International Journal of Computer Information Systems and Industrial Management Applications.
ISSN 2150-7988 Volume 13 (2021) pp. 266-274

Received: 24 May 2021; Accepted: 7 August 2021; Published: 15 August 2021

Selection of Conceptual Design for Spin Grind Dryer Seaweed Powder Machine

Hambali Arep@Ariff [1], Muhamad Edhan Md Raizi [2], Noordiana Mohd Ishak[2], Norazlina Mohamad Yatim[2], Mohd Fairuz Dimin@Mohd Amin[2], Abdul Karim Mohamad Nasir[3]

[1] Advanced Manufacturing Centre, Universiti Teknikal Malaysia Melaka,
Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia.
hambali@utem.edu.my

[2] Fakulti Kejuruteraan Pembuatan, Universiti Teknikal Malaysia Melaka,
Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia
edhan95@gmail.com, noordianaishak@yahoo.com, norazlina.yatim@utem.edu.my, fairuz@utem.edu.my

[3] Saanen Utama Sdn Bhd,
No 39, Jalan Mj 2, Taman Merdeka Jaya, 75350 Melaka, Malaysia.
saanengm@hotmail.com

***Abstract*: Seaweeds are one of the important sources of raw material for food or additives in food industries. To minimize the costs of production as well as increasing life expectancy, a new spin grind dryer seaweed powder machine is proposed, which combined the four processes in one machine to replace the conventional approach called spin grind dryer seaweed machine. Therefore, this paper presents a selection process that integrates the Analytical Hierarch Process along with Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) in the selection process. This paper focus on determining the most appropriate decision on the conceptual design of spin grind dryer seaweed machine using AHP and TOPSIS. There were 4 different conceptual design of spin grid dryer seaweed machine have been proposed. 3D modelling designs were produced using CATIA software. To determine the best concept design there are 5 criteria were considered namely ease of use, ergonomics, size, cost and ease of maintenance. The AHP was employed to determine the priority vector for each criteria and TOPSIS was used to determine the appropriate design concept during the selection process. The results of the selection process showed that design concept 1 was selected as the best conceptual design for the spin grid dryer seaweed powder machine due to it has the maximum relative closeness to the ideal resolution. AHP and TOPSIS are capable of helping designers to determine the best decision at the early stage of the design process.**

***Keywords*:** concept selection, AHP, TOPSIS, MCDM, spin grid dryer, seaweed.

I. Introduction

Nowadays, seaweeds are important as a source of raw material for food or additives which is nutritionally valuable whether in fresh or dried form [1]. A significant amount of lipids, protein, vitamins and minerals contain in seaweed which is beneficial for the human body [2]. According to the Global Market Insights [3], commercial seaweed market is projected to exceed USD85 billion by 2026 due to the rising demand for food applications, cosmetics, medical and pharmaceutical sector, etc.

Seaweed is much more nutrient-dense than any vegetable on the ground. It is an excellent source of micronutrients such as folate, calcium, magnesium, copper, iron and selenium. More specifically, seaweed is a healthy source of iodine. Seaweed contains several antioxidants. Seaweed can help guard against oxidative stress and reduce chronic diseases such as cancer and intestinal disorders as part of a balanced diet. All plants produce fibre, but seaweed still has other strange carbohydrates that we miss digestive enzymes. That includes carrageenan, fucan, galactan, and more. These carbohydrates would then become fodder for the bacteria.

Seaweeds also use as a fertilizer to improve the crop yield as well as reducing cost. The helps of fertilizers by inbuilt strength in resisting the pests such as red spider mites and aphids. The development of powder seaweed segment is expected to gain and develop more than liquid seaweed products in industries application such as textile, direct food, pharmaceutical and medical, and food additives depending on the demands. To minimize the costs of production as well as increasing life expectancy, seaweed has been extracted in form of dry product or powder [4-5]. Figure 1 shows the fresh seaweed form to seaweed powder.

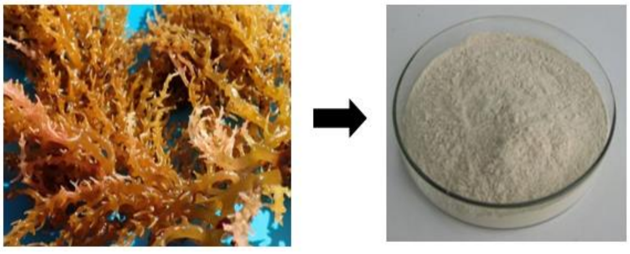


Figure 1. Fresh seaweed form to seaweed powder

Seaweed powder has many advantages compared to fresh seaweeds. Decaying is one of the reason seaweed is being process to increase the life time instead of removing enough moisture content. Moreover, seaweed powder is more compact and less store space needed while shipping the product [6]. Less cost is needed when compact material is transported rather than fresh seaweed.

