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ARTICLE

Conceptual Design and Selection of Natural Fibre Reinforced Biopolymer Composite (NFBC) Takeout Food Container

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ABSTRACT

Biopolymer composite has gained huge attention for its beneficial properties such as biodegradable and less impact to the environment. This consequently would diminish the dependency on the petroleum-based polymer. Abundance of studies have been done on the development and characterization of biopolymer composite materials for food packaging application, but work on the conceptual design of biopolymer composite packaging product is hardly found. Using the Kano Model, Quality Function Deployment for Environment (QFDE), morphological map, and Analytic Hierarchy Method (AHP) framework combination, this paper presents the conceptual design of a natural fibre reinforced biopolymer composites take-out food container. To understand customer satisfaction with the current use of takeout food containers, the Kano model was applied, and the findings were integrated into QFDE. The highest weight of voices of customer and environment (VOCE) as the solution parameters for the design characteristics were later refined using the aid of morphological chart (MC) to systematically develop conceptual designs. Lastly, AHP was utilized to pick the final concept design. The concept design with the highest score (8.3%) was chosen as the final conceptual design.

KEYWORDS

Conceptual design takeout food container; biodegradable packaging; biopolymer composite; Kano model; QFDE; AHP

1 Introduction

Industry today encounters increasing global competitiveness which impose them to revise their approach in product development and manufacturing. Companies are facing greater challenges due to the higher competition in the market and continuously expanding customers' demands. Being environmental conscious is one of the vital requirements in new product design and development today [1]. Environmental aspects and life cycle limitations integrate with customer requirements are crucial at the early stage of product design process [2]. There is more flexibility in dealing with changes and improvements to the product during this preliminary phase. Environmental considerations are included in the analysis of material selection to replace traditional materials with more sustainable materials [3]. In this work of developing concept design of a more sustainable takeout food container, a fully biodegradable natural fiber reinforced biopolymer composite material is proposed to be utilized.

In various product applications, including packaging, natural fibre reinforced biopolymer composite (NFBC) materials have a high potential to replace petrol-derived plastic materials. The prospects to substitute the conventional materials have increased due to the growing interest where researchers have proven through their experiments that NFBC materials are a great alternative to be applied in such applications. Through the use of natural fibre reinforcement, the production cost of the composite making process can also be decreased [4,5]. In addition, entirely bio-based packaging materials such as NFBC do not leave biological systems because, after the post-use period, they eventually return to the environment [6]. NFBC, with its status as a natural material, are more environmentally friendly [7].

Particularly for packaging application, many studies carried out are on the characterization of NFBC and utilization of latest technology to enhanced functional and commercial fulfilments of the alternative materials. To mention a few of these studies: 1) Fabra et al. [8] developed thermoplastic corn starch based films (TPCS)-bacterial cellulose nanowhiskers (BCNW) biocomposites; 2) Atikah et al. [9] analysed sugar palm nanofibrillated cellulose (SPNFCs) and sugar palm starch (SPS); 3) Owi et al. [10] developed empty fruit bunch (EFB) nanocellulose reinforced tapioca starch nanocomposites; 4) Ashrafi et al. [11] created chitosan-kombucha tea (KT) biocomposites; 5) Sánchez-Safont et al. [12] characterized PHB-lignocellulosic wastes fiber composites; and 6) Abral et al. [13] designed and appraised poly(vinyl alcohol) (PVA)/ginger nanofiber (GF) bionanocomposite. Each biocomposite designed and tested has its own unique characteristics and the performance and properties of each biocomposite material are highly affected by the individual components used in the composites [4]. It will be necessary to systematically evaluate constituent materials for NFBC that best meet the requirements of an environmentally conscious [14,15]. The material selection process plays a major role in a product's functionality, efficiency, customer satisfaction characteristics and production processes. In addition, the increasing global understanding of the environment has integrated sustainable concepts to stimulate the exploration of new eco-friendly alternatives [16]. The works on selection process of the constituents' materials of the NFBC for the design of takeout food container in this study have been done in authors' previous published works [17,18], with the essence of concurrent engineering environment. Sago starch biopolymer matrix and sugar palm fiber as the reinforcing material have been selected in these studies.

The composite product development method, comprising material selection, design concept selection, manufacturing process selection, and life cycle analysis, must be studied at an early stage in the concurrent engineering setting. This is known as the product's conceptual design phase [19]. In the first stage of product development, the conceptual design phase is one of the most crucial elements, and concept selection is often one of the most important decisions to be made [20]. Commonly, the overall conceptual design stage can be divided into four main areas: 1) Concept clarification; 2) Concept generation; 3) Concept selection; and 4) Concept development [21]. Basically, designers need to generate ideas systematically for design concepts of the product and there are numerous methods to assist them available to carry out this task. Many concept designs would be produced after the process of ideas generation and later in the concept development stage is concept design selection process. Related to composite materials, Sapuan [22] presented the idea generations stage by using morphological chart for new polymer composites automotive pedals conceptual designs. This approach helps create new design ideas by integrating several design features. Mansor et al. [21] explored conceptual design of kenaf fiber polymer composites automotive parking brake lever using the integration of Theory of Inventive Problem Solving (TRIZ), morphological chart and followed by Analytic Hierarchy Process (AHP) in making decision of the best design. Azammi et al. [23] employed similar methods using the integration of TRIZ and morphological chart to develop a systematic framework for the conceptual design of kenaf fiber polymer automotive engine rubber mounting composites but utilized Analytic Network Process (ANP) methods to perform the multi-criteria decision-making process of selecting the final concept design. Recently, Asyraf et al. [24] too worked on similar method of integrating TRIZ, morphological chart, and ANP for conceptual designs of creep testing rig for a full-scale cross arm. Yusof et al. [25] too applied the same combination but with additional biomimetics technique which took nature creature as inspiration in the concept designs and afterward applied AHP to pick the best design. It is also worth to mention unique innovation by Mastura et al. [3] in the development of design concepts of automotive anti-roll bar where quality function deployment for environment (QFDE) was integrated with TRIZ and blue ocean strategy (BOS).

As previously mentioned, there is an abundance of studies that have been carried out in the field of product development using several strategies, models, and tools for different kinds of product applications. Nevertheless, there is minimal research on models and instruments tailored for the production of packaging products [26]. It is also important to note that recent biocomposite-related product design and development studies concentrate mainly on automotive components or parts as a creative attempt to make options more sustainable. At the same time, the production of biocomposite materials for packaging applications has been continuous to achieve the equivalent performance of traditional materials in moving towards sustainability. In general, sustainable packaging is characterized as safe and healthy packaging for people and the environment, and as effective in the use of materials and resources [26]. Furthermore, Widaningrum [27] highlighted that design of packaging product must be reasonable, economical, and environmentally friendly. The trend of buying prepared food from restaurants or food sellers to be eaten somewhere else is common nowadays but those single-use and short use phase of takeout food packaging has contributed greatly to solid waste. In short, this growing demand for the accessibility of takeout food initiating the foodservice establishments seeking approaches to comply with this challenge [28].

In the scope of conceptual design clarification and idea generation topic, Quality Function Deployment for Environment (QFDE) method is a widespread method adopted. There are handful of studies integrating QFDE method with decision making methods to attain an optimized product development. Mastura et al. [3] combined QFDE with TRIZ, BOS and morphological chart (MC) in order to include all the design elements required for a conceptual design of NFBC automotive anti-roll bar. While Sakao et al. [29] applied combinatorial utilization of QFDE and life cycle assessment (LCA), as characteristic tools for eco-design of an industrial pump. Whereas Bao et al. [30] and Trappey et al. [31] both integrated QFDE with theory of inventive problem solving (TRIZ) in their works on innovative product design ideas during the concept design stage. There are also other studies adopted the combination methodology of quality function deployment (QFD-without the 'E' for the environmental consideration) and Kano model to find customer requirements and as well as technical requirements of a product. Kano model is a customer satisfaction model based on product quality feature and a technique used in product development to identify the most appropriate features in order to maximize the satisfaction of a product [32]. Furthermore, Ozalp et al. [33] recently acknowledged that Kano model is embedded into house of quality of QFD to define marketing advantage by classifying customer requirements. A study by Gangurde et al. [34] used this combinatorial method for the design innovation of a smart cell phone. Before that, Hashim et al. [35] applied the same approach to improve the workstation at a rural secondary school. Other recent study utilizing QFD-Kano approach is done by Avikal et al. [36] where customer satisfaction based on aesthetic sentiments for the design of sports utility vehicle (SUV) were assessed. Last but not least, Chen et al. [37] applied the Kano model-QFD method to understand how customers perceive service attributes and to describe the relationships among the critical service attributes as well as to identify the priority for these improvements. From this integrated Kano-QFDE technique, loads of concept designs may possibly be generated and developed, and therefore decision makers need to decide on the final concept design. There are various techniques available to aid this selection process.

