

Awareness and attitude towards 3D food printing technology: the case of consumer responses from Klang Valley, Malaysia

Ng, W.E., Pindi, W., Rovina, K. and *Mantihal, S.

Faculty of Food Science and Nutrition, Universiti Malaysia Sabah, Jalan UMS 88400, Kota Kinabalu, Sabah

Article history:

Received: 16 July 2021

Received in revised form: 22 August 2021

Accepted: 6 December 2021

Available Online: 26 August 2022

Keywords:

3D food printing,

Consumer,

Awareness,

Attitude

DOI:

[https://doi.org/10.26656/fr.2017.6\(4\).530](https://doi.org/10.26656/fr.2017.6(4).530)

Abstract

This study aimed to investigate the Malaysian consumer response to 3D food printing. The objectives were to evaluate the awareness of consumers on 3D food printing and identify the factors that influence consumers' final attitude towards 3D food printing and assess consumers' change in attitude towards 3D food printing after being further informed about the technology. An online consumer survey was conducted in Klang Valley which involved 394 Malaysians of age between 24 to 55 years old. From the survey, the respondents showed a relatively low awareness of 3D food printing. Their initial attitudes toward the technology indicated a neutral (mean 3.99 ± 0.98) due to the lack of knowledge and experience on 3D food printing. Multiple linear regression analysis indicated that consumers' willingness to consume 3D printed food ($B = 0.397$) and their benefit perception towards 3D food printing ($B = 0.308$) significantly led to a positive attitude. Food technology neophobia ($B = -0.202$) and familiarity ($B = -0.180$) were the factors that significantly contributed to a negative attitude among the respondents. From the paired t-test, it was found that the respondents' overall attitude has improved significantly (mean 0.707 ± 0.904) with the aid of an infographic included in the survey as the medium for the respondents to know more about 3D food printing. This shows that information delivery is important in influencing consumers' attitudes towards 3D food printing. A well-designed communication strategy that is appropriate to the target consumers may be able to develop a positive response to 3D food printing among the consumers.

1. Introduction

Three-dimensional (3D) printing or known as additive manufacturing uses computer-aided design (CAD) software that instructs a digital fabricating machine to extrude materials layer by layer to produce 3D objects (Lupton and Turner, 2016). This disruptive and revolutionary technology contributed to the third industrial revolution potentially affecting the manufacturing industry, global supply chain and economy (Mohr and Khan, 2015). The 3D printing technology originated in the 1980s when it was initially intended for the prototyping industry (Savini and Savini, 2015). The application of 3D printing in food processing began about a decade ago (Brunner *et al.*, 2018). Currently, a 3D printer can be used to print out almost anything from prosthetic limbs and human organs to even food products (Manstan and McSweeney, 2020). In 3D food printing, the cartridges are filled with the 'ink', an edible ingredient that can be paste, puree, powder, dough, liquid, or gel forms. The ingredient can be made

from different types of food substances such as sugar, chocolate, fruits, vegetables, flour and animal proteins. It is then extruded through the nozzles onto the printer bed to generate edible substances in intricate designs (Mantihal *et al.*, 2019). Some of the common 3D-printed food products are chocolates, pancakes, pizza bases, biscuits, bread and pasta (Lupton and Turner, 2016). Post-printing treatments such as freezing, baking and frying can be used to manipulate the product further to make them edible or to set their structure (Manstan and McSweeney, 2020).

The demand for customised food is increasing as consumers are searching for healthy options that do not compromise food flavour. 3D food printing provides a solution that satisfies this demand as it is a way to distribute food in a personalized manner (Mantihal *et al.*, 2020; Pant *et al.*, 2021). The application of 3D food printing has brought the food industry into the digital age. This technology has made it possible for fast automated and repeatable processing methods. Besides,

*Corresponding author.