However current seaweed powdering process still using a conventional process which leads to time consuming and complex flow sequences. Current process required 6 steps to complete the cycle which is washing, chopping, drying, grinding, sieving and packaging (Figure 2). The process takes time by moving the extract seaweed from one process to another process to complete each cycle.

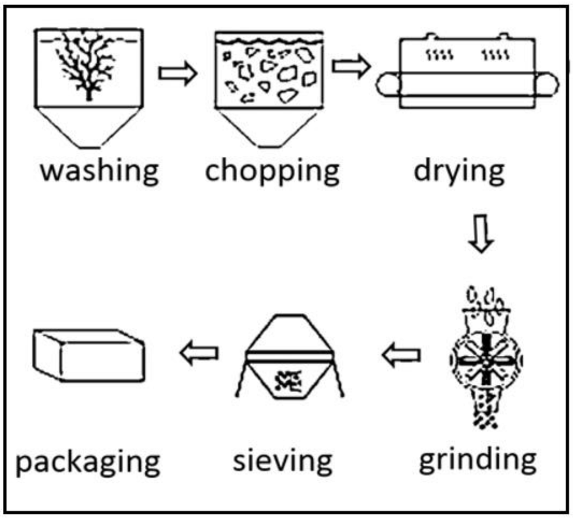


Figure 2. Seaweed powdering process

Conventional process is normally employed to an external open air drying whereas seaweed is spread on grass or plastic sheeting to expose the area according to the sun light and heat exposure. The method is not applicable for a long terms used due to seaweed structure changes and contamination concern or unsanitary conditions [7]. Drying is one of the important process that need to be considered while producing seaweed powder in terms of moisture content, particle size and antioxidant activity. The size of particle and antioxidant of processing seaweed increase when there is an increment in term of temperature, meanwhile moisture content shows an opposite result. The nutritional value also will be affected while drying the seaweeds either through direct losses of the nutrients or chemical modifications. Apart from moisture contents, powder or particle size and antioxidant activity while drying process are also important while protecting and retaining some of volatile compounds [8].

Open drying is a traditional method that used for large production seaweed powder due to larger area and required high labour intensive. However, it has limitation whereas the probability of product losses or contaminant increase due to raining seasons causes humidity reabsorption or remoistening [9]. This method is widely used by small entrepreneurs in the village and even the medium-small production industry. Figure 3 shows the open drying method practiced by the local entrepreneurs in Sabah, Malaysia.

Figure 3. Open drying method [9]

Spinning is used to reduce the time for seaweed powder production instead of using temperature by rotating the material continuously. By combining these two processes, the cycle time will be reduced and energy consumption is lower. Cutting is the combining process within drying and spinning to cut the raw seaweed into small pieces in the range of time to complete the process.

Therefore, a new spin grind dryer seaweed powder machine (Figure 4) is proposed, which combined the washing, chopping, drying and grinding process in one machine to replace the conventional approach. Several conceptual designs of spin grind dryer machine have been developed and the most appropriate conceptual design needs to be selected to give high benefits to the industry especially in seaweed powder production.

Determining the most appropriate decision in the concept selection process of the design process is very essential. Recently, researchers concerned about the design process especially the concept selection activity which has a direct consequence to the quality of the final model [10].

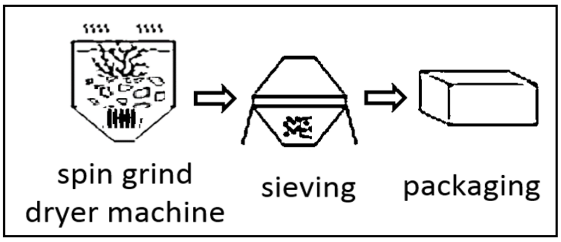


Figure 4. Proposed spin grind dryer seaweed powder machine

The incorrect selection of concept for a particular product leads to an increase in design modification, which increases the functional cost and generating time [11]. Improper selection of concept also can lead to dissatisfied consumers and manufacturers. To resolve the issues of the design selection process, utilization of multiple criteria decision making (MCDM) method that employs combination of Analytical Hierarchy Process (AHP) and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) techniques have been proposed and implemented in the literature. Multi-criteria decision-making (MCDM) refers to the preference of the best option with a variety of, usually contradictory, criteria from a finite range of 29 alternatives [12]. The method is useful to solve problems in several ways. However, classical standardization methods do not always take into consideration conditions where the different existence of the decision matrix data could make the alternative ranking very unpredictable [13].

A number of researchers have conducted studies on the utilization of integrated AHP and TOPSIS in determination of the appropriate concept design in various field of studies. In general, AHP and TOPSIS are among the most common methods used by decision makers to solve decision making problems. Saaty developed AHP technique to determine the most suitable clarification to any problems through optimization of qualitative and quantitative features [14]. Hwang and Yoon [15] developed a TOPSIS method that defined a multi-criteria evaluation approach to selection. This approach provides a basis for decision making strategies where the number of options is limited, but each has a large number of attributes. Integration of MCDM method gives a higher degree of confidence to the decision maker where it provides a systematic and scientific selection process [16].