Concluded from literature and to the best of authors' knowledge, characterization works of NFBC for packaging application are generally common but work on conceptual design of NFBC packaging product is scarce. It is also worth to note that studies on design and development of packaging products are limited. Therefore, in this study, a more sustainable option without compromising the functional performances, a conceptual design of sugar palm fiber reinforced sago starch composite takeout food container is presented. A systematic framework is proposed to effectively design a fully biobased and biodegradable takeout food container. In the concurrent engineering environment, and based on the project requirements, Kano Model, QFDE and morphological chart were employed to ensure all design essentials required for a conceptual design of NFBC-based takeout food container were incorporated. In the last part of this study, a final conceptual design is selected based on the requirements' satisfaction, concerning customers and environment requirements by applying AHP method via Expert Choice v11.5 software.

2 Methodology of Study

In order to integrate the interpretation of NFBC values in the development of a biodegradable and entirely bio-based composite of a takeout food container conceptual design, a hybrid concurrent approach is proposed. The conceptual design method starts with the description of the problem, which is a standard preliminary phase as outlined in the model of Pugh. Designers must consider the basics of the packaging product functions in a sustainable food packaging design to draw up solutions after the issues have been identified. In general, the basic packaging functions are containment, protection and preservation, marketing and communications [38,39]. The hybrid approach proposed in this work to compute solutions in the conceptual design of NFBC food containers is therefore illustrated in Fig. 1 to avoid leaving any significant design components. The work done were broken down into three main stages namely, 1) Conceptual design generation, 2) Conceptual design development, and 3) Conceptual design determination. QFDE is the extended version of the QFD (Quality Function Deployment Method) and has a wide area of application within the sustainability context. The QFDE approach is used in this research as it is an efficient instrument for the environmentally conscious design process [40]. Whereas, Kano model is the customer satisfaction model based on product quality feature [36]. The process of integrating Kano model and QFDE methodology adopted in this study is shown in Fig. 2.

The relationship matrix was established in the next process to evaluate the relationship between desirable features (customer requirements/VOCE) and technical requirements (engineering characteristics). The main aim of the relationship matrix is to build a relation between 'What' and 'Hows'. [39]. Then, Kano values ('k' values) will be obtained from Kano model analysis where Kano class decides the value of 'k'. After that, the customer satisfaction (CS) will be calculated for each feature from the Kano model framework. CS level indicates whether satisfaction can be increased by meeting a product requirement or fulfilling the product requirement. At the end, CS target was determined for each requirement defined where the target value would be higher than the current customer satisfaction value.

2.1 Conceptual Design Generation: Kano-QFDE Approach

The development of the house of quality (HOQ) is the most significant step in QFDE. The goal of HOQ is to determine the quality of customer needs, the link between customer needs and technical requirements, to analyze technical requirements and ultimately to determine the targeted value for the technical requirements of the product [41]. Results obtained from Kano Model, i.e., customer's expectations for a NFBC takeout food container were integrated into the HOQ. At the last stage of the HOQ, it will identify requirements to be given priority.

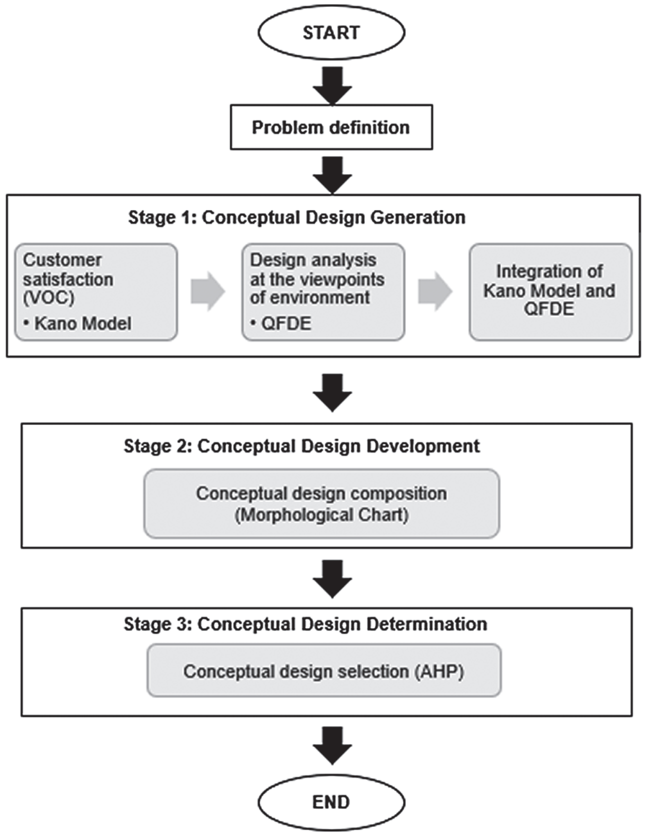


Figure 1: General framework of the integrated approach for the conceptual design of natural fibre-reinforced biopolymer composite takeout food container

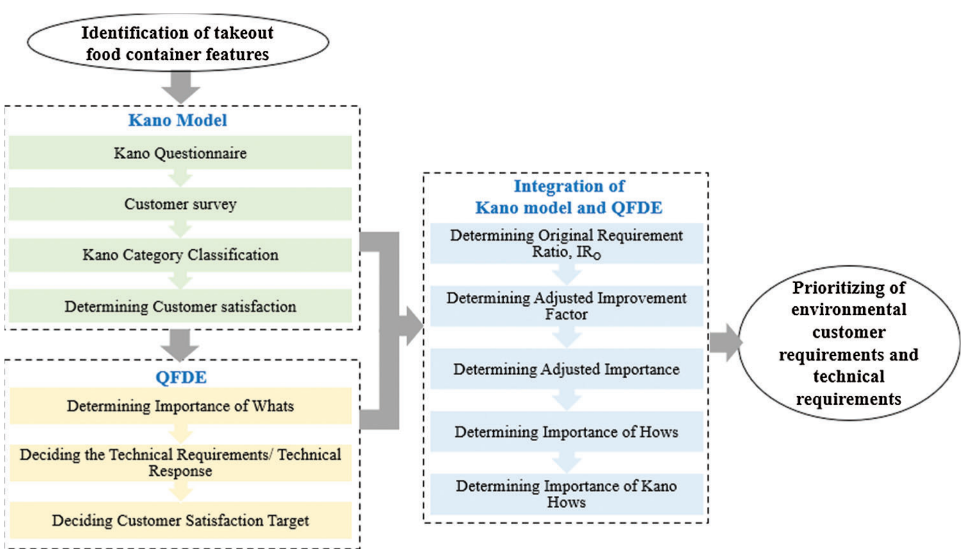


Figure 2: Flow of work in integrating Kano Model and QFDE

The work process of incorporating the Kano model and QFDE methodology started by using the Kano questionnaire in a survey to identify the characteristics of takeout food containers. The results of the Kano survey were analysed and then the findings were integrated into QFDE's HOQ. The findings then indicated the features that should be paid attention to. From this, using morphological maps, all design proposals were arranged and later AHP was used in the final design decision making.

2.1.1 Kano Model to Identify Product Features

The first step done was preparing the list of Voices of Customer and Environment (VOCE) in the QFDE-Kano Model framework. This list of VOCEs is the 'Whats' list. Through performing market research, the required product features can be defined and selected. The improvement of the product consists of adding new features to a product or updating existing features to boost the efficiency of a product [42]. Kano questionnaires were then used to better understand, discover and fulfil a container's specifications for packing takeout food. Basically, the purpose of Kano questionnaire is to focus on important features of product and to identify the Kano category. A Kano questionnaire was constructed for the NFBC takeout food container and the features determined were identified from literature. The determined attributes of green biocomposite takeout food container selected in the study are described in Tab. 1.

