	82.54	3	560 0
		14 0	0.16	0.03	4.40	1.31	2.00	1.00	10.00	81 11	3	559.0
	Aver	13.50	0 17	0.03	3.90	1.25	2.26	1.36	8.83	82 41	3	560.30
System total average			0.21	0.03	3 44	1.31	2.41	1.68	10.2	80.1	3	534 8
(M2)	G 178	13.0	0 15	0.03	1.70	0 34	2 10	0.80	4.90	89.97	2	1291.0
		13.5	0.14	0.04	1.70	0.35	1.90	0.80	5.20	89.87	2	1290.0
		14.0	0 10	0.04	2.00	0.35	1.70	0.90	5.30	89 61	2	1285.0
	Aver	13.5	0.13	0.03	1 80	0.34	1.90	0.83	5.13	89.81	2	1288.6
	G. 171	13.0	0.13	0.02	2.20	0 37	1.90	0.60	3.60	90.78	2	1315.0
		13.5	0 10	0 03	2.30	0.39	1.70	0.90	3.90	90.68	2	1310.0
		14.0	0.09	0.03	2.50	0.41	1.60	1.00	4.10	90.27	2	1308.0
	Aver.	13.5	0.10	0.02	2.33	0.39	1.73	0.90	3.93	90.57	2	1311.0
	Reho	13.0	0.08	0.02	2.60	0.43	1.80	1 00	3.00	91.07	2	1346.0
		13.5	0.06	0.02	2.70	0.44	1.80	1.00	3.20	90 78	2	1338.0
		14.0	0.05	0.02	2.80	0.47	1.60	1.10	3.30	90 65	2	1333.0
	Aver	13.5	0.1	0.0	2.7	0.4	1.7	1.0	3.2	90.8	2	1339 0
System total average			0.10	0.03	2.28	0.33	1.90	0.85	4.27	90 3	2	1310
(M3)	G. 178	13.0	0.05	0.02	1.40	0.21	1.35	0.53	2.50	93.95	1	1115.0
		13.5	0.04	0.02	1.60	0.23	1.20	0.53	2.90	93.48	1	1109.0
		14 0	0.04	0.02	1.70	0.24	1.20	0.52	3.10	93.18	1	1106.0
	Aver.	13.5	0.04	0.02	1.56	0.22	1.25	0.52	2.83	93.53	1	1110.0
	G. 171	13.0	0.04	0.02	1.80	0.23	1.25	0.51	2.20	93.95	E	1138.0
		13.5	0.04	0.02	1 90	0.24	1.24	0.50	2.30	93.77	1	1136.0
		14.0	0.04	0.01	2.00	0.26	1.10	0.50	2.40	93.69	1	1129.0
	Aver.	13.5	0.04	0.01	1.90	0.24	1.19	0.50	2.30	93.79	1	1134.0
	Reho	13.0	0.04	0.02	1.60	0.24	1.20	0.52	2.00	94.39	E	1165.0
		13.5	0.03	0.02	1.80	0.24	1.15	0.50	2.00	94.28	E	1163.0
		14.0	0.03	0.02	1.60	0.25	1 10	0.50	2.20	94.1	1	1162.0
	Aver	13.5	0.03	0.02	1.73	0.24	1.13	0.50	2.06	94.25	E	1163.3
System total average			0.04	0.01	1 65	0.21	1.18	0.51	2.60	93.66	1	1132
(M4)	G. 178	13.0	0.45	0.10	7.30	1.80	3.50	2.10	26.00	58.75	5	280.0
		13.5	0.43	0.08	6.50	1.75	3.50	2.00	27.00	58 74	5	278.0
		14.0	0.39	0.08	5.30	1.70	3.40	2.00	29.00	58.13	5	275.0
	Aver	13.5	0.42	0.06	6.63	1.75	3 46	3.03	27.33	58.54	5	277.6
	G. 171	13.0	0.40	0.10	7.50	1.90	3.40	2.10	24.00	60.6	5	286.0
		13.5	0.38	0.06	7.00	1.90	3.20	2.00	25.00	60.46	6	284.5
		14 0	0.37	0.05	6.90	1.70	3.20	1.90	26.00	58.88	6	284 0
	Aver	13.5	0.38	0.07	7.13	1.83	3.26	2.00	25.00	59.98	5	284.8
	Reho	13.0	0.36	0.08	7.60	1.70	3.40	2.00	23 00	60.86	5	309.0
		13.5	0.36	0 07	7.40	1.60	3.30	2.00	23.00	62.27	5	306.6
		14.0	0.34	0.04	7 00	1.40	3.20	2.00	25.50	61.03	5	306.0
	Aver.	13.5	0.35	0.06	7.33	1.56	3.23	2.00	23.83	61 76	5	307.8
System total average			0.44	0.07	6.92	1 68	3.13	2.05	26.70	58.7	5	289.2

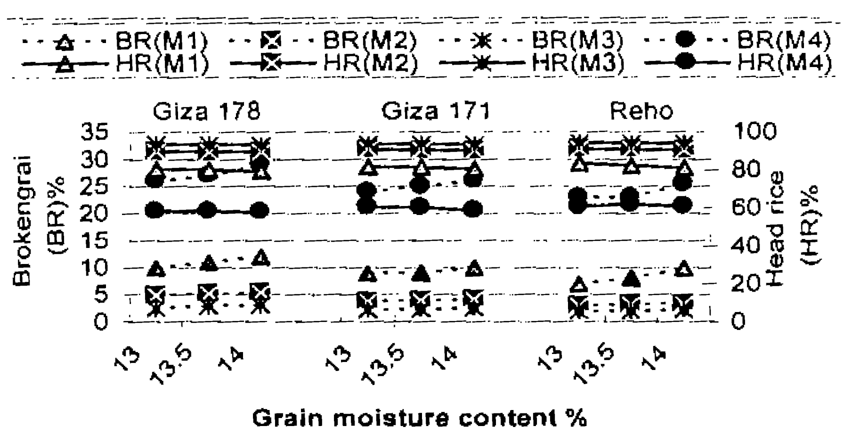
HR= head rice percent
Sys.= tested milling system

Mc%=grain moisture content
BR= broken grain percent

It should be denoted that the lowest grain broken ratio was accomplished the three pass system (M3). It reveals an average grain broken ratio of 2.60 %, versus 10.24, 4.27, and 26.7 % for M1, M2 and M4 milling systems respectively. Also using M3, Reho variety exhibited the highest head rice (94.25%), while milling the same variety by M1, M2, and M4 resulted in head milled rice of 82 41,90.83,and 61.76 % respectively. On the other side the Engelbarg system (M4) resulted in the highest broken ratio with an average 27.3,25.0 and 23.8% for Giza178, Giza171 and Reho respectively.

The recorded data shows also that, milling by any tested system, the Reho rice variety exhibited the lowest broken ratio and the highest head rice percent. Giza 171, and Giza 178 as the higher broken ratio and lower head rice percent follow that arrangement.

The combined effects of machinery system and Mc % parameters do not show any steady trend. It can be concluded that increasing the grain moisture content from 13 to14% leads to slightly increase the grain broken ratio by about 0.75, 0.25, 0.25, and 1.6 % and also slightly decrease the head rice product by about 1.30, 0.75, 0.20, and 1.7 % for M1, M2, M3, and M4 respectively. While the combined effects between machinery system and paddy variety parameters reveal that milling different rice varieties in the Engelbarg and the one-pass systems will gave random head rice results.



Fig(3) Grain broken(BR),and head rice(HR)ratio as affected by milling system, and rice variety under different grain moisture content

But it should be denoted that milling rice in both two and three-pass milling systems gave steady head rice result.

Milling energy consumption: -

The accounted data of energy use in the four compared mills include the electrical and the human energy, which has been dissipated for each processing unit (cleaner, elevators, husker and whiteners). The computed data reveal that the average electrical energy consumption are

19.22,35.00,36.00 and 21.17 kWh for systems M1, M2, M3 and M4 respectively. While the human energy consumption are in general represented a small fraction (1-2%)of electrical energy consumption.

Fig (4) provides useful insights on the effects of the studied variables on, the average specific energy consumption. It is easily noticed that the milling system parameter is the dominant parameter affecting the energy consumption. But it should be denoted that the average specific energy consumption is about 38.43, 28.06, 32.34, and 74.71 kWh/ton for M1, M2, M3 and M4 respectively. Also the data of this figure reveals that, the energy consumed by the tested milling systems is affected by the rice variety more than moisture content. On the other side it can be noticed that Giza178 exhibited the highest electrical energy consumption followed Giza171 came at the end Reho variety. This result trend may be due to the grain properties. Since the shorter grain of Giza178 my be stronger enclosed with husk than the taller one (Reho) and vice versa

Also it may be stated that the effects of moisture content on specific energy consumption can be negligible That is because the variations in the electrical energy measurements were very low by varying grain moisture content between 13 and14%.

The combined effect of both milling system and rice variety parameters on the electrical and human specific energy consumption inside each processing unit are presented in table (4).

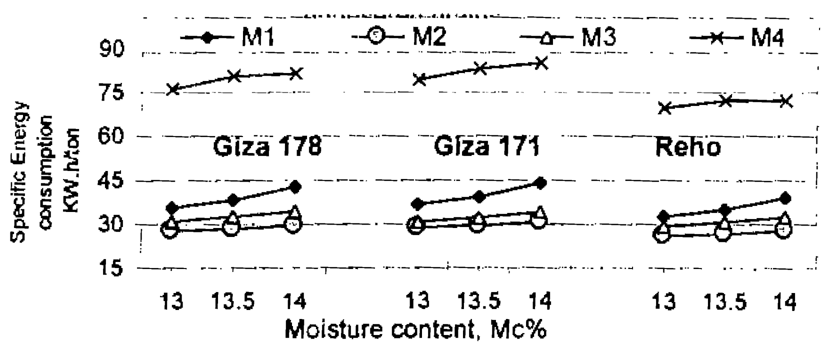


Fig (4): Specific energy consumption as affected by milling, rice variety,under different grain moisture content

Table (4): The combined effect of milling system and rice variety parameters on the electrical and human energy consumption inside each processing unit.

Mill sys	Milling equipment	Rice variety											
		Giza 178				Giza 171				Reho			
		Energy type		Total energy		Energy type		Total energy		Energy type		Total energy	
		Elect.	Hum	kWh/t	%	Elect.	Hum	kWh/t	%	Elect.	Hum	kWh/t	%
M1	Cleaner	2.3	0.3	2.6	6.6	1.3	0.1	1.4	4.2	1.7	0.1	1.8	5.2
	Elevator	6.9	0.3	7.2	18.4	5.7	0.1	5.9	17.9	6.3	0.1	6.5	18.5
	Miller	28.5	0.8	29.3	75.0	25.0	0.4	24.4	77.8	26.3	0.4	26.7	76.3
	Total	37.7	1.4	39.1	100	32.0	0.7	32.7	100	34.3	0.7	35.0	100
	%	96.4	3.6	100		98.0	2.0	100		97.9	2.1	100	
M2	Cleaner	1.9	0.1	1.9	6.9	1.6	0.1	1.7	6.2	1.5	0.1	1.6	5.9
	Elevator	6.7	0.1	6.7	24.1	6.4	0.1	6.5	24.1	6.2	0.1	6.3	24.0
	Husker	5.7	0.1	5.8	20.8	5.3	0.1	5.4	20.1	5.1	0.1	5.1	19.7
	Abrasiv	*7.0*	*0.1*	*7.0*	25.3	6.6	0.1	6.7	25.0	6.4	0.1	6.5	24.8
	Fraction	6.2	0.2	6.4	22.9	6.4	0.2	6.6	24.5	6.5	0.2	6.7	25.6
	Total	27.5	0.4	27.9	100	26.4	0.4	26.8	100	25.7	0.4	26.1	100
	%	98.5	1.5	100		98.5	1.5	100		98.5	1.5	100	
M3	Cleaner	1.7	0.1	1.8	5.5	1.5	0.1	1.6	5.1	1.3	0.1	1.4	4.6
	Elevator	6.8	0.1	6.8	21.0	6.4	0.1	6.5	21.1	6.1	0.1	6.2	21.0
	Husker	5.9	0.1	5.9	18.2	5.6	0.1	5.7	18.5	5.3	0.1	5.4	18.4
	Abrasiv	6.1	0.1	6.2	19.0	5.7	0.1	5.8	18.8	5.5	0.1	5.6	19.0
	Abrasiv	6.0	0.1	6.1	18.8	5.7	0.1	5.8	18.8	5.5	0.1	5.6	19.0
	Fraction	5.5	0.2	5.7	17.5	5.2	0.2	5.4	17.5	5.1	0.2	5.3	18.0
	Total	32.0	0.5	32.5	100	30.2	0.5	30.8	100	28.8	0.5	29.3	100
	%	98.3	1.7	100		98.3	1.7	100		98.3	1.7	100	
M4	Cleaner	1.8	0.3	2.1	2.8	1.1	0.3	1.3	1.8	1.0	0.2	1.2	1.8
	Elevator	7.6	0.3	7.9	10.6	6.7	0.3	6.9	9.6	6.1	0.2	6.4	9.6
	Miller	63.8	0.8	64.7	86.7	63.4	0.8	64.2	88.6	58.4	0.7	59.1	88.6
	Total	73.2	1.3	74.6	100	71.1	1.2	72.4	100	65.5	1.2	66.7	100
	%	98.2	1.8	100		98.2	1.7	100		98.2	1.8	100	

Referring table (4), it can be seen that the whitening operation is the most consumed energy compared to the other processing operations inside each system. Since, it consumed about 77, 70,74, and 88 % of the total energy consumed by the milling systems M1, M2, M3 and M4 respectively. The corresponding percentages for cleaning operation are 5, 6,5,and 2%. While these percentages are as 18,24,21,and10 for elevating operations.

Milling Machinery System Costs:

Table (5) shows the important assumptions and the estimated items that are necessary for calculating the two cost types (Coa) and (Cop). While Fig (5) shows the estimated cost components which are coincided the four investigated milling systems.

Table (5): The important assumptions necessary for calculating the cost

Items	M1	M2	M3	M4
			Milling Machinery Systems	
Pu. Price , (LE)	15000	30000	150000	5000
Salv.value = 0.1 Pu	1500	3000	15000	500
Insurance=2 % Pu	300	600	3000	100
Interest = 10% Pu	1500	3000	15000	500
Elec.cons. kW/h	19.22	35	36	21.17
Elec price LE/kW	0.18	0.18	0.18	0.18
Machine life Years	10	10	10	5
Yearly operating (h)	2000	2000	2000	2000
Production, (kg.h)	534.8	1310	1132	289.2
Number of labor	5	7	8	5
Repair factor F1	0.54	0.54	0.54	0.54
Repair factor F2	2.1	2.1	2 1	2.1

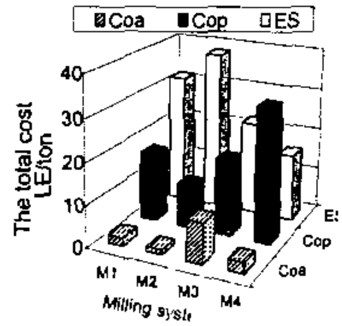


Fig.(5):The estimated cost components coincided the four studied systems.

According to *Srivastava et al.(1995)* it can be found that the annual ownership cost (Coa) are 2175 LE/Y for M1 versus 4350, 21750 and 1195 LE/Y for M2, and, M3 and M4 respectively. The average mill product are 534.8, 1310, 1132 and 289.2 Kg/h for M1, M2, M3 and M4 respectively. Hence the per-ton ownership costs, are as 2.03, 1.2, 9.62 and 2.06 LE/ton for the four milling systems M1, M2, M3 and M4 respectively Fig (5).

While, according to Hunt (1983) and *ASAE, (1992)* the operating cost (Cop), has been calculated. The (Cop) includes labor cost (Lc), electricity cost (Ce), maintenance and repair costs (Crm). The estimated Lc, Ce, and Crm for milling one ton using one-pass milling system (M1) is found about 2.34,6.75,and 0.49 LE/ton. While the corresponding Lc, Ce, and Crm values for milling one ton using M2, M3 and M4 are found about 0.95, 1.10 and 4.3; 4.26,6.40 and 13.20, and0.90, 5.25 and 1.40 LE/ton, respectively. Thus the total costs for operating the four milling systems M1, M2, M3 and M4 may be as 16.59, 10.50, 18.03 and 31.86 LE/ton, respectively.

Furthermore, the sum of ownership and operating costs for the four compared milling systems (M1, M2, M3 and M4) are estimated as18.62, 11.79, 27.65 and 33.92 LE/ton. It can be seen that the lowest cost is accomplished M2 milling system. Hence M2 system may be saved about 65.46, 37.10, and 57.65%% compared to the milling systems M1, M3 and M4 respectively. Referring the previous values It can be stated that the machine purchase price is not lonely the parameter which is influenced both ownership and operating costs. But also the productivity has its own significant effect.

The economic income may be as; 53400, 131000,113100 and 28900 LE/Y for milling system M1, M2, M3 and M4 respectively, Eq.(2) was used to estimate the annual economic save (ES) for all compared milling system Thus the net economic save values may be as shown in fig(5) as follows 31.38,38.21,22.35 and 16.03 LE/ton for M1, M2, M3 and M4 respectively.

Finally from the analysis of the cost data it can be stated that it is completely unwise to use the Engelbarg system, if M1 or M2 or even M3 systems are available., Consaquently replacing M2 or M3 systems instead of M1 and M4 will be provided good to save economic in Egypt.

CONCLUSIONS

The gained results can be summarized in the following points:

Based on the milled grain quality the three-pass milling system (M3) is superior to the other compared systems. Since, it gave high extra grade rice of 94.26 %, and low seed broken ratio of 2 %.

Energy consumption rates of 38.340, 28.062, 32.337, and 74.709 kWh/ton, are accomplished M1, M2, M3, and M4, systems respectively.

Two-Pass system (M2) may be saves about 65.46, 37.10, and 57.65% of the milling costs compared to M4, M1, and M3 milling system respectively.

The highest rice quality and the lowest energy consumption for all systems occurred at moisture content of 13 %.

The whitening equipment units of all system consumed the highest energy consumption compared to cleaning, and elevator units.

Owing to all milling operation constraints, the two-pass or the three-pass milling system is recommended to be replaced instead of the Engelbarg system. That is because the Engelbarg system exhibited the highest specific energy consumption (74.708 kWh/ton), and the highest broken grain ratio (26.72 %) and the lowest grade rice (grade No. 5).

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الاختيار الأمثل لآليات مضارب الأرز المصرية

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يقترب الفقد الراجع لصناعة ضرب الأرز فى مصر من ١٠% من إجمالى إنتاج حبوب. هذا الفقد يرجع بدرجة كبيرة إلى عدم كفاءة الآلات الرئيسية داخل المضرب والتى تقوم بعمليات التنظيف والتقشير والفصل والتبييض وخلافه. ولذلك فطن المتخصصين الى تصميم نظم آلية بمضارب الأرز يتعدد فيها عدد مرات مرور الحبوب فى مرحلة التبييض على عدة وحدات آلية تستخدم ما يسمى نظام ضرب أرز آلى أحادى أو ثنائى أو ثلاثى المرور .ونتيجة لنشاط القطاع الخاص بمصر أدخلت أنظمة ضرب آلية من النوع ساتاكى ثنائية وثلاثية مرور الحبوب. لتحل محل الأنظمة الشائع استخدامها الآن هى الإنجلبير وساتاكى أحادى المرور .إلا أن النظامين ثنائى وثلاثى المرور يعتبرا حديثى التواجد بمصر.

لذلك كان الهدف من هذا البحث "هو توفير قاعدة البيانات الخاصة لتقييم أربعة أنظمة آلية مختلفة لضرب الأرز على ضوء درجة جودة المنتج ومقدار الطاقة النوعية الكهربية، والبشرية اللازمة لإنتاج طن ارز أبيض وايضا التكاليف الآلية لضرب طن أرز شعير بكل نظام بالاضافة الى دراسة تأثير عوامل خاصة بمواصفات الحبة قبل الضرب على كفاءة آليات كل مضرب وجودة المنتج.

متغيرات الدراسة تضمنت :-

- أربعة أنظمة آلية مختلفة لضرب الأرز هى:-
  ١-أحادى المرور M1 (Satake one-pass)
  ٢- ثنائى المرور M 2 (Sataky two-passes)
  ٣- ثلاثى المرور M3 (Satake three-passes)
  ٤- نظام الإنجلبير M4 (Englbereg system)
- ثلاث أصناف هى: جيزة ١٧٨ ؛ جيزة ١٧١؛ ريهو تم تبييضها بمستويات رطوبة هى:١٣ ؛١٣,٥؛ ١٤%

وقد تم إجراء الاختبارات الفعلية بمضارب مختلفة بمحافظة دمياط، حيث خصص مضرب واحد لأجراء التجارب الخاصة لاختبار كل نظام. وقد روعى بقدر الإمكان توافر التجانس للعينات المخصصة لكل مضرب قبل بدء عملية الضرب مباشرة .

مستخلص النتائج:

- حقق النظام ثلاثى المرور أعلى نسبة(٩٤,٢٦ % تقريبا) من الأرز الأبيض ذو الجودة الممتازة فى مقابل ٨٠,٩٨ % و ٩٠,٢٦ % و٥٨,٧ % للأنظمة أحادى وثنائى المرور والأنجلبير على الترتيب .
- متوسط نسبة الكسر فى الأرز المنتج باستخدام نظام الأنجلبر قدرت ب ٢٦,٧ %، فى مقابل ١٠,٢٤ ؛ ٤,٢٧ ؛٢% للأنظمة أحادى وثنائى وثلاثى المرور على الترتيب .

أشارت النتائج أن صنف ريهو قد سجل أقل نسبة كسر بينما يليه صنف جيزة ١٧١ ويأتى فى المؤخرة صنف جيزة ١٧٨. أيضا سجلت أفضل النتائج من حيث نسبة الكسر عند نسبة الرطوبة ١٣ %.

- عملية التبييض كانت الأعلى استهلاكا للطاقة حيث استهلكت حوالى ٣٧و٧٥ ؛ ٦٢و٥٠ ؛ ٨٤و٥٨ ؛ ٥٢و٨٦ % من إجمالي الطاقة اللازمة للمضارب أحادية وثنائية وثلاثية المرور والانجلبير على الترتيب. مقارنة بعمليات التنظيف والتقشير والفصل والنقل داخل كل مضرب
- النظام ثنائى المرور هو الأقل استهلاكا للطاقة النوعية (كهربية وبشرية) حيث استهلك ٦٠و٢٨ كيلوات.ساعة/طن . فى مقابل ٤٣و٣٨ ؛ ٣٤و٣٢ ؛ ٧١و٧٤ كيلوات ساعة/طن لكل من الانظمة أحادى المرور ؛ ثلاثي المرور ؛ والإنجلبير على الترتيب .
- سجل النظام ثنائى المرور أقل تكلفة آلية لضرب طن أرز وبإحلال هذا النظام محل الأنظمة أحادى المرور والإنجلبير وثلاثى المرور فان التكاليف ربما قد تنخفض بنسب ٣٧ ؛ ٦٥ ؛ ٥٧ % على التوالى.