Hanine et al. [17] engaged AHP and TOPSIS methods to examine the formation of the ETL software selection issue. Mansor et al. [18] implemented AHP and TOPSIS methods to define the exact hybrid natural fiber composites for the design of parking brake lever parts. Tian et al. [19] proposed a framework by integrating AHP and TOPSIS for evaluating automotive style design alternatives' performance, organized with automotive style design features. Komlan et al. [20] used AHP to figure the weighting principles and TOPSIS to evaluate the self-service technologies ratings through the help of five experts in the fields. Febriansya et al. [21] applied integrated AHP and TOPSIS methods to define the importance of improving the management of the government's properties. Panda et al. [22] proposed combination of AHP and TOPSIS methods for the selection of rapid prototyping structure. Karim and Karmaker [23] employed an integrated approach of AHP and TOPSIS in machine evaluation process.

From various integrated methods discussed as mentioned earlier, there is no research work carried out by previous researchers on the combination of AHP and TOPSIS has found in the spin grind dryer design. The motivation of this paper is to implement combination method of AHP and TOPSIS for determining the best design of spin grind dryer seaweed powder machine during the design selection process.

II. Material and method

Figure 5 depicted the flow of integration process between AHP and TOPSIS to determining the best design of spin grind dryer seaweed powder machine during the design selection process.

The selection process started with concept selection, identification of the important criteria, weighting of the criteria, performance measuring and ranking of selection. The selection process was divided into two stages, first was the determination of the weightage for the identified criteria based on AHP method and followed by ranking of the selection using TOPSIS method. The success probability of the product can be influence by the weighting criteria in the ranking results during selection process [24].

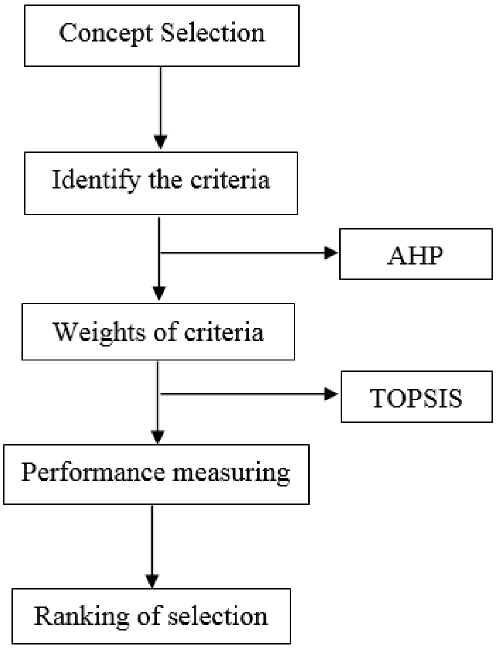
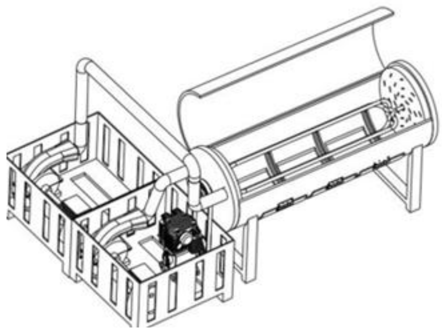


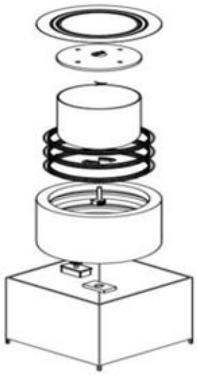
Figure 5. Integration process of AHP and TOPSIS to determining the spin grind dryer machine

A. *Concept selection*

Based on the design strategy, 4 concept designs of the spin grind dryer machine were developed as shown in Figure 6.

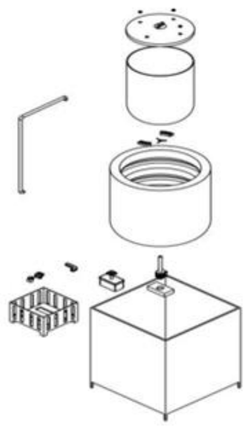


(a) DC-1



(b) DC-2

(c) DC-3



(d) DC-4

Figure 6. Concept designs of the spin grind dryer machine

Figure 5a shows the design concept 1 (DC-1) for development of spin grind dryer seaweed powder processing machine. The size follows the product design specification given by the industry. In this conceptual design, a blower is used simultaneously with a heating element at the main body area while the blade is used as a concept of spinning for grinding purpose. The orientation is in horizontal.

Figure 5b shows the design concept 2 (DC-2) for development of spin grind dryer seaweed powder processing machine. The orientation of the machine is vertical. In this conceptual design, a heating element is used in the main body area while the blade is used as a concept of spinning for grinding purpose. Design specifications followed by industry guideline.

Figure 5c shows the design concept 3 (DC-3) for development of spin grind dryer seaweed powder processing machine. The vertical orientation is used. The design is the nearly same with the design concept 2. However, the used blade is different for grinding purpose. Design is within the industrial specifications.

Figure 5d shows the design concept 4 (DC-4) for development of spin grind dryer seaweed powder processing machine. The size follows the product design specification given by the industry. In this conceptual design, a blower is fit at the sides of the body. The orientation of the body is in vertical with the blade attached inside the body. While rotating, the raw seaweed will be cut automatically. The blade is fixed at the machine's body.

B. AHP and TOPSIS selection process

The criteria of the final product such as ease of use, ergonomics, size, cost and ease of maintenance are considered while determining the best possible result for the conceptual design. Table 1 shows the criteria that taken into account for designing and developing a spin grind dryer design. Criteria involved in the selection of the conceptual design for spin grind dryer seaweed powder machine are as follows:

a) Ease of use:
This criteria describes on how easily the users can use or handle the spin grind dryer seaweed powder machine.

b) Ergonomic:
Ergonomic element is important in this conceptual design since the machine is used for mass production of the seaweed powder, therefore, the ergonomic criteria is very important to reduce injuries due to the repetitive human motions.

c) Size:
Size in this design describes the overall size of the spin grind dryer seaweed powder machine. Since this machine will be used by the medium-small production industry, therefore the space required by the industry is essential to minimize the production space

d) Cost:
Cost in this selection process involved the overall cost needed in manufacturing the spin grind dryer seaweed powder machine

e) Ease of maintenance:
Ease of maintenance in this selection process elaborate on the simple or easy way to maintain the spin grind dryer seaweed powder machine which will increase the reliability, efficiency, system performance and life span of the spin grind dryer seaweed powder machine

Regular	Criteria
1	Ease of use
2	Ergonomic
3	Size
4	Cost
5	Ease of maintenance

Table 1. Criteria's of Spin Grind Dryer design

Weighing scale is used to estimate the relatives' importance of criteria for each design. Each attribute is given certain points on 0-10 rating scale by a team of experts or decision makers. Table 2 shows the rating scale that had been used for managing and evaluating the design decision.

No.	Regular	Criteria
1	Ease of use	10 Very good – 1 None
2	Ergonomic	10 Very good – 1 None
3	Size	10 Very good – 1 None
4	Cost	10 Low – 1 High
5	Ease of maintenance	10 Easy – 1 Complicated

Table 2. Rating Scale

There are seven steps have been conducted to determine and rank the best conceptual design of spin grind dryer using integrated AHP and TOPSIS. The process of determining and ranking the best design is described as follows: -

1) Step 1: Determine attribute weights for each design

Table 3 to Table 6 show the method of determining the attribute weight. Six decision makers (DM) rate each criteria of each design concept. Decision maker should be an expert or at least be very familiar with the intended field since evaluation by the decision maker is very important in establishing the right decisions [25]. In this selection process of the conceptual design for spin grind dryer seaweed powder machine, the decision makers consist of seaweed manufacturer, seaweed researcher and professional engineer.

Determining the attribute weight play a very significant role in the ranking result of the conceptual design selection process where every criteria of the design concept will be evaluate to ensure the reliability and accuracy of the decision [26]. The attribute weight obtained are then used in TOPSIS and AHP for the selection process.

Criteria	Decision Makers						Attribute Weighting $W = \frac{\sum N}{n}$
	1	2	3	4	5	6	
Ease of use	9	9	9	8	10	9	9
Ergonomic	9	8	8	8	9	8.5	8.41
Size	8	8	8	8	8	8	8
Cost	5	5	4	4	4	4.33	4.38
Maintenance	8	8	8	9	9	8.33	8.38

Table 3. Attribute weights for DC- 1

Criteria	Decision Makers						Attribute Weighting $W = \frac{\sum N}{n}$
	1	2	3	4	5	6	
Ease of use	7	7	7	6	6	7	6.67
Ergonomic	7	6	6	6	7	6	6.33
Size	8	7	7	8	7	7	7.33
Cost	5	5	4	4	5	5	4.67
Maintenance	7	7	7	6	6	6	6.5

Table 4. Attribute weights for DC- 2

Criteria	Decision Makers						Attribute Weighting $W = \frac{\sum N}{n}$
	1	2	3	4	5	6	
Ease of use	8	7	7	8	7	7	7.33
Ergonomic	7	6	6	6	7	6	6.33
Size	8	8	7	7	7	7	7.33
Cost	4	4	5	5	5	5	4.67
Maintenance	6	6	6	7	7	7	6.5

Table 5. Attribute weights for DC- 3

Criteria	Decision Makers						Attribute Weighting $W = \frac{\sum N}{n}$
	1	2	3	4	5	6	
Ease of use	7	7	7	8	8	8	7.5
Ergonomic	6	6	6	7	6	7	6.33
Size	7	7	7	8	7	8	7.33
Cost	5	4	4	4	5	5	4.5
Maintenance	7	6	7	6	6	6	6.33

Table 6. Attribute weights for DC- 4

2) Step 2: Establish the decision matrix

Table 7 shows the 5 main criteria and 4 different design concepts have been considered. The elements of the matrix are related to the values of criteria with respect to design concepts. Attribute weighting for all criteria was defined using equation (1).

$$\text{Attribute Weighting} = \sqrt{a^2 + b^2 + c^2 + d^2} \tag{1}$$

Criteria	Decision Makers				Attribute Weighting
	DC 1	DC 2	DC 3	DC 4	
Ease of use	9	6.67	7.33	7.5	15.34
Ergonomic	8.5	6.33	6.33	6.33	13.87
Size	8	7.33	7.33	7.33	15.01
Cost	4.33	4.67	4.67	4.5	9.09
Maintenance	8.33	6.5	6.5	6.33	13.93

Table 7. *Decision matrix*

3) Step 3: Normalize decision matrix

Each column of the decision matrix are then normalized as depicted in Table 8.

Criteria	Decision Makers				Attribute Weighting
	DC 1	DC 2	DC 3	DC 4	
Ease of use	0.59	0.44	0.48	0.49	15.34
Ergonomic	0.61	0.46	0.46	0.46	13.87
Size	0.53	0.49	0.49	0.49	15.01
Cost	0.48	0.51	0.51	0.50	9.09
Maintenance	0.60	0.47	0.47	0.45	13.93

Table 8. Normalize decision matrix

4) Step 4: Weighted normalized decision matrix

Table 9 to Table 10 show the method to determine the weighted of each criteria using AHP. All the values assigned for each cell is determined by design experts. Since the value of reliability proportion for the primary criteria is less than 0.1, the judgements are acceptable.

Criteria	AHP Attributes				
	Ease of use	Ergonomic	Size	Cost	Maintenance
Ease of use	1	7	5	3	4
Ergonomic	1/7	1	1/3	1/5	1/4
Size	1/5	3	1	1/5	1/3
Cost	1/3	5	5	1	5
Maintenance	1/4	4	3	5	1

Table 9. Attribute Weight (AHP)

Criteria	Priority vector (W)
Ease of use	0.461
Ergonomic	0.302
Size	0.125
Cost	0.071
Ease of Maintenance	0.041

Table 10. Priority vector of each criterion

Weighted normalized decision matrix using equation (2) via multiplying the normalized decision matrix with its correlated weights. Table 11 shows the results of the weighted normalized decision matrix.

$$V = W_{ij} = W_x R_{ij} \qquad (2)$$

	Weighted	DC 1	DC 2	DC 3	DC 4
Ease of use	0.461	0.272	0.203	0.221	0.226
Ergonomic	0.302	0.184	0.139	0.139	0.139
Size	0.125	0.066	0.061	0.061	0.061
Cost	0.071	0.034	0.036	0.036	0.036
Ease of Maintenance	0.041	0.025	0.019	0.019	0.018

Table 11. Weighted normalized decision matrix

5) Step 5: Positive ideal resolution

Determine the positive ideal resolution (A+) value using equation (3).

$$PIS = A^+ = \{V_1^+, V_2^+ \ldots\ldots, V_n^+\} \qquad (3)$$

$$where: V_j^+ = \{(max(V_{ij}) if\ j \in J); (min\ V_{ij}\ if\ j \in J^1)\}$$

While measurement of the separation distance for the positive ideal solution of each competitive alternative by using equation (4). Table 12 shows the positive ideal solution value.

$$S^+ = \sqrt{\sum_{j=1}^{n} (V_j^+ - V_{ij})^2} \qquad (4)$$

$$where\ \ i = 1 \ldots\ldots m$$

Criteria	Ideal Solution *Si**			
	DC 1	DC 2	DC 3	DC 4
Ease of use	0	0.0062	0.0033	0.0028
Ergonomic	0	0.0011	0.0011	0.0011
Size	0	0	0	0
Cost	0	0	0	0
Ease of Maintenance	0	0.0003	0.0003	0.0004
*Si**	0	0.0872	0.0686	0.0656

Table 12. Positive Ideal Solution Si*

6) Step 6: Positive ideal resolution

Determine the negative ideal resolution (A-) value using equation (5).

$$NIS = A^- = \{V_1^-, V_2^- \ldots\ldots, V_n^-\} \qquad (5)$$

$$where: V_j^- = \{(min(V_{ij}) if\ j \in J); (max\ V_{ij}\ if\ j \in J^1)\}$$

While the measurement of the separation distance for the non-ideal solution of each competitive alternative by using equation (6). Table 13 shows the negative ideal solution value.

$$S^- = \sqrt{\sum_{j=1}^{n} (V_j^- - V_{ij})^2} \qquad (6)$$

$$where\ \ i = 1 \ldots\ldots m$$

Criteria	Ideal Solution *Si⁻*			
	DC 1	DC 2	DC 3	DC 4
Ease of use	0.0062	0	0.0004	0.0007
Ergonomic	0.001	0	0	0
Size	0	0	0	0
Cost	0	0	0	0
Ease of Maintenance	0.0004	0	0	0
Si⁻	0.0872	0	0.02	0.0265

Table 13. Negative Ideal Solution Si-

7) Step 7: Relative closeness to ideal resolution

Quantify the relative closeness of respective design to the ideal resolution using equation (7). For every competitive alternative, the relative closeness of the possible design with respect to the ideal resolution is figured. The relative closeness to the ideal resolution are then ordered from higher to a lower value. The first rank for the higher value has relative closeness resolution. Table 14 shows the relative closeness to the ideal resolution.

$$C_i = \frac{S_i^-}{(S_i^+ - S_i^-)}\ ,\ 0 < C_i^+ < 1 \qquad (7)$$

$$where\ \ i = 1,2 \ldots\ldots m$$

(3)

	DC 1	DC 2	DC 3	DC 4
*Si**	0	0.0872	0.0686	0.0656
Si^-	0.0872	0	0.02	0.265
$Si^* + Si^-$	0.0872	0.0872	0.0886	0.0921
C_i	1	0	0.2257	0.2877
Rank	1	4	3	2

Table 14. Relative closeness to the ideal resolution

III. Result and discussion

Based on the combination of AHP and TOPSIS methods, DC-1 (Figure 7) has been selected as a suitable model to develop a spin grind dryer machine based on industrial guidelines to produce seaweed powder with highest value of the relative closeness to the ideal resolution with 1 score, where the DC-2 the lowest value of the relative closeness to the ideal resolution value which is 0. DC-4 was in second ranking with 0.2877 scores, followed by DC-3 with 0.2257 scores.

By identifying the problems of surrounding creation, the design of the spin grind dryer machine is achieved and idea is generated to select the best design of product specification. Decision makers involved in this project have agreed that this design concept can fulfil all the criteria needed; ease of use, ergonomic, size, cost and ease of maintenance.

This innovative spin grind dryer seaweed powder machine that combined the washing, chopping, drying and grinding process in one machine can replace the conventional approach and can contribute to the seaweed industries, especially the local entrepreneurs. Besides that, the quality of the seaweed powder produced by this machine is better than the conventional process since the involved processes are lesser and can be controlled according to the needed specifications.

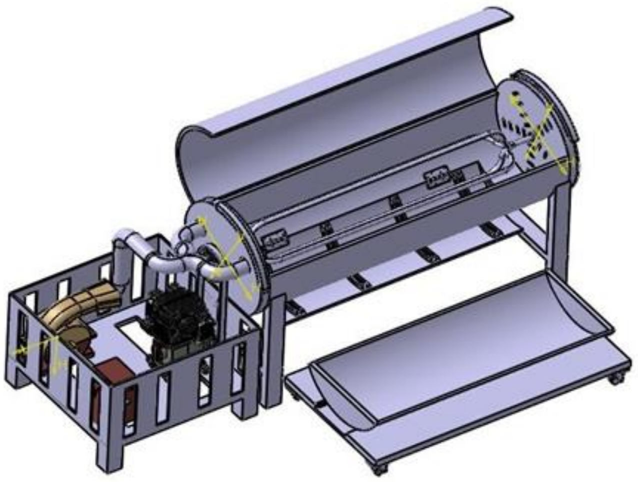


Figure 7. Selected concept designs of the spin grind dryer seaweed powder machine

IV. Conclusions

Concept selection is one of the essential task in the design process and it is a complex decision making problem due to involving many influencing factors. A systematic approach by combining AHP and TOPSIS is employed to evaluate the best decision of spin grind dryer seaweed powder machine. There are five criteria; ease of use, ergonomic, size, cost and ease of maintenance, evaluated by six decision makers consist of seaweed manufacturer, seaweed researcher and professional engineer involved in discussing and evaluating four designs; DC-1, DC-2, DC-3 and DC-4 of the spin grind dryer seaweed powder machine. Based on the descending order of the combination of AHP and TOPSIS methods, the result shows that the DC-1 was the most appropriate design for the development of the spin grind dryer seaweed powder machine as it has the highest value rather than other design concepts. Determining the attribute weight in the combination of AHP and TOPSIS methods play a very significant role in the ranking result of the conceptual design selection process where every criteria of the design concept will be evaluated to ensure the reliability and accuracy of the decision making. This innovative spin grind dryer seaweed powder machine that combined the four main process; washing, chopping, drying and grinding process in one machine can replace the conventional approach and can contribute to the seaweed industries, especially the local entrepreneurs. The quality of the seaweed powder produced by this machine is also better than the conventional process since the involved processes are lesser and can be controlled according to the needed specifications besides maintaining the amount of lipids, protein, vitamins and minerals contain in seaweed which could benefit the users.

Acknowledgment

Authors want to thank Ministry of Higher Education (MOHE), Universiti Teknikal Malaysia Melaka (UTeM) and Saanen Utama Sdn Bhd for financial support through industrial grant scheme (INDUSTRI(MTUN)/SANEEN/2020/FKP-COSSID /I00042) awarded for the project.

References

[1] A. Bono, Y. Y. Farm, S. M. Yasir, B. Arifin, and M. N. Jasni, “Production of fresh seaweed powder using spray drying technique,” Journal of Applied Sciences, 11(13), pp. 2340–2345, 2011.

[2] D. I. Sánchez-Machado, J. López-Cervantes, J. Lopez-Hernandez, and P. Paseiro-Losada, “Fatty acids, total lipid, protein and ash contents of processed edible seaweeds,” Food Chemistry, 85(3), pp. 439–444, 2004.

[3] A. P. Kiran Pulidindi. (2020) Commercial Seaweed Market size to exceed $85bn by 2026. [Online]. Available:https://www.gminsights.com/pressrelease/commercial-seaweed-market.

[4] M. Cano-Chauca, P. C. Stringheta, A. M. Ramos, and J. Cal-Vidal, “Effect of the carriers on the microstructure of mango powder obtained by spray drying and its functional characterization,” Innovative Food Science & Emerging Technologies, 6(4), pp. 420–428, 2005.

[5] M. Djaeni and D. A. Sari, “Low temperature seaweed drying using dehumidified air,” Procedia Environmental Sciences, 23(2), pp. 1–9, 2015.

[6] A. Bono, S.M. Anisuzzaman and O. W. Ding, “Effect of process conditions on the gel viscosity and gel strength of semi-refined carrageenan (SRC) produced from seaweed (Kappaphycus alvarezii),” Journal of King Saud University-Engineering Sciences, 26(1), 3-9, 2014.

[7] G. B. Pradana, K. B. Prabowo, R. P. Hastuti, M. Djaeni and A. Prasetyaningrum, “Seaweed drying process using

tray dryer with dehumidified air system to increase efficiency of energy and quality product," IOP Conference Series: Earth and Environmental Science 292 (1), pp. 012070, 2019.

[8] E. Duran Frontera, "Development of a process approach for retaining seaweed sugar kelp (Saccharina latissima) nutrients", University of Maine, 2017.

[9] M. M. Rahman, H. K. Phang, C. M. Chu, S. Kumaresan, and S. M. Yasir, "A Cold-inflow Free Solar Chimney Dryer for Seaweed Drying in Sabah, Malaysia," In *Proceedings of the International Conference on Industrial Engineering and Operations Management* pp. 3062-3070, 2018.

[10] O. M. Olabanji and K. Mpofu, "Hybridized fuzzy analytic hierarchy process and fuzzy weighted average for identifying optimal design concept," Heliyon, 6(1), p. e03182, 2020.

[11] G. N. Zhu, J. Hu, J. Qi, J. Ma, and Ying Hong Peng, "An integrated feature selection and cluster analysis techniques for case-based reasoning," Engineering Applications of Artificial Intelligence, 39, pp. 14–22, 2015.

[12] E. Roszkowska, "Multi-criteria decision making models by applying the TOPSIS method to crisp and interval data," Multiple Criteria Decision Making/University of Economics in Katowice, 6(1), pp. 200-230, 2011.

[13] S. Rohanah, "An evaluation of students performance using TOPSIS and Entropy approaches," IOSR Journal of Research & Method in Education, 8(6), pp. 1-6, 2018.

[14] T. L. Saaty. "Decision Making for Lleaders: the Analytic Hierarchy Process for Decisions in a Complex World". RWS Publications- Pittsburgh, United States 1990.

[15] K. Yoon and C. L. Hwang, Multiple Attribute Decision Making: Methods and Applications. Springer-Berlin/Heidelberg, Germany ,1981.

[16] N. M. Ishak, D. Sivakumar, and M. R. Mansor, "Thermoplastic matrix selection for fibre metal laminate using fuzzy VIKOR and entropy measure for objective weighting," Journal of Engineering Science and Technology, 12(10), pp. 2792–2804, 2017.

[17] M. Hanine, O. Boutkhoum, A. Tikniouine, and T. Agouti, "Application of an integrated multi-criteria decision making AHP-TOPSIS methodology for ETL software selection," Springerplus, 5(1), 2016.

[18] M. R. Mansor, S. M. Sapuan, E. S. Zainudin, A. A. Nuraini, and A. Hambali, "Application of integrated AHP-TOPSIS method in hybrid natural fiber composites materials selection for automotive parking brake lever component," Australian Journal of Basic and Applied Sciences, 8(5), pp. 431–439, 2014.

[19] G. Tian, H. Zhang, H. Jia, Y. Liu, G. Xu, and J. Wang, "Automotive style design assessment and sensitivity analysis using integrated analytic hierarchy process and technique for order preference by similarity to ideal solution," Advances in Mechanical Engineering, 8(5), pp. 1–10, 2016.

[20] G. Komlan, "Integrating AHP-TOPSIS approach on prioritizing self-service technology (SST) decision making in financial institution (Togo)," Journal of Advances in Mathematics and Computer Science, pp. 1–22, 2016.

[21] A. Febriansyah, J., Gernowo, R., & Kusumawardhani, "Implementation of AHP and TOPSIS method to determine the priority of improving the management of government's assets," International Journal of Innovative Research in Advanced Engineering, 4(3), pp. 46–53, 2017.

[22] B. N. Panda, B. B. Biswal, and B. B. L. V. Deepak, "Integrated AHP and fuzzy TOPSIS approach for the selection of a rapid prototyping process under multi-criteria perspective," in Design and Research Conference (AIMTDR), 2014.

[23] R. Karim and C. L. Karmaker, "Machine selection by AHP and TOPSIS methods," American Journal of Industrial Engineering, 4(1), pp. 7–13, 2016.

[24] N. M. Ishak, S. D. Malingam, and M. R. Mansor, "Weighting of natural fibre criteria for fibre metal laminate using entropy method for car front hood utilization," Key Engineering Material, 740, pp. 75–80, 2017.

[25] Z. Ayağ, and R. G. Özdemir, "An intelligent approach to machine tool selection through fuzzy analytic network process. Journal of intelligent manufacturing", 22(2), pp. 163-177, 2011.

[26] N. M. Ishak, M. R. Mansor, and A. F. Ab Ghani. "Conceptual design development and selection of green product." In Design for Sustainability, pp. 25-56, 2021.

Author Biographies

Hambali Arep@Ariff is a professor from the Faculty of Manufacturing Engineering and currently holds the position as deputy director of Advanced Manufacturing Centre in University Teknikal Malaysia Melaka. He received his Ph.D. from the Universiti Putra Malaysia in 2010, Masters from Loughborough University, United Kingdom, in 2003, and Bachelor (Hons) from Universiti Teknologi Mara, Malaysia in 1996. His research of interest includes new product development, concurrent engineering and green manufacturing.

Muhamad Edhan Md Raizi is an executive (PROTON Young Talent) at Perusahaan Otomobil Nasional Sdn. Bhd. He received his Bachelor in Manufacturing Engineering from Universiti Teknikal Malaysia Melaka, Malaysia in 2020 and Diploma in Automotive Manufacturing Engineering from Kolej Kemahiran Tinggi Mara, Malaysia in 2015. His research of interest includes new product development, concurrent engineering and design process.

Noordiana Mohd Ishak is a researcher in University Teknikal Malaysia Melaka. She received her Ph.D. in Mechanical Engineering from the Universiti Teknikal Malaysia Melaka in 2019, M.Sc from Universiti Tun Hussein Onn, Malaysia, in 2014, Bachelor (Hons) in Product Design from Universiti Kuala Lumpur, Malaysia in 2009 and Diploma in Mechanical Engineering Design and Development from Universiti Kuala Lumpur, Malaysia in 2006. Her research of interest includes new product development, concurrent engineering and green manufacturing.

Norazlina Mohamad Yatim is a Post-Doctoral researcher in University Teknikal Malaysia Melaka. She received her Ph.D. in Manufacturing Engineering from the Universiti Teknikal Malaysia Melaka in 2017, M.Sc in Biotechnology Engineering from International Islamic University, Malaysia, in 2012 and Bachelor (Hons) in Biochemical-Biotechnology Engineering from International Islamic University, Malaysia in 2008.

Her research of interest includes biochemical and biotechnology and green manufacturing.

Mohd Fairuz Dimin@Mohd Amin is a senior lecturer in University Teknikal Malaysia Melaka. He received his M.Sc and Bachelor from Universiti Malaya, Malaysia, in 2005 and 1993. His research of interest includes physics and green manufacturing.

Abdul Karim Mohamad Nasir is a General Manager in Saanen Utama Sdn. Bhd. Malaysia. He received his M.Sc in Business, from United States in 1984. Saanen Utama Sdn. Bhd. is a soap based goat milk production company and this company has contributed in financial support through an industrial grant scheme collaboration with Universiti Teknikal Malaysia Melaka.