Table 1: Attributes selected in this work for the conceptual design of a green biocomposite takeout food container [28,39,43–48]

Attributes/ Requirements	Description
Containment	Effectively contained food without spillage/leakage and protect the food until it is to be consumed
Convenience	A characteristic that simplifies its usage or consumption and adds to one's ease or comfort and could be related to both the logistical and marketing
Transparency	Transparency of container to display food content
Compartments	Container can keep individual food separated when packed
Open/Close structure	Container can be closed and open easily, without using any tools
Re-closibility	Container can be re-closed to keep unfinished food for later consumption
Coloured	Containers with colour
Straight/Curve design	Characteristics design of container either straight or curvy
Display Information	Display information as dimensions or elements that communicates marketing messages
Reusability	Container that can be used more than one time
Easy disposal	Facilitate disposal processes and biodegrade quickly

For each feature determined, a pair of questions is formulated in the survey to which the customer can answer in one of five different ways. The first question is: "How do you feel if that feature is present in the product (functional form of the question)", and the second one is: "How do you feel if that feature is not present in the product (dysfunctional form of the question)" [34,49]. For each part of the questions, the customer selects one of five choice of answers. These five options are "I am impressed"; "I expect it"; "I am neutral"; "I could tolerate with it"; and "I am disappointed". The responses were then evaluated into quality dimensions based on how the respondents perceived the functional and dysfunctional form of a quality attribute according to the Kano evaluation table (Tab. 2). Kano model classifies product features into six categories, i.e., "Must-be" (M), "One-dimensional" (O), "Attractive" (A), "Indifferent" (I), "Questionable" (Q) and "Reverse" (R) and "Attractive quality" (A) as described in Tab. 3.

Table 2: Kano evaluation table

Customer requirement		**Dysfunctional form**				
		1	**2**	**3**	**4**	**5**
Functional form	**1**	Q	A	A	A	O
	2	R	I	I	I	M
	3	R	I	I	I	M
	4	R	I	I	I	M
	5	R	R	R	R	Q

Note: 1 – I am impressed; **2** – I expect it; **3** – I am neutral; **4** – I could tolerate with it; **5** – I am disappointed

Table 3: Six Kano categories of product features [36]

No.	Kano category	Description
1	Must-be quality (**M**)	These features are the basic requirements, and if these requirements are not provided, the customer will be dissatisfied. But by providing these needs the customer satisfaction will not increase.
2	One-dimensional quality (**O**)	These features are the ones demanded by the customers. The customer satisfaction is proportional to the level of fulfilment of the requirements. That is higher the level of fulfilment, higher will be the customer satisfaction and vice versa.
3	Attractive quality (**A**)	Additional features are not demanded or expected by the customer. If these are fulfilled, the customer satisfaction will be higher. If not fulfilled, the customer will not be dissatisfied.
4	Indifferent quality (**I**)	The customer does not have concern about these requirements whether it is added or not. Furthermore, increase or decrease in customer satisfaction of the product does not caused by these features.
5	Questionable quality (**Q**)	The answers should not fall into this category. Questionable scores indicate that the question expressed was not correct or that the respondent/customer did not understand the question and gave a wrong answer.
6	Reverse quality (**R**)	If a product feature is reverse, it means that the attribute causes customer dissatisfaction and the customers are not required this product feature.

The Kano survey carried out was a simple random sampling by using online survey where a link was created for dissemination through emails and other internet communication platforms, and participants could easily access and forward the survey to others. This technique is more cost effective compared to paper survey [50]. Size of sample survey was calculated using Eq. (1) [34];

$$ME = Z \times \sqrt{\frac{P(1-P)}{n}} \tag{1}$$

where,

ME–Margin of error

P–Prior judgment of the correct value.

Z–Z-score of confidence level. The standard Z-score of confidence levels are

99% = 2.58; 95% = 1.96; and 90% = 1.645

n–Sample size.

Now,

ME = Margin of error is assumed 10%

Z = Z-score of confidence level is selected 99% i.e., 2.58

P = Prior judgment of correct value is assumed 30%.

Therefore, n = 139.7844 ≈ 140 respondents.

Kano values ('k' values) were to be obtained from Kano analysis where different Kano groups determine the value of 'k' F that can be obtained by the DI-SI plot [36]. The values of 'k' are: 'Must-be' (M) = 0.5; 'One-dimensional' (O) = 1; 'Attractive' (A) = 2, respectively. Then, from the Kano model system, customer satisfaction (CS) was calculated for each quality. The level of customer satisfaction states whether by fulfilling a product requirement or fulfilling this product requirement, satisfaction can be increased. Finally, according to each criterion, the designer must identify the customer satisfaction target. The target value must be greater than the current value of customer satisfaction, although it is not possible to reach 100 percent satisfaction [34].

2.1.2 Customer Satisfaction (CS)

Customer Satisfaction (CS) or Satisfaction Index (SI) represent the ideas of fulfilment of a customer need. In another words, the customer satisfaction level implies whether satisfaction can be increased by implementing a product requirement to prevent the dissatisfaction from customer. These customer satisfaction level values were used in the HOQ during the integration of Kano model with QFDE. It is especially important to know the average impact of a product requirement on the satisfaction of all the customers. The satisfaction index (SI) and dissatisfaction index (DI) are calculated using the following equations:

$$\text{Customer satisfaction (SI)} = \frac{A+O}{A+O+M+I} \tag{2}$$

$$\text{Customer dissatisfaction (DI)} = \left(\frac{M+O}{A+O+M+I}\right)(-1) \tag{3}$$

The negative (−ve) symbol in the DI formula denotes consumer disappointment. The positive (+ve) SI limit is 0 to 1, and as the value gets closer to 1, the degree of customer satisfaction increases. The SI reaches 0, indicating that it will not cause dissatisfaction if the function does not meet [36].

2.1.3 Integrating Kano in QFDE

In order to capture many topics that are important to the planning process, QFD uses a matrix format. The House of Quality (HOQ) matrix is the most popular and widely used tool based on marketing research for translating customer requirements. The results will be translated into a sufficient number of engineering goals for the new product design to be met. It is often known as the conceptual map that offers the most detailed information for process planning and communication [34]. VOCE steer the process of applying QFDE in the product development process, so the satisfaction of consumers with products can be greatly increased. By introducing QFDE, awareness of all department members in a company can be improved to meet consumer and environmental requirements [51]. In general, the standard HOQ format consists of six key components, namely consumer requirements, technical criteria, a planning matrix, a matrix of relationships, a matrix of technical correlations, and technical priorities and targets. The format of HOQ used in this study of integrating Kano model with QFDE is shown in Fig. 3.

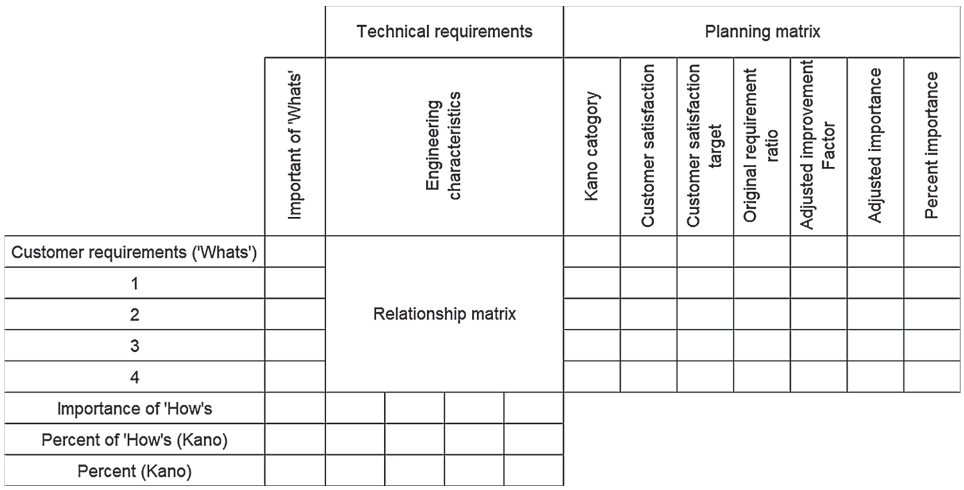


Figure 3: House of Quality (HOQ) with Kano model

The early steps in forming the HOQ were included determining, clarifying, and specifying the list of customer requirements or the 'Whats' list. By integrating Kano Model analsyis in QFDE, this list was achieved. Importance of 'Whats' were obtained from a separate survey to frequent takeout food buyers (at least two times a week). The self-stated survey questionnaire using an online survey form, and, in this survey, the customers were asked to rate each identified VOCE in a Likert scale (1 = Unimportant to 9 = Most important). The survey carried out was applying snowball sampling for its reputation in current research on consumer perceptions [50]. The results of the self-stated questionnaire were used as a value of importance of Whats in a QFD [34].

By applying Shannon's Entropy method to obtain the weights of importance for each of the VOCE specified in HOQ, the responses collected were then analysed. In information theory, Shannon's entropy is significant, but it has now been used as a guide to a general measurement of uncertainty and determines weight values by solving mathematical models without taking into account the decision-makers' preferences [18]. Entropy is merely an objective weight determination method [52]. Weights of meaning derived from entropy are defined as 1 minus the value of entropy. The rating of alternative i with respect to criterion j is represented by X_{ij} and w_j is the weight of criterion j (the rating of alternative i with respect to criterion j is assumed non-negative). Based on its probability function, the probability of each element was distributed. The corresponding value x is needed to be normalized for each criterion to gain the projection value of each criterion. The element of this matrix for j^{th} criterion was shown in Eq. (4).

$$P_{ij} = \frac{x_{ij}}{\sum_{j=1}^{m} x_{ij}} \tag{4}$$

where, P_{ij} is the projection value of i according to j^{th} criteria, x_{ij} is the aggregated fuzzy rating, and m is the number of alternatives.

After normalized the corresponding value, the entropy value, e_j was calculated using (5),

$$e_j = -k \sum_{j=1}^{n} P_{ij} \ln P_{ij} \tag{5}$$

where, e_j is the entropy value, n is the number of criteria, and k is the number of decision makers and k is a constant ($k = (ln(m))–1)$).

The degree of divergence (d_j) of the basic information for each criterion was calculated using (6),

$$d_j = 1 - e_j \tag{6}$$

The final step in calculating Shannon's entropy was to determine the weight by using Eq. (7),

$$W_j = \frac{d_j}{\sum_{k=1}^{n} d_k} \tag{7}$$

where W_j is the subjective weight according to the j^{th} criteria.

The next move was to decide on the technical criteria and what needs to be done to fulfil these requirements after gaining weight significance of the 'whats' (VOCE). The designer had to pick the basic standards and specifications. The technical requirements established in this work were adopted from Widaningrum [27] namely: 1) Biomaterials 2) Characteristic design 3) Information design 4) Aesthetic design, and 5) Quality conformance. Forming a planning matrix was the subsequent step in the QFDE process where its main purpose was to compare current product with competitors' product. In the implementation of the QFDE method and during integration with the Kano model, this comparison part was used. The planning matrix showed the weighted value of each condition to be met by all manufacturers. To measure the overall performance, the customer ratings were combined with the weighted value of each requirement.

The relationship matrix that was developed was to decide the relationship between VOCE and technical requirements (or engineering characteristics). A correlation between 'What' and 'Hows' was the primary reason for the relationship matrix. The key role of the relationship matrix is to create a connexion between the product's environmental and consumer requirements and the technical requirements for the enrichment of the product. There are typically four types of relationships, i.e., a strong relationship, a middle relationship, a weak relationship, and no relationship. In this work, the measurement scale used ranges from 0–1–3–9 to assess the four relationships above, where 9 = strong relationship, 3 = medium relationship, 1 = weak relationship and 0 = no relationship. These values are used by engineers or designers to solve the matrix of relationships based on their own judgement or knowledge. Then, to get more customer satisfaction, the designer will evaluate which technological requirements should be handled first. A collection of target values for each technical requirement to be realised by the new design is the final performance of the matrix. To determine the level of customer satisfaction for each VOCE specified, the customer satisfaction improvement ratio or Original Requirement Ratio (IR_O) column in the HOQ was required. Eq. (8) was used to measure this.

$$Original\ Requirement\ ratio\ (IR_O) = \frac{Customer\ Satisfaction\ Target}{Customer\ Satisfaction\ (SI)} \quad (8)$$

The designers themselves have defined the customer satisfaction target for each VOCE. The value varies from 0 to 1 and is higher than the value of customer satisfaction derived from the Kano results. Next, using Eq. (9), which utilised important parameters from Kano model analysis, an adjusted improvement factor was calculated.

$$Adjusted\ Improvement\ Factor = (IR_O)^{1/k} \quad (9)$$

where, k = Kano value (for M = 0.5, O = 1, A = 2)

From multiplying the adjusted improvement factor to customer 'Importance of Whats' using Eq. (10), adjusted importance values were obtained. For each function, the percentage values of significance were then computed. These principles will provide a clear vision of setting the priority of change standards for consumers and the environment.

$$Adjusted\ Importance\ =\ Adjusted\ Improvement\ Factor\ \times\ Importance\ of\ Whats \quad (10)$$

There was a need to assess the relationship between consumer needs and technological requirements or engineering characteristics. The 'Importance of Hows' was calculated by Eq. (11), which is the summation of the 'Importance of Whats' of product with the Technical Requirement relationship. 'Importance of How s' included the details on the technical requirements should be important in the customer-relevant design of the new takeout food container.

$$Importance\ of\ Hows\ =\ \sum (Importance\ of\ Whats\ \times\ Relationship\ rating) \quad (11)$$

The final step at this point was to decide the 'Importance of How s (Kano)' where the knowledge on how to evolve the new product concept based on the results of the Kano Model was provided by these values. From the sum of the multiplication of 'Modified Value' with the relation of each Technical Requirement using Eq. (12), the 'Importance of Hows (Kano)' can be achieved.

$$Importance\ of\ Hows\ (Kano)\ =\ \sum (Adjusted\ importance\ \times\ Relationship\ rating) \quad (12)$$

2.2 Conceptual Designs Development: Morphological Chart (MC)

The next step was to integrate all ideas to create new innovative designs for the new green biocomposite takeout food container after specifying prioritisation of VOCE and technical specifications in the previous stage. Various conceptual designs will be created by the combination of all the ideas from all elements. The designers would have to determine which conceptual design from all concept designs produced was going to be the final concept design. The morphological chart (MC) was used in this proposed hybrid method to show all the ideas in one place. To build the conceptual design for the takeout food container, the design component solutions were combined one by one. In a list of conceptual designs, all the possible solutions from the MC were combined and described. In the selection process for the final one, all conceptual designs were later evaluated. The evaluations of all conceptual designs were based on the value of their Von Mises stress, which used to evaluate the strength, while the value of deformation used to evaluate the stiffness. The size of the container will be evaluated by the weight and volume while the cost to evaluate the material cost and complexity of the design [3].

2.3 Conceptual Design Selection: Analytic Hierarchy Process (AHP)

From all concept designs produced in the previous processes, final conceptual designs for the takeout food container were selected. Due to its key advantage in providing systematic and comprehensive multi-criteria decision-making processes, the Analytic Hierarchy Process (AHP) is one of the most used selection methods in design [21]. The AHP approach has the benefit of offering a critical solution in the decision-making phase where multiple attributes and design alternatives need to be evaluated at the same time [3]. In this study, The selection process was made based on the product design specifications (PDS) elements of the takeout container as shown in Fig. 4. AHP via Expert Choice v11.5 software was utilized to rank all the developed conceptual designs.

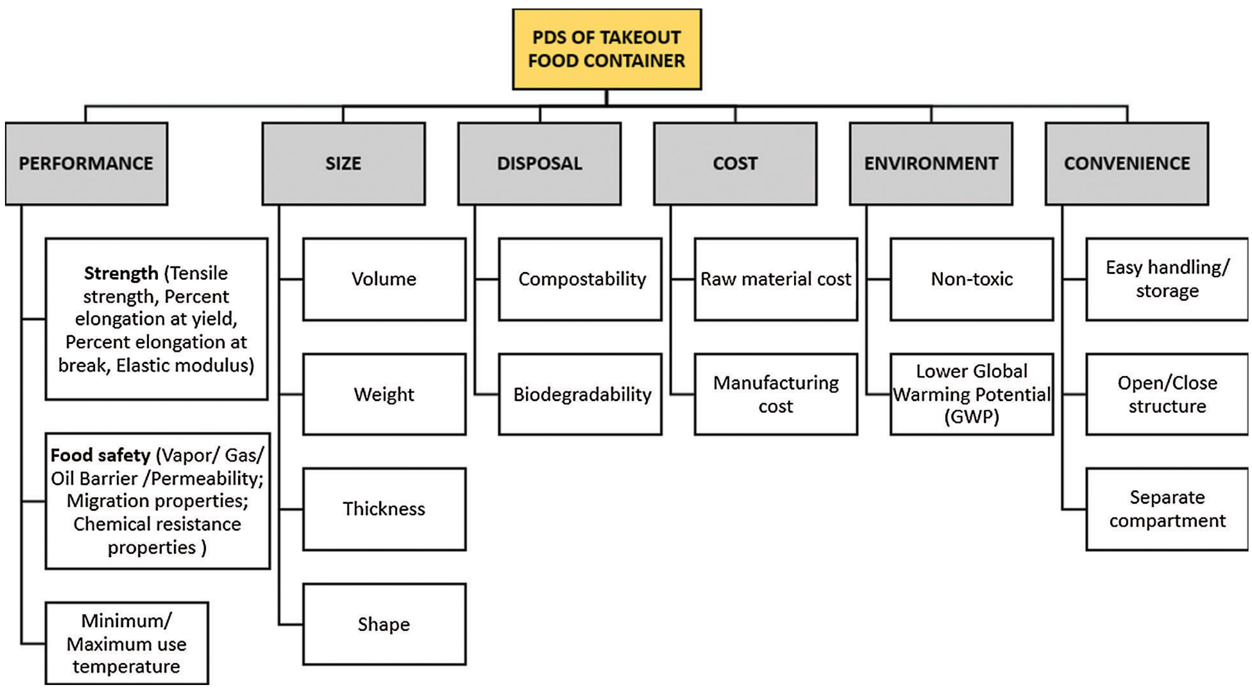


Figure 4: Product design specification (PDS) elements of fully biodegradable NFBC takeout food container

3 Results and Discussion

The conceptual design phase in concurrent engineering approach using the integration of Kano model–QFDE-Morphological Chart–AHP method was applied to explore the appropriate solutions specifically in the conceptual design stage for the NFBC takeout food container. The Kano model and QFDE was applied as the solution tool for idea generation while morphological chart was utilized as idea refinement tool based on the HOQ recommended solutions for concept design developments. Finally, the AHP method was implemented as concept design selection instrument based on the takeout food container product design specification elements.

3.1 Kano Survey Results in Identifying Product Features

The 147 responses were obtained from the Kano survey where 52% of them were women and the balance 48% were men. Their age spread between 20 to more than 60 years old, but almost 80% of them were in the age group of 30 to 50 years old, and all of them buy takeout food at least once every month. The number of responses was small but sufficient to illustrate the purpose of the Kano model for a better understanding of customers' requirements. Furthermore, it was more than the number calculated by

Eq. (1) in Section 2.1.1. Nonetheless, a larger customer sample with a higher number of response could extend the study's perspective representing [53]. Data from the survey were processed by the Kano model to determine the Kano category. Tab. 4 shows the Kano category of each VOCE determined for the takeout food container. From the classification results, features classified as 'attractive' (A), 'one dimensional' (O) and 'must be' (M) in Kano were considered for the integration of Kano model with QFDE. The features are 'containment', 'opening structure', 're-closability', 'convenience', 'compartments', 'display information' and 'easy disposal'. The other three Kano category namely, indifferent (I), reverse (R) and questionable (Q) are eliminated because of their insignificant impact on customer satisfaction. Afterwards, the customer satisfaction (CS) values were calculated using Eq. (2). These values were used in the HOQ of QFDE to decide the priorities of VOCE and as well as technical requirements.

Table 4: Kano model analysis

		Kano category							
Customer requirements (VOCE)	CR	M	O	A	I	R	Q	Total	KANO category
Containment	CR1	**70**	42	15	14	2	4	147	**M**
Convenience (Pack/Carry)	CR2	12	21	**63**	47	0	4	147	**A**
Transparency	CR3	17	9	22	**88**	11	0	147	**I**
Compartments	CR4	9	17	**65**	54	1	1	147	**A**
Open/Lock structure	CR5	**52**	36	16	41	2	0	147	**M**
Re-closibility	CR6	**54**	47	17	28	0	1	147	**M**
Colour	CR7	1	1	27	**108**	10	0	147	**I**
Straight/Curve	CR8	3	3	2	**114**	23	2	147	**I**
Display Information	CR9	9	18	**61**	57	2	0	147	**A**
Reusability	CR10	16	29	41	**61**	0	0	147	**I**
Easy disposal	CR11	12	**66**	52	16	0	1	147	**O**

3.2 Entropy Weight of Importance of VOCE in House of Quality (HOQ)

From the survey carried out as described in Section 2.1.4, 150 responses were gathered, but only 123 were categorised as frequent buyers of takeout food (at least two times per week), and used for the analysis to determined importance of each VOCE selected from Kano model. The sample size has a confidence level of 95% that the real value is within ±10% of the surveyed value. The respondence were 72% woman and spread from the age of 18 to more than 50 years old, but 63.4% of them were from the age of 30 to 49 years old. For reliability of data the Cronbach's alpha obtained was 0.746. The gathered responses were processed by Shannon's entropy method and the results obtained are tabulated in Tab. 5. From these premature results, it demonstrated that all weights have not much difference though 'containment' and 'open/lock structure' both have the highest entropy weight (14.36%). Next highest weight values are 14.34% which attained by another two VOCEs namely 'convenience' and 're-closability'. Subsequently, 'display information' with weights values of 14.24% and closely followed by 'compartment' (14.22%) and finally 'easy disposal' with the lowest weight value of 14.14%.

Table 5: Entropy analysis on importance of each VOCE

VOCE		Entropy values, e_j	Degree of divergence, d_j	Objective weight, W_j
Containment	C1	18.3061	−17.3061	0.1436
Convenience	C2	18.2805	−17.2805	0.1434
Compartments	C3	18.1334	−17.1334	0.1422
Open/Lock structure	C4	18.2986	−17.2986	0.1436
Re-closibility	C5	18.2783	−17.2783	0.1434
Display Information	C6	18.1551	−17.1551	0.1424
Easy disposal	C7	18.0399	−17.0399	0.1414

The Kano model results and the Shannon's entropy weights analysed were integrated in the QFDE procedure to develop the HOQ. After that, all values in all columns were calculated using the specified formulas. The final HOQ results is shown in Tab. 6. From the results, 'easy disposal' obtained the highest percent of importance for VOCE with the value of 21.76%. Next are 'convenience' and 'containment' with only slight difference of their percent of importance values, i.e., 18.65% and 18.5% respectively. The fourth highest importance VOCE is 'open/lock structure' with 17% of value. Meanwhile, for technical requirement, the final Kano importance values revealed that 'physical characteristics' is the highest with almost 34% of importance values. Following not far after is 'quality conformance' with 30.4% importance. Therefore, from this Kano-QFDE results, to design a new fully biodegradable NFBC takeout food container, below suggestions were carefully considered: 1) New takeout food container design must have the feature of easy disposal where it could be disposed easily, and this could be prompted by the physical design or the material used. Biodegradable and compostable materials used would be best where wastes produced would return to the environment safely [12]; 2) Physical design of the food container must have the feature of convenience in every aspect of used and handling e.g., stackable for easy storage, easy to hold during food being consumed etc. This physical design is as important as another feature that need to be given emphasis in the design of new takeout food container, which is good containment, e.g., food contained is safe until it is to be consumed, no easy spillage, etc. [39,54]; and 3) Another important feature that need to be explored, is the feature of open/close structure of the container where the design structure shall be effortlessly effective [55].

3.3 Morphological Chart to Assist Concept Design Development

In order to present all possible ideas in one place, the morphological chart (MC) is used and the solution ideas of design elements suggested for the food container are combined one by one to create the conceptual design [24,56]. Fig. 5 is the MC built in this design generation work. The conceptual designs were developed from the combination of each solution in MC and nineteen conceptual designs generated are described in. All the design properties presented were obtained during design modelling in Autodesk Inventor Professional 2020. Six of the concept designs generated are presented in Figs. 6a–6e.

3.4 Performing Final Concept Design Selection Using Analytic Hierarchy Process (AHP) Method Based on the Product Design Specification Elements

In this study, AHP method was utilized to decide on the final concept design from the nineteen concepts developed. A more detailed review of the attributes of all design concepts with regard to the 'size' selection criteria (mass and volume) could be carried out by translating the existing conceptual design into 3D models into 3D models in Autodesk Inventor Professional software. Stress analysis was also performed for each of the concept design to predict their structural performance. In addition, the weight attribute (mass property) recognised from the models was then further used to estimate the cost of raw material for each concept design developed. As for complexity design attribute, it is related to the manufacturing cost criteria [21]. The selection process was made based on the product design specifications (PDS) elements of the takeout container Fig. 4. Three main crietria and their sub-elements were selected namely performance, size, and cost for the concept design selection purpose. Furthermore, the sub-elements were translated into equivalent design indicators as itemized in Tab. 7. Other elements shown in the overall PDS specifically disposal and environment were not incorporated in the concept design selections as both are related to the material selection requirements for the overall biodegradable takeout food container design and all concept designs analysed were utilizing the same natural fiber reinforced sago starch-based composites material for their construction. The PDS elements Tab. 7 were later used to define the main criteria and sub-criteria for the AHP hierarchy framework. The goal of project was specified at the top level of the hierarchy and followed by the key criteria and sub-criteria of the design selection at level-2 and level-3, respectively. Finally, the alternatives of design concept for the fully bio-based takeout food container were at level-4 of the hierarchy. The AHP hierarchy formulated is as shown in Fig. 7.