Email: s.mantihal@ums.edu.my

it allows freedom in design as well as large and easy variability of the cooking process which is customisable (Pallottino *et al.*, 2016). With the usage of a robotic layer-based printing system, food recipes can be digitised and saved to produce highly repeatable and quality dishes with minimal to no margin of operator error (des Aufsatzes *et al.*, 2013). Moreover, this technology can create new, customised and personalised foods (Mantihal *et al.*, 2019). The specific amount of nutrients can be incorporated to meet the consumer's nutritional preference, and accommodate allergies, intolerance and other nutritional conditions. Not only that, the usage of 3D food printing can reduce food waste by printing only the amount of food required and utilising ingredients that are usually being thrown away such as bruised fruits or defective vegetables (Manstan and Sweeney, 2020).

Although 3D food printing provides many possible uses and benefits, consumers need to be able to accept the new food and its processing method first in order for this technology to thrive in the food industry. As a competitive and innovative industry, there is a high chance of product failure and market withdrawals in the food industry (Bruhn, 2007; Dijksterhuis, 2016). 3D food printing is undeniable a novel technology and consumers usually perceived new technology with suspicion (Popa and Popa, 2012). This may lead to consumers rejecting the new food technology because of mistrust. Consumers may associate novel foods with danger such as negative reactions and toxicity, making them avoiding to eat novel foods (Martin and Pliner, 2006). Food and food technology neophobia which is the fear of trying new food and food technology may hinder consumers from consuming 3D-printed food or attempting to consume 3D food printing (Brunner *et al.*, 2018; Manstan and McSweeney, 2020). Also, consumers may refuse to accept 3D food printing because they are anxious about the new technology (Jaeger *et al.*, 2015; Brunner *et al.*, 2018). Consumers are less likely to accept the new food technology and the food produced as they may be unfamiliar with it (Manstan, 2018). The sense of unfamiliarity with the processing method as well as the ingredients may lead to consumers' concerns about the safety of the 3D printed product (Lupton and Turner, 2018).

However, not all new technology or product triggers uncertainties and rejection among the consumers. The evaluation process of acceptance is highly influenced by the technology itself (Frewer *et al.*, 2011) and the individual's knowledge background (Greenhy *et al.*, 2013). This means that the awareness of the new technology plays an important role in the 3D food printing technology being accepted. In addition, consumers' acceptance can also be heightened by other

factors such as convenience, improved flavour and health benefits aspects of the novel food technology (Bruhn, 2007; Rollin *et al.*, 2011). Exposure to novel technology and food may encourage a positive attitude among consumers. The actual presentation of the 3D food printing demonstration contributed to consumers' awareness and knowledge which led to benefit perception (Mantihal *et al.*, 2019). As consumers are introduced and exposed to novel food, their initial attitudes and beliefs about that food can change (Manstan, 2018).

Currently, there are limited studies that focus on the perception of consumers towards 3D printed food and responses towards this technology. Several researchers studied the application of 3D printing in creating different types of food products (Godoi *et al.*, 2019) but there has been not much study on evaluating consumers' opinions on 3D food printing (Manstan and McSweeney, 2020). An in-depth study of consumers' attitudes toward this new food technology will evaluate the potential of new food concepts and identify potential customers (Brunner *et al.*, 2018). Hence, the assessment of consumers' perception, needs and fears are relevant when marketing such innovations (Frewer *et al.*, 2011).

3D food printing is relatively a new technique in Malaysia's food industry. Therefore, this research aimed to study the Malaysian consumer response to 3D food printing through a quantitative survey in order to fill the current knowledge gap. From the survey, consumers' awareness and changes in attitude towards 3D food printing after being further informed about the technology are assessed while factors affecting consumers' attitudes are also determined. This study will provide an insight into the acceptance of Malaysian consumers toward novel food technology, thus contributing to the development of an appropriate marketing strategy to introduce this technology in the market.

2. Materials and methods

An online consumer survey was carried out through a self-administered questionnaire using Google Form to obtain consumer responses to 3D food printing. The questionnaire was distributed through social media platforms and word of mouth to Malaysians aged between 24 to 55 years old and residing in Klang Valley. A total of 394 respondents were obtained for this study. The socio-demographic aspects of the respondents are shown in Table 1.

2.1 Questionnaire

The questionnaire consisted of five sections. Section

Table 1. Socio-demographic aspects of respondents

Aspects	Number of Respondents	Percentage (%)
Age		
24 – 29	206	52%
30 – 39	98	25%
40 – 49	61	16%
50 – 55	29	7%
Gender		
Male	167	42%
Female	227	58%
Race		
Malay	162	41%
Chinese	148	38%
Indian	54	14%
Others	30	7%
Highest Education Level		
Primary	1	< 1%
Secondary	47	12%
Pre-university	44	11%
Undergraduate	252	64%
Postgraduate	50	13%

A was the respondents' socio-demographic profile. Respondent's awareness of 3D food printing was asked in section B as the respondents have to indicate their level of awareness using a six-point Likert scale ranging from 1 = 'strongly disagree' to 6 = 'strongly agree'. Next, a short paragraph introducing 3D food printing was provided at the beginning of section C. The respondents' initial attitudes towards the technology were assessed. They were asked whether they think 3D food printing is good, important, to be supported and positive using the six-point Likert scale. An infographic on 3D food printing was then presented to inform the respondents about the technology further as shown in Figure 1. The representative image and brief descriptions of a 3D food printer, 3D printed foods as well as the usage and benefits of 3D food printing were included in the infographic. Section D consisted of various statements related to the factors affecting consumers' attitudes towards 3D food printing which are benefit perception, willingness to consume, food familiarity, food neophobia and food technology neophobia. These factors were chosen to be analysed in this study based on the insights from previous research by Lupton and Turner (2016), Brunner *et al.* (2018) and Manstan and McSweeney (2020). In this section, respondents were also required to indicate their notions towards the statements provided by utilising the six-point Likert scale. Lastly, respondents' final attitudes towards 3D food printing were assessed in section E. The identical construct (as in section C) was applied in this section. However, respondents were considering the newly gained knowledge of the technology. As ethical

consideration, consent from the respondent was required prior to participating in the survey. Respondents; names were not recorded on the survey document to keep personal information confidential. Details about the items and sources of the questionnaire are summarised in Table 2.

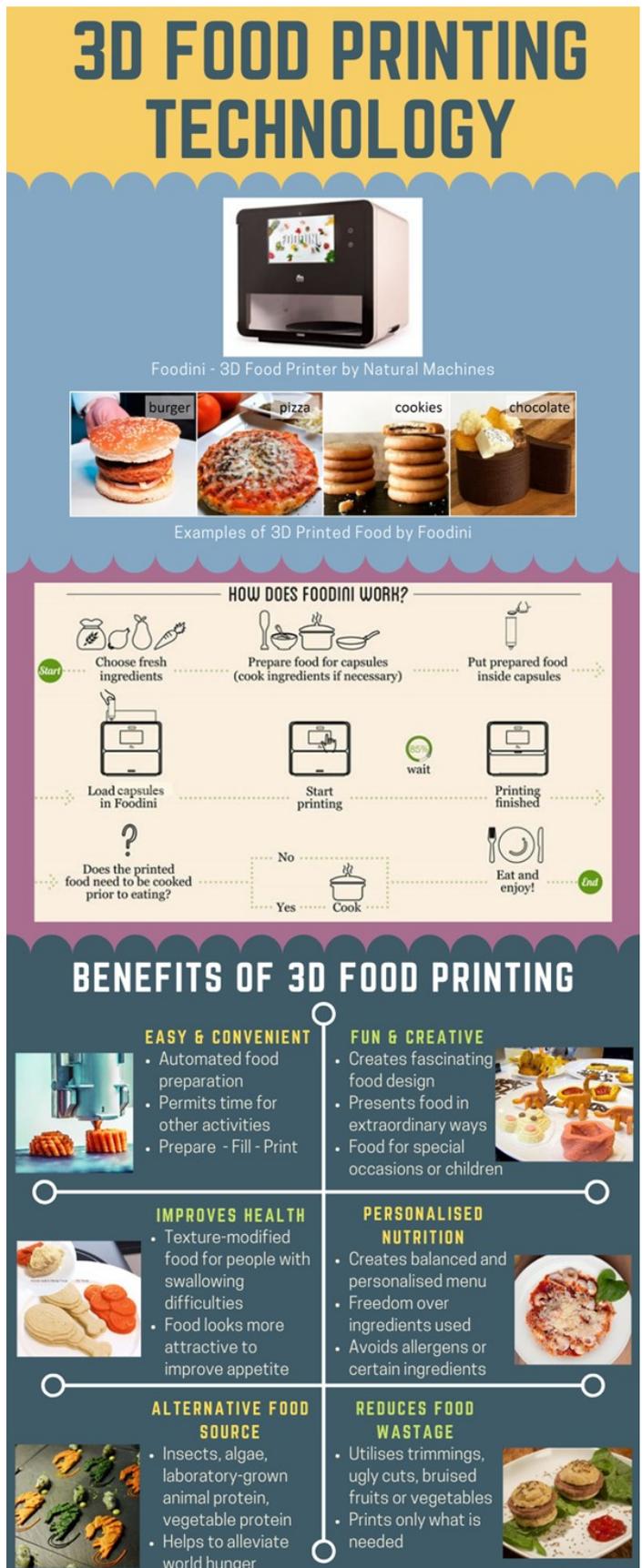


Figure 1. Infographic on 3D food printing

Table 2. Items and sources of a questionnaire

Items	Source
1 Socio-Demographic - Age - Gender - Race - Highest Education Level	-
2 Awareness - Already heard or read about 3D food printing - Roughly know how a 3D printer works - Dealt with 3D food printing before - Consumed 3D-printed food before	Brunner <i>et al.</i> (2018)
3 Initial Attitude: I think that 3D food printing is generally... - Good - Important - To be supported - Positive	Brunner <i>et al.</i> (2018)
4 Benefit Perception: 3D food printing can... - Produce food easier and more convenient - Produce food to meet the dietary needs of people with health issues - Design food with personalised nutritional needs - Help to reduce food wastage	Brunner <i>et al.</i> (2018), Manstan and McSweeney (2020)
5 Willingness to Consume: I have no trouble consuming 3D-printed food because it is... - Safe to consume - Beneficial to health - A fun experience - Not disgusting	Brunner <i>et al.</i> (2018), Manstan and McSweeney (2020)
6 Food Familiarity: It is important to me that... - The food to be eaten is what I usually eat - I am familiar with the food to be eaten - The food to be eaten is similar to the food I ate during my childhood	Brunner <i>et al.</i> (2018)
7 Food Neophobia - Afraid to eat food that I have never eaten before - Will not try a new food if I do not know what is in it - Do not trust new food - Do not like trying out new and different food	Brunner <i>et al.</i> (2018)
8 Food Technology Neophobia - Do not need new food technology because there is already much tasty food around - Benefits of new food technology are always overstated - New food technology reduces the natural quality of food - Will not try out high-tech food products because the ones I eat are already good enough	Brunner <i>et al.</i> (2018)
9 Final Attitude: After knowing more about the technology, I think that 3D food printing is generally... - Good - Important - To be supported - Positive	Brunner <i>et al.</i> (2018)

2.2 Data analysis

Statistical Package for Social Sciences (SPSS), version 27 software was used to perform statistical data analysis. Descriptive analysis was done to obtain the mean and standard deviation for the items representing respondents' awareness of 3D food printing. Next, multiple linear regression analyses were conducted to test the strength of the effect of each factor in affecting consumers' overall final attitude towards 3D food printing. Descriptive analysis was used to obtain the mean and standard deviation of each of the four items representing consumers' initial and final attitudes. The significant changes in consumers' attitudes towards 3D food printing after being further informed about the

technology were measured using paired t-test at a level of significance, $\alpha = 0.05$.

3. Results and discussion

3.1 Consumer awareness on 3D food printing

Table 3 shows the measures of awareness level of the respondents toward 3D food printing technology. As shown in the table, the respondents' awareness level on 3D food printing is relatively low. Their knowledge of the technology is lacking (mean 3.29 ± 1.37) and they have less experience on 3D food printing (mean 1.41 ± 0.79). This is because the 3D food printing technology is still in its infancy stage and Malaysians

Table 3. Measures of awareness level towards 3D food printing

Awareness	Mean	SD
Knowledge:	3.29	1.37
Already heard or read about 3D food printing	3.29	1.68
Roughly know how a 3D printer works	3.29	1.36
Experience:	1.41	0.79
Already dealt with 3D food printing before	1.39	0.83
Consumed 3D-printed food before	1.43	0.97

were not exposed to this technology yet. 3D printing is more common in the non-food industry such as medical and engineering than in the food industry. Moreover, 3D food printers and 3D printed food are not available to the end consumers in Malaysia thus, the respondents would not have direct experience with technology or the product. It is expected that the respondents show low awareness of 3D food printing, similarly to previous studies conducted by Lupton and Turner (2016) in Australia and Brunner *et al.* (2018) in Switzerland. Both studies reported that the respondents showed little knowledge and experience on 3D food printing due to the same reason which was the technology and product itself were nearly not available to the end consumers (Lupton and Turner, 2016; Brunner *et al.*, 2018).

3.2 Factors affecting consumers' final attitudes

Multiple linear regressions were conducted to assess the factors affecting consumers' final attitudes towards 3D food printing. The results of the normality, homoscedasticity and collinearity tests showed that the data were suitable for the analysis. Among the eleven factors analysed, four factors were identified to significantly affect consumers' final attitudes at a significant level, $p < 0.05$ as shown in Table 4. Consumer's willingness to consume 3D printed product ($B = 0.397$) and benefit perception of 3D food printing technology ($B = 0.308$) led to a positive attitude whereas

food technology neophobia ($B = -0.202$) and familiarity ($B = -0.180$) indicated a negative attitude. This model indicated 56.7% of the variance in consumers' final attitudes, of which the F-ratio shows that the regression model is a good fit for the data. Likewise, Brunner *et al.* (2018) indicated that the willingness to consume ($B = 0.27$) and benefit perception ($B = 0.19$) were also strong predictors of positive attitudes among the informed respondents. In contrast, food technology neophobia ($B = -0.38$) significantly contributed to a negative attitude. Moreover, Lupton and Turner (2016) concluded that familiarity with the technology could enhance consumers' acceptability of 3D-printed food. When consumers are familiar with the processing method and ingredients used as well as being assured of the food quality and safety concerns, they will be able to accept 3D food printing (Lupton and Turner, 2016).

3.2.1 Willingness to consume 3D printed product

In this study, a concise explanation and images associated with the benefits and applications of 3D food printing were provided in the form of the infographic as a medium of information regarding the technology somewhat a promising tool aiding in increasing the respondents' willingness to consume 3D printed food, thus leading to a positive attitude towards the technology. Information on the benefits of a new food technology may reduce the unfavourable perception of the technology, contributing to the acceptance and willingness to consume the food product (Bruhn, 2007). Consumers' acceptance of technology may also be contributed by the feeling of joy and pleasure when they have the opportunity to utilise the technology (Kulviwat *et al.*, 2007). Table 5 shows the measures of motivation of consumers' willingness to consume 3D printed food. Based on Table 5, enjoyable experience has achieved the highest mean score (4.70 ± 1.081) as the motivation for the respondents' willingness to consume 3D printed

Table 4. Multiple linear regressions analysis factors affecting consumers' final attitudes

Factors	B	95% CI	Std. Error B	β	p
Constant	2.531	(1.594, 3.468)	0.477		0.000
Age Group	-0.063	(-0.029, 0.154)	0.047	0.058	0.180
Gender	0.069	(-0.080, 0.217)	0.076	0.033	0.364
Race	0.007	(-0.070, 0.084)	0.039	0.006	0.854
Highest Education Level	-0.040	(-0.135, 0.055)	0.048	-0.32	0.406
Knowledge	0.038	(-0.065, 0.121)	0.030	0.050	0.210
Experience	0.028	(-0.065, 0.121)	0.047	0.021	0.555
Benefit Perception	0.308	(0.191, 0.426)	0.060	0.229	0.000
Willingness to Consume	0.397	(0.290, 0.505)	0.055	0.355	0.000
Familiarity	-0.180	(-0.252, -0.109)	0.036	-0.212	0.000
Food Neophobia	-0.023	(-0.112, 0.066)	0.045	-0.022	0.616
Food Tech. Neophobia	-0.202	(-0.300, -0.104)	0.050	-0.185	0.000

Notes: $R^2 = 0.567$, $F(11, 382) = 45.383$, $p < 0.05$

food. 3D food printing potentially offers an exciting opportunity for the consumers to engage in the creation of their own food experiences where the designing process is guided by digital tools and the production is handled by the printing technology (Gayler *et al.*, 2018). This shows that the enjoyable experience associated with 3D food printing contributed to the respondents' willingness to consume 3D printed food which then led to a positive attitude toward 3D food printing as suggested by Brunner *et al.* (2018).

Table 5. Measures of motivations for consumers' willingness to consume 3D printed food

Motivation	Mean	SD
Safe to consume	4.44	1.020
Beneficial to health	4.38	0.958
Enjoyable experience	4.70	1.081
Not disgusting	4.44	1.097

3.2.2 Benefit perception

The information regarding the promising application and benefits of 3D food printing included in the infographic was able to convince the respondents about the usefulness of the technology. Most of the respondents agreed that 3D food printing can aid to produce food efficiently and more convenient besides being capable to utilise the nutritional needs of people with health issues and is a promising tool to reduce food wastage (Dick *et al.*, 2021). These benefit perceptions contributed to a positive attitude on 3D food printing among the respondents. Brunner *et al.* (2018) also showed that benefit perception contributed to a positive attitude on 3D food printing. The study (260 residents from Switzerland ranging from 18 to 80 years old) reported that the benefit perception of 3D food printing in terms of fun, convenience, health and nutrition were relevant to promote the technology to the early adopters (Brunner *et al.*, 2018). Consumer acceptance of a novel technology was crucially affected by the perception of benefits. Consumers may doubt the need for and the benefits of a novel food technology when there is a lack in benefit perception. As the benefit is the firm predictor of consumer acceptance, other factors such as the perceived risks and morals regarding the novel food technology may be a concern (Gaskell, 2000; Siegrist, 2008; Rollin *et al.*, 2011).

3.2.3 Food technology neophobia

The present study showed that food technology neophobia affects consumers' attitudes negatively ($B = -0.202$) as shown in Table 4. Food technology neophobia is the perception of resistance to foods produced by a new food production or processing technology (Seur *et al.*, 2015). Thus, food technology neophobia is one of the possible drivers of rejection for 3D food printing

(Brunner *et al.*, 2018; Tuorila and Hartmann, 2020). The elements of foreignness, unnaturalness and wariness associated with the new food technology can be the reasons for fear of that food technology (Lupton and Turner, 2016; Tuorila and Hartmann, 2020). Due to the limited knowledge and experience on 3D food printing, consumers do have not much clue about the technology as well as the product. Consumers still view 3D food printing suspiciously as it is a novel technology in Malaysia's food industry. Thus, the respondents are uncertain whether this technology and its product are genuinely safe and edible. 3D food printing might also be considered unnatural because it is a highly-processed food production method with the utilisation of digital data and high technology than that of conventional food processing. The lack of naturalness and perceived quality could intrigue the fear of unknown risks associated with 3D food printing (Lupton and Turner, 2016; Tuorila and Hartmann, 2020). In addition to that, the idea of associating 3D printing with food production may be hard for people to accept as 3D printing technology is more commonly associated with non-food production (Lupton and Turner, 2016).

3.2.4 Familiarity

The factor of familiarity significantly contributed to the respondents' negative attitudes toward 3D food printing ($B = -0.180$) as shown in Table 4. Manstan (2018) and Lupton and Turner (2016) suggested that the unfamiliarity with the technology among consumers contributed to a negative attitude towards 3D food printing. As consumers are unfamiliar with a certain food technology or food product, they are more likely to reject it (Tuorila and Hartmann, 2020). 3D food printing is a new concept of producing food in layer-by-layer motion. Hence, 3D food printing seems to be an unfamiliar food processing method in Malaysia, where not many people have knowledge or experience of it. 3D food printing also utilises alternative ingredients such as insects and laboