

## Application of Multiple Criteria Decision Making System Compensatory (TOPSIS) in Selecting of Rice Milling System

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**Abstract:** Rice is one of the most important food resources in Iran. Considering that Iran is one of the biggest rice importers, plans need to be set to pave the way for becoming self sufficient in the production of this product. Using a suitable rice milling system with low loss and reasonable costs is very important to reach this aim. Therefore, it is necessary to select the proper rice milling system considering all the effective parameters in the efficiency of rice milling systems. For this aim a proper technical Multi-Criteria Decision Making (MCDM) was used to select the most proper rice milling system. The optimization process was accomplished using multiple criteria decision making system compensatory (TOPSIS). Several aspects, the percentage of white rice breakage, the market appeal of final production, energy consumption, the capacity of systems and system's costs were considered as rice milling attributes. Three kinds of traditional and modern rice milling systems were defined as rice milling candidate alternatives. The TOPSIS technique indicated that the percentage of white rice breakage by 0.01 score is the most important decision making factor in selecting rice milling system and system's costs with 0.88 score is a less important parameter. Although the results of TOPSIS technique showed rice milling system 3 with the highest value (0.84) was the most suitable systems.

**Key words:** Rice . rice milling . TOPSIS . Multi-Criteria Decision Making (MCDM)

### INTRODUCTION

Rice is one of the most important resources of food in Iran and it is also a source of income for many countries. The per capita rice consumption in Iran is 38 kg/year, keeping into account the increasing trend of population, it is estimated that by the year 2020, national consumption will increase to 4 million tons per annum [2]. Increasing the area under cultivation together with suitable agricultural management, increasing the production per unit of area, better agricultural practices and reduction of rice milling systems loss are the most important ways to increase the volume of the final product. The crop condition in different periods of cultivation, harvest condition, methods of drying, physical properties of grain, environmental conditions of the factory, type and condition of the machines are effective factors upon white rice breakage in the milling process [10]. Rice milling system which will physically affect the roughness after the harvest operation is one of the most important phases in rice production. The total loss of rice milling process in

Iran is estimated between 18 to 27% [6]. All things considered, lack of labor days in the harvest season has encouraged the farmers to use the direct harvest methods. Rice harvest operation in north of Iran consists of two stages. Using the modern drying and milling systems with proper capacity are vital for direct harvest with high efficiency; whereas the most drying and rice milling systems in north of Iran use the old and weary mechanism. Clearly, the lack of use of the modern rice milling systems is mainly due to the relatively high price and financial restrictions faced by farmers. Therefore, these factors show the importance of selecting proper rice milling systems. Several studies have been accomplished on the factors affecting the efficiency of rice milling system in laboratory scale, but all of these studies focus on just 1 or 2 factors affecting the efficiency of rice milling system [5, 9, 11, 16, 21]. Most of these studies investigate parameters affecting the breakage of white rice and do not pay attention to other effective factors in the selection of the proper systems.

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Due to the complex interrelation of the relevant factors, this selection requires precise management strategies and use of decision making techniques. When solving decision making problems with more than one effective factor, Multi-Criteria Decision Making (MCDM) can be a promising technique. The theoretical aspects of this technique can be found elsewhere [4] but MCDM models are widely used in many areas such as business, economics and manufacturing [4]. It has also been employed in areas related to agriculture such as irrigation [7, 14, 18, 22], sustainable rural development [8, 12, 19, 20, 23] and choosing farm machinery [3]. Researchers suggested that Analytic Hierarchy Process (AHP) has some potential in resolving certain decision problems in agriculture [3].

The objective of this research is the evaluation of modern and conventional systems based on different attributes. TOPSIS was used in this study for selecting, thereby testing its capacity as a decision making tool in the selection of rice milling system.

## MATERIAL AND METHODS

This study is comprised of two major sections; experimental setup and theoretical development. Five major factors including the Percentage of white rice breakage (PB), the market appeal of final production (MA), Energy Consumption (EC), Capacity of Systems, (CS) and System's Cost (SC) were considered as technical attributes and thereby they were measured.

This study was performed in 3 rice milling factories, in the cities of Rasht and Lahidjan, located in Guilan province, Iran in 2008. The mechanisms of rice milling systems in this study were as below: A. S1: sieve, paddy separator, rubber roll husker, Abrasive whitener, polisher and paddy sieve; B. S2: sieve, 2 rubber roll huskers were placed parallel to one another, 2 blade whiteners were placed parallel to one another, paddy sieve; and C. S3: sieve, blade husker, 2 blade whiteners were placed parallel to one another, paddy sieve.

In order to ensure the uniformity of the rice, 2 kinds of local variety (Hashemi and Kazemi) and high yield seed (Hybrid GRH1) were used in this study. All studied cultivars were produced in similar field providing uniformity in experimental material and eliminating different environmental growth factors on treatments. To eliminate the effect of different drying methods and conditions the whole rough rice was dried simultaneously within 48 hours in a fixed bed drier. Relative humidity in this kind of dryer was approximately 9%. Ultimate temperature of the dryer was in the range of 40-45 °C. preventing moisture exchange with the environment. The rough rice was stocked in polythene bags as long as the appropriate moisture level was obtained. Each experiment

was carried out by entering 120 kg of rough rice into different systems. After required adjustments, while the optimized levels of rice quality were attained, ten samples were collected in equal intervals in polythene bags.

All experimental operations and measurements were carried out at the laboratory of Engineering and Technical section of Iran's Rice Research Center in Rasht.

## MEASUREMENT FACTORS

**A) Percentage of white rice breakage:** According to definition, rice with more than 3/4 of the length of a sound rice was considered as sound rice. The proportion of the weight of broken rice grain to the weight of the whole sample was defined as the percentage of rice breakage [15].

For separating sound and broken rice a rotary sieve was utilized. After required adjustments 50 grams sample was sieved for 30 seconds. Finally, sound and broken rice were separated and weighed.

After measurements of samples, the results were recorded and the data were analyzed by the SAS software. The Duncan test was used to calculate the variance of each group of data.

**B) Costs:** The systems' costs include fix costs and variable costs. The costs of construction, storehouse and installation mechanisms were considered as fix costs. Labor costs, energy costs, repair and maintenance costs were considered as variable costs. All costs were calculated according to current value.

**C) Market appeal of final production:** To determine the market appeal of final production, 20 samples of final product were delivered to 20 experts and they were asked to score the samples from 0 to 10.

**D) Energy consumption:** This parameter was calculated using the entire electrical current and electromotor's specifications. For measuring the entire electricity, a digital clamp meter was used.

**E) Capacity of systems and costs:** Nominal capacity of rough converting to white rice in 1 hour was considered as the capacity of system.

**Decision making technique (TOPSIS):** For selecting the best system the preferable relative importance of each indicator grade (objective) should be identified. To Achieve this goal Decision matrix with 3 rows and 5 columns were planned as follows [1]:

To identify the preferable relative importance of each indicator grade (objective) in comparison with other indicators for decision making, the assessment method

Table 1: Matrix of decision making for selection of rice milling systems

Alternative	Attribute				
	PB (%)	MA	EC (kwh/ton)	SC (Rials)	CS (kg/h)
S1	19.86	7.30	53.00	420000000	1200
S2	21.25	8.05	35.14	205000000	920
S3	22.97	9.15	46.40	105000000	580

was used for the index weights. Due to the existence of the decision-making matrix, entropy technique was used to determine the relative importance of each indicator. Entropy in data theory is an indicator to measure the amount of uncertainty expressed by a discrete probability distribution ( $P_i$ ). Entropy technique and formulas, ( $P_{ij}$ ) were calculated as follows:

$$P_{ij} = \frac{r_{ij}}{\sum_{i=1}^m r_{ij}}; \forall i, j \quad (1)$$

$E_j$  was calculated for each attribute from  $P_{ij}$  set by the following equation:

$$E_j = -k \sum_{i=1}^m [P_{ij} \times \ln P_{ij}] \quad (2)$$

Degree of uncertainty or diversion ( $d_j$ ) of data for  $j$ th indicators was achieved by the equation:

$$d_j = 1 - E_j; \forall j \quad (3)$$

Ultimate weights ( $W_j$ ) of 6 indicators were calculated by the following equation:

$$w_j = \frac{d_j}{\sum_{j=1}^n d_j}; \forall j \quad (4)$$

Having a subjective judgment ( $\lambda_j$ ) as a relative importance index of  $j$ th indicator,  $w_j$  was calculated by the following equation:

$$w'_j = \frac{\lambda_j \times w_j}{\sum_{j=1}^n \lambda_j \times w_j}; \forall j \quad (5)$$

There are two models for processing data in multiple criteria decision-making, non compensatory and compensatory. In non compensatory model, exchanging of indicators was not allowed.

Compromiseness subgroup is one of the subgroups of compensatory model, which selects the best option by considering the distance of the desired option from the ideal solution. Among these methods, TOPSIS applies the distance of desired option from the desired positive and negative ideal point to select the best system.

In this method at first the decision matrix was converted to a non Scale matrix as the following equation:

$$n_{ij} = \frac{r_{ij}}{\sqrt{\sum_{i=1}^m r_{ij}^2}} \quad (6)$$

Subsequently, the weight of non Scale matrix was calculated by equation:

$$V = N_D \times W_{n \times n} = \begin{bmatrix} V_{11} & \dots & V_{1j} & \dots & V_{1n} \\ \dots & \dots & \dots & \dots & \dots \\ V_{m1} & \dots & V_{mj} & \dots & V_{mn} \end{bmatrix} \quad (7)$$

Next, the ideal solution and negative ideal solution are defined as follows:

$$A^+ = \left\{ \left( \max_i V_{ij} \mid j \in J \right), \left( \min_i V_{ij} \mid j \in J' \right) \mid i = 1, \dots, m \right\} \quad (8)$$

$$= \{V_1^+, \dots, V_j^+, \dots, V_n^+\}$$

$$A^- = \left\{ \left( \max_i V_{ij} \mid j \in J \right), \left( \min_i V_{ij} \mid j \in J' \right) \mid i = 1, \dots, m \right\} \quad (9)$$

$$= \{V_1^-, \dots, V_j^-, \dots, V_n^-\}$$

Then the desired distance of options from ideal solution and negative ideal solution were calculated by the following equations:

$$d_{i+} = \left\{ \sum_{j=1}^n (V_{ij} - V_j^+)^2 \right\}^{0.5}; i = 1, \dots, m \quad (10)$$

$$d_{i-} = \left\{ \sum_{j=1}^n (V_{ij} - V_j^-)^2 \right\}^{0.5}; i = 1, \dots, m \quad (11)$$

Finally, the relative closeness of  $A_i$  to ideal solution was calculated as follows:

$$cl_{i+} = \frac{d_{i-}}{(d_{i+} + d_{i-})}; 0 \leq cl_{i+} \leq 1; i = 1, \dots, m \quad (12)$$

## RESULTS AND DISCUSSION

**A) The percentage of white rice breakage:** In Table 2, the results of the variance analysis, the effect of the milling

Table 2: ANOVA, the effect of rice milling system and cultivar on breaking of sound rice

	MS	F	P
Treatment	0.01543**	18.45	<0.0001
Milling system	0.01121**	13.40	<0.0001
Cultivars	0.04885**	58.38	<0.0001
Milling system×cultivars	0.00083 ns	1.00	0.4107
Error	0.00083		

\*And \*\* means significantly different at probability  $p = 0.05$  and  $p = 0.01$ , respectively

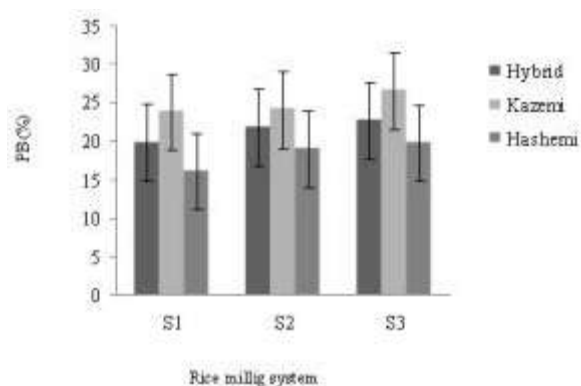


Fig. 1: Breakage percentage of rice in different rice milling systems

systems and the different cultivars on the white rice breakage is shown.

The results of the analysis of the systems showed that System 1(S1) had the least loss with 19.86% white rice broken, while System 2 (S2) had the highest loss with 23.38 %. Hashemi cultivar, in each milling system had the lowest and Kazemi cultivar, had the highest amount of loss in each milling System, respectively (Fig. 1). Hybrid cultivar, as a productive and new cultivar which the milling industry has yet to familiarize with the specification of it, was also a suitable remedy in reduction of rice loss. Furthermore, increasing pressure and using strike to increase the level of whitening are conducive to increasing rice temperature in milling process and this leads to the increase of the breakage of rice during milling process [13].

The reason behind higher loss in the conventional milling systems (S2, S3) is the bladed whitening mechanism which converts brown rice to white rice through a strike effect. Furthermore, the minimal loss in the S1 is due to the abrasive mechanism used in the machine for the processes of peeling and whitening. Also, utilization of a rubber roll husker in S1 and S2 is the reason for the lower loss (%) in the peeling step in these systems. Another reason for lower loss in S1 was using paddy separators before the whitening process, which

spreads rough and brown rice, to reduce the force needed for the whitening process.

In analysis of the effective factors on the husking loss with rubber roll huskers reported that machinery has a significant effect in the generation of conversion loss [17]. Other research that studied the effects of combining several equipments on the rice milling loss, found that the highest rate of conversional loss were in systems which utilize blade whitener for peeling [16]. In another study an 8.06% decrease in the rate of loss in the systems which utilize paddy separator after the whitening process was reported [17].

**B) Market appeal:** Energy resources cost much lower in Iran than other countries in the world (Table 1). This fact affects the energy consumption of the entire rice milling process. In the past, rice milling process was done in a higher temperature than the international temperature. Therefore, the final product of each system in this situation was whiteners. Unfortunately, this issue influenced the market tendency. The obtained results indicated that the traditional systems (S2, S3) had higher market appeal than S1. With S1, it is because using the polisher after whitening phase creates a more transparent final product. In this study the Hashemi and Kazemi variety had higher market appeal than hybrid GRH1. Consequently, hybrid variety needs to be further studied (Table 1).

**C) Energy consumption:** In this study, S1 had the highest power consumption because it was comprised of more parts compared to the other systems (Table 1). Considering the system's capacity S1 had the highest energy consumption. Whitening in S1 had the highest energy consumption. The important factor in this parameter is, system capacity, for example S2 had higher power consumption (32.54 Kw) than S1 (26.89 Kw) but because of higher capacity (920 Kg/h) on the contrary S2 (580 Kg/h), this system had lower energy consumption. Results of a research showed that almost half of the energy consumption in rice milling systems is consumed when the system starts [13] therefore, the use of condensers with high efficiency has a considerable effect on energy consumption. This is an important issue in designing the electrical systems of rice milling factories.

**D) Capacity:** Modern system's parts have had higher labor capacity and the factor S1 had the highest capacity amongst all system's studied. S2 used rubbers and had a higher whitening capacity than S1 (Table 1).

**E) Decision-making analysis:** To select the best rice milling system, TOPSIS technique was applied. Five criteria were adopted to select the best rice milling system. The weight and rank (preference) of each

system were determined through the TOPSIS. Results of measurements and calculations of indices (percentage of white rice failure, energy consumption, costs, system capacity and market appeal) were investigated for conversion systems and a summary of the decision matrix is reported as follows:

The weight of BP, MA, EC, SC and CS were calculated as 0.0107, 0.0175, 0.0423, 0.8875, 0.0417 and 0.0417, respectively. This shows that PB had the least role in decision making, but SC can strongly influence the decision-making process.

The results indicated that costs (current and fix), energy consumption, capacity devices and market appeal have the most effect on decision. These results were so unexpected for someone looking for the ownership of the rice milling system. The energy consumption factor and market appeal are the two factors that increase the efficiency of rice milling system and outcome of factory. According to analysis the importance of these factors are considered as the next important level.

To evaluate the model by using TOPSIS model, decision matrix was converted to non Scale matrix. Then preference matrix of each attribute was obtained by applying weights. Positive and negative ideal solutions were calculated, using the preference matrix.

Finally, attribute distances were calculated by the positive and negative solution options and relative closeness of each option. Final value of each system was obtained as follows:

$$A1 = 0.1407$$

$$A2 = 0.6807$$

$$A3 = 0.8586$$

The results show that, S3 obtained the highest score and S1 was in the next level. Although modern systems had the lowest influence on seeds and led to the lowest waste, but due to high costs and low market appeal, it obtained the lowest score in comparison with other systems. Therefore S3 achieved the highest score due to lower costs and higher market appeal compared to the others.

Some of Specifications of a multi-criteria decision making are flexibility, mobility and the dynamics of the system. The importance of the indices can be determined based on the specific standards and if needed an index can be ignored in order to choose another system.

## CONCLUSION

On the whole, the TOPSIS technique appears to be an efficient decision-making tool for rice milling

selection. The results showed that rice milling systems and cultivars on the rate of white rice breakage were significant at the 1% level; however, the interaction effect of system and cultivar was not significant. Also, the S1 with 19.86% had the lowest rice loss. Furthermore, the investigations showed the SC had the most influence on decisions and S1 is the most proper rice milling system.

These predictions from MCDM demonstrate the flexibility of this method for solving agricultural management problems in general and machinery operations in particular. Since the problem investigated is widespread throughout Iran, a comprehensive suitability assessment for rice milling systems, employing MCDM, could be performed to establish a nationwide mechanization strategy.

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