The judgement process between all concept designs with regard to each main criterion selection and sub-criteria was made using pair-wise comparison technique on the basis of the AHP system. On a pairwise comparison basis, each criterion was evaluated at each level based on their relative significance. The evaluation was performed based on the importance of the criteria for the natural fibre-reinforced biopolymer composite takeout food container, where the cost and size have more priority. Cost become an important factor in selecting takeout food package as businesses always choose packages that can meet the basic functions with the lowest cost [47]. Cost is the main criterion in the selection of the final conceptual design in terms of the design's material cost and complexity, and material cost was determined to have higher importance [3]. For the pair of size and performance, size was determined to have slightly higher importance than performance [57]. Mass of product influence the cost and lightweight packaging is always preferrable [26,58] The main criteria weightage determined by the software calculation were 26%, 32.7% and 41.3% for 'performance', 'size' and 'cost' respectively. As for the relative preference between each conceptual design, the pairwise basis were performed based on the design attributes established for each concept design in Tab. 8. The judgment values for each assessed pair were based on the comparison ratio technique such as applied in Sapuan [59] and Salwa [17]. Utilization of Expert Choice v11.5 software assisted the process of priority scores calculation and generated a rank for all concept designs. An example of the pair-wise judgment between the concept designs with respect to the mass sub-criterion under size main-criteria using the AHP method via Expert Choice software is shown in Fig. 8. Conceptual design 9 (CD 9) is heavier than conceptual design 14 (CD 14) but lighter design preferrable, hence relative preference for CD 14 was higher by the difference of mass between the two concept designs. The results of priority vectors and consistency test for the concept design alternatives with respect to every sub-criterion were calculated by the software. The priority vectors and the consistency ratio must be analysed after performing judgment on pairwise comparison. For consistency ratio (CR) values less than 10% (0.1), the judgment was accepted, but if the value was more than 0.1, the judgment was reviewed and corrected to obtain a more consistent matrix.

The ranking based on priority values obtained by each concept design shown in Fig. 9. Concept design 18 (CD18) evidently scored the highest priority score of 8.3% and followed by concept design 2 (CD2) and concept design 5 (CD5) with 7.3% and 7.0% priority score, respectively. Next on the rank are concept design 4 (CD4), concept design 3 (CD3), concept design 14 (CD14), and concept design 1 (CD1) with only 0.1% difference on their priority values from each other, i.e., 6.7%, 6.6%, 6.5% and 6.4% correspondingly. Concept design 9 (CD9) obtained the lowest priority score of only 3.4% and hence appear at the bottom rank. The stability of results obtained can be analysed by performing a sensitivity analysis [60]. The weightages for performance, size, and cost by 20%, respectively. This altered the final weightage and ranking of the conceptual design alternatives and is shown in Fig. 10.

Table 6: House of Quality (HOQ) in QFDE

			Engineering metrics/Technical requirement					Planning matrix							
	VOCE	Importance of WHATs (from Entropy weight)	Biocomposite materials	Physical characteristics	Information design	Aesthetics design	Quality conformance	Kano category	*K* value	Customer satisfaction (CS)	Customer satisfaction target	Original requirement ratio, IR_0	Adjusted improvement factor	Adjusted importance	Percent importance
CR1	Good Containment	0.1436	9	9	0	3	9	M	0.5	0.4043	0.8	1.9790	1.4068	0.2021	**18.504**
CR2	Convenience in use/handling	0.1434	0	9	1	3	9	A	2	0.5874	0.7	1.1917	1.4201	0.2037	**18.652**
CR3	Compartments	0.1422	0	9	0	3	1	A	2	0.5655	0.6	1.0610	1.1257	0.1601	14.659
CR4	Open/Lock structure	0.1436	1	9	3	1	9	M	0.5	0.3586	0.6	1.6731	1.2935	0.1857	**17.007**
CR5	Re-closibility	0.1434	3	9	3	1	9	M	0.5	0.4384	0.6	1.3688	1.1699	0.1678	15.364
CR6	Display Information	0.1424	3	0	9	1	1	A	2	0.5448	0.6	1.1013	1.2128	0.1727	15.814
CR7	Easy disposal (Biodegradable/ Compostable)	0.1414	9	9	3	0	9	O	1	0.4762	0.8	1.6800	1.6800	0.2376	**21.759**
	Importance of Hows		3.566	7.719	2.710	1.717	6.723	22.435			Total adjusted importance			1.0919	
	Percent		15.896	34.404	12.079	7.653	29.968	**Total**							
	Importance of Hows (Kano Model)		5.164	10.411	3.531	2.223	9.304	30.633							
	Percent (Kano model)		**16.857**	**33.988**	11.526	7.258	**30.371**								

		Solution ideas			
Design strategy	**Sub-element**	**1**	**2**	**3**	**4**
Good containment	A. Type	Container with lid	Clamshell		
	B. Shape	Round	Square	Rectangle	
	C. Body type	Foam	Solid		
	D. Rib	Non-rib	Ribbing at corner of container base only	Ribbing at walls of container base	Ribbing at all walls of container base and lid
	E. Rib pattern	I	V	X	
Easy disposal	F. Reduced material	Thinner wall	Reduce size		
Convenience in use/ handling	G. Cross section profile	Symmetry	Asymmetry		
Close/Open structure	H. Lock structure	Latching (male-female)	Self-locking tabs	Snaps	Lid/friction fit

Figure 5: Morphological chart to combine all the ideas to develop new conceptual designs for the new biocomposite takeout food container

Results of sensitivity analysis are outlined in Tab. 9. It was observed that conceptual design 18 (CD18), the topmost rank, stays at the top for two out of three circumstances tested. Both conceptual design 2 (CD2) and conceptual design 5 (CD5) too remain at the same rank for those same circumstances. CD18 falls to the third rank when ‘performance’ criterion’s weightage was increased by 20% with minor difference of priority scores with the two higher ranked concept designs. CD2 and CD5 go down to fourth and sixth rank in this case. However, when ‘size’ and ‘cost’ criterion’s weightage increased by 20%, CD18’s priority score is at the highest and evidently greater than the other concept designs. CD18 is a clamshell type container design with I-rib around the wall as well as bottom of container base, whereas its locking structure is a latching (male-female) type located at all four corners of the container. Therefore, CD18 was then selected as the final concept design for the biopolymer composite takeout food container design. The next best option is CD2, a round container with flat lid and the wall of container base has few I-ribs. Though CD2 falls to the fourth rank for the 20% increased weight of ‘performance’ circumstance, it still seized the second rank for the other two conditions tested. Interestingly, conceptual design 10 (CD10) which is at the nineth rank and goes to much lower rank for two circumstances tested (i.e., rank 10 for 20% increased of ‘size’ and rank 13 for 20% increased of ‘cost’), turns out to be at the topmost rank when weightage of ‘performance’ criterion was increased by 20%. CD10 is a rectangle shape container with I-rib all around the wall of the container base with roomed-lid. Amount and type of food packed in the container will give different loads to the base of the containers and container need to be strong enough to hold. CD10 has the highest maximum displacement and Van Misses Stress, which indicates this concept design can withstand higher applied force (as shown in Fig. 11) better compared to other concept designs. However, for cost and size criteria, which are having higher selection weightages, CD10 is not desirable. Therefore, CD10 do not have high priority in the overall results. Observation at the bottom rank for all circumstances tested in the sensitivity analysis, CD8, CD9, CD17 and CD19 were concluded as among the least preferred concept designs.

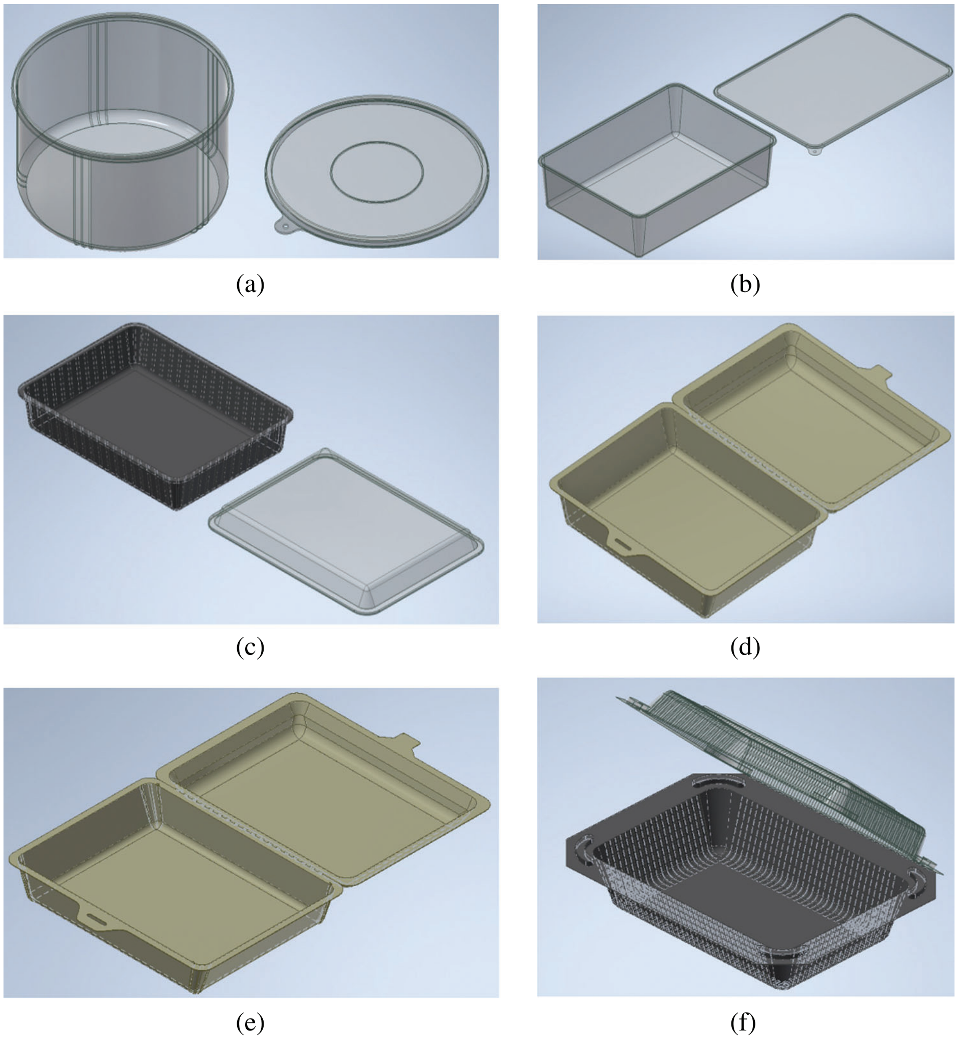


Figure 6: a) Conceptual design 2. b) Conceptual design 6. c) Conceptual design 10. d) Conceptual design 13. e) Conceptual design 14. f) Conceptual design 18

Table 7: NFBC takeout food container PDS features and their equivalent design indicators

PDS main features	PDS sub-elements	Equivalent design indicators
Performance	Strength	Van Misses Stress (MPa)
	Stiffness	Displacement (mm)
Size	Size	Volume (mm^3)
	Weight	Mass (kg)
Cost	Material cost	Material cost (RM)
	Complexity	Complexity

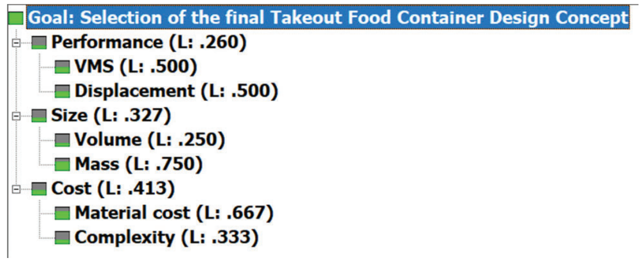


Figure 7: AHP structure developed by Expert Choice software for the selection of the final conceptual design

Table 8: Conceptual design of the natural fiber reinforced starch composites takeout food container

CD	Description	Volume (mm^3)	Mass (kg)	Maximum stress: VMS (MPa)	Maximum displacement (mm)	Material cost (RM)	Complexity
1	FC1	18712.7	0.01683	13.5514	20.556	0.0168	7
2	FC1–1	15953.8	0.01434	14.5761	23.475	0.0143	7
3	FC1–1–1	17499.2	0.01573	10.5300	23.406	0.0157	7
4	FC1–1–2	17249.2	0.01551	10.7138	19.894	0.0155	7
5	FC1–2	15839.5	0.01424	10.6413	24.002	0.0142	8
6	FC2	36014.8	0.03238	6.9487	23.738	0.0324	7
7	FC2–1	31361.8	0.02819	11.4143	54.246	0.0282	7
8	FC3	425674	0.38268	11.6358	52.912	0.3827	7
9	FC3–1	425674	0.38268	11.6142	52.923	0.3827	8
10	FC3–2	422133	0.37950	26.8709	126.06	0.3795	8
11	FC3–3	422400	0.37974	28.8974	111.137	0.3797	8
12	FC3–4	425736	0.38274	22.6558	49.720	0.3827	8
13	FC4	29317.6	0.02636	7.9901	18.433	0.0264	5
14	FC4–1	23495.5	0.02112	13.5865	38.482	0.0211	5
15	FC4–5	30264.9	0.02721	10.3041	14.825	0.0272	7
16	FC4–6	34735.3	0.03123	10.3206	19.316	0.0312	7
17	FC5	46724	0.04201	9.0015	15.045	0.0420	7
18	FC5–1	13154.7	0.01183	10.9497	15.163	0.0118	7
19	FC5–2	47469.1	0.04268	8.7962	14.747	0.0427	7

Note: For comparison purposes, assumed that the density of sugar palm fiber reinforced sago starch NFBC is 0.899 g/cm^3 and raw material cost is RM1.00/kg

	CD1	CD2	CD3	CD4	CD5	CD6	CD7	CD8	CD9	CD10	CD11	CD12	CD13	CD14	CD15	CD16	CD17	CD18	CD19
CD1		1.173	1.069	1.085	1.181	1.925	1.676	22.748	22.748	22.559	22.573	22.751	1.567	1.256	1.617	1.856	2.497	1.423	2.537
CD2			1.097	1.081	1.007	2.257	1.966	26.682	26.682	26.46	26.476	26.686	1.838	1.473	1.897	2.177	2.929	1.213	2.975
CD3				1.015	1.105	2.058	1.792	24.325	24.325	24.123	24.138	24.329	1.675	1.343	1.73	1.985	2.67	1.33	2.713
CD4					1.089	2.088	1.818	24.678	24.678	24.473	24.488	24.682	1.7	1.362	1.755	2.014	2.709	1.311	2.752
CD5						2.274	1.98	26.874	26.874	26.651	26.668	26.878	1.851	1.483	1.911	2.193	2.95	1.204	2.997
CD6							1.148	11.819	11.819	11.721	11.729	11.821	1.228	1.533	1.19	1.037	1.294	2.738	1.318
CD7								13.573	13.573	13.46	13.469	13.575	1.07	1.335	1.036	1.108	1.49	2.384	1.514
CD8									1.0	1.008	1.008	1.0	14.519	18.117	14.065	12.255	9.11	32.359	8.967
CD9										1.008	1.008	1.0	14.519	18.117	14.065	12.255	9.11	32.359	8.967
CD10											1.001	1.009	14.399	17.966	13.948	12.153	9.035	32.09	8.893
CD11												1.008	14.408	17.978	13.957	12.161	9.04	32.11	8.898
CD12													14.522	18.12	14.067	12.527	9.112	32.364	8.969
CD13														1.248	1.032	1.185	1.594	2.229	1.619
CD14															1.288	1.478	1.989	1.786	2.02
CD15																1.148	1.544	2.301	1.568
CD16																	1.345	2.641	1.367
CD17																		3.552	1.016
CD18																			3.609
CD19																			

Figure 8: Pairwise comparison matrix of conceptual design 9 (CD9) and conceptual design 14 (CD14) with respect to mass (cell highlighted in yellow)

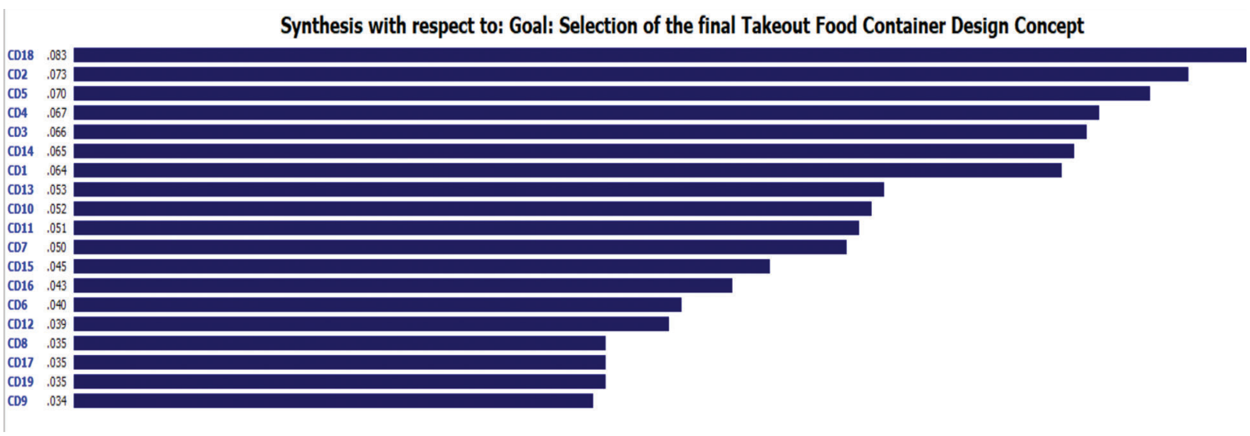


Figure 9: Ranking of the fully biodegradable takeout food container conceptual designs

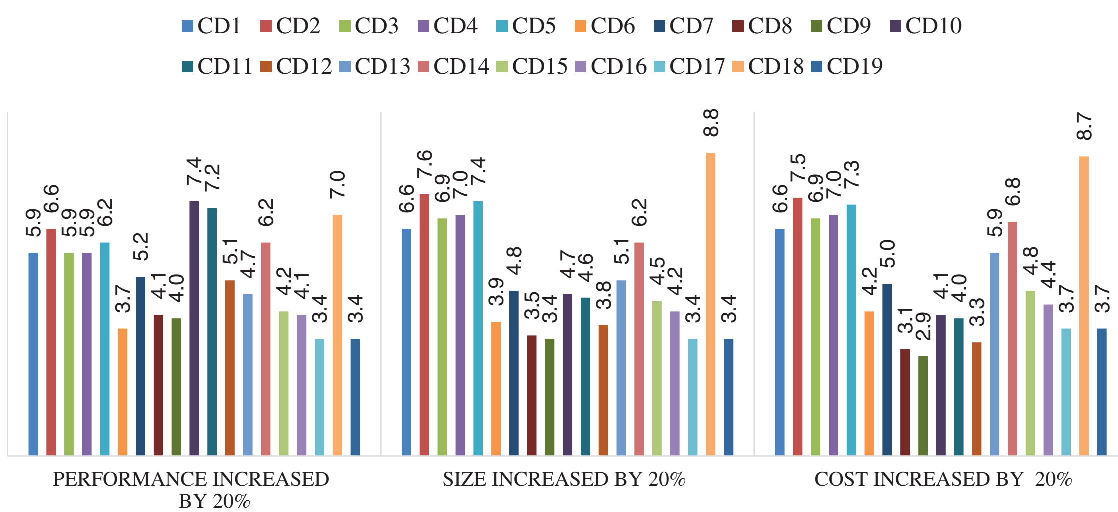
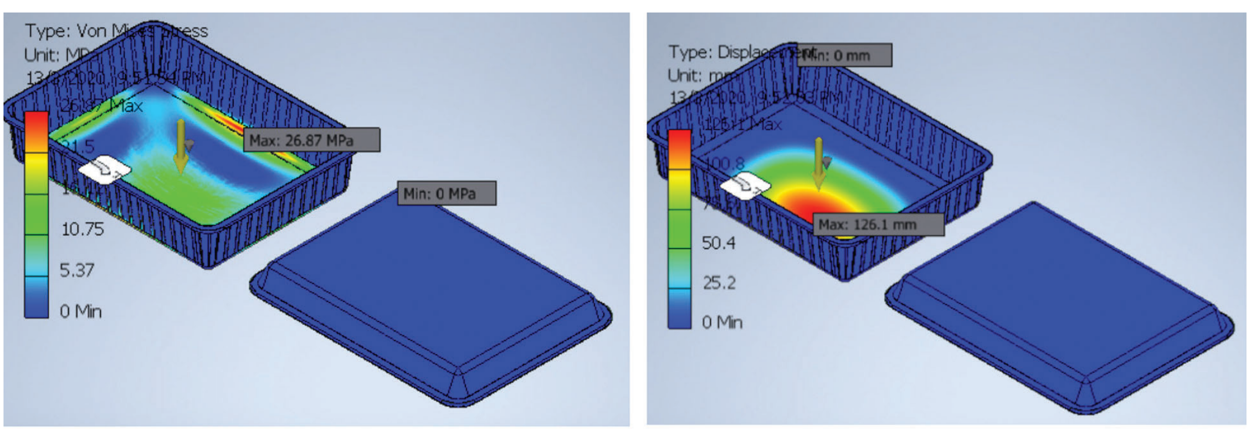


Figure 10: Summary of sensitivity analysis results on the selection of the final conceptual design

Table 9: Rank of concept design alternatives obtained after demonstrating three different scenarios of sensitivity analysis for different main criteria with respect to goal

Rank	Original results	Performance: Increased weight by 20%	Size: Increased weight by 20%	Cost: Increased by 20%
1	**CD18**	CD10	**CD18**	**CD18**
2	**CD2**	CD11	**CD2**	**CD2**
3	**CD5**	**CD18**	**CD5**	**CD5**
4	CD4	**CD2**	CD4	CD4
5	CD3	CD14	CD3	CD3
6	CD14	**CD5**	CD1	CD14
7	CD1	CD1	CD14	CD1
8	CD13	CD3	CD13	CD13
9	CD10	CD4	CD7	CD7
10	CD11	CD7	CD10	CD15
11	CD7	CD12	CD11	CD16
12	CD15	CD13	CD15	CD6
13	CD16	CD15	CD16	CD10
14	CD6	CD8	CD6	CD11
15	CD12	CD16	CD12	CD17
16	CD17	CD9	CD8	CD19
17	CD19	CD6	CD9	CD12
18	CD8	CD17	CD19	CD8
19	CD9	CD19	CD17	CD9



(a) (b)

Figure 11: (a) Stress distribution (von misses stress, VMS), and (b) Displacement for concept design 10 (CD10)

4 Conclusions

In conclusions, there were nineteen concept designs of NFBC (sugar palm fiber reinforced sago starch composite) takeout food container developed in this study. This development of NFBC takeout food container has gathered all the techniques that could satisfy the requirements from material characteristics and technical design specifications. A combination of Kano Model, QFDE, morphological chart and AHP could generate more conceptual designs for other type of packaging products that would assist designers to decide in the concept design selection process. The more conceptual designs developed, there will be less potential for the designers to repeat the same mistakes that may cause the same design failure. Additionally, more conceptual designs would lead to better discussion among design project team from different department throughout the product design process. In the process of picking the final NFBC takeout food container design, cost has higher weightage through the AHP pairwise comparison from the three main selection criteria namely performance, size and cost. The final conceptual design of the NFBC sugar palm fiber reinforced sago starch composite takeout food container that satisfied the design criteria was selected which has lower complexity and mass but strong enough to hold food contained. Concept design 18 (CD18) scored 8.3%, the highest priority score of all nineteen conceptual designs and has been verified with a sensitivity analysis. CD18 remain at top rank for two of three conditions tested. CD18 was a rectangular clamshell type with I-rib around the wall as well as bottom of container base, and its locking structure is a latching (male-female) type at its all four corners. Nevertheless, for actual production purposes, this final conceptual design chosen would need to go through more modifications and more thorough drawing. Nevertheless, the integrated Kano Model-QFDE-AHP approach has been shown to be able to carry out processes of idea creation, idea refining, concept design development and concept design selection, and offers a systematic and comprehensive concurrent engineering approach to achieve the desired solution. The strategy suggested in this paper will assist engineers/designers to generate ideas that are motivated by the satisfaction of customers as well as environmental issues and then choose the best design in the conceptual design process using a systemic approach and justified solutions of AHP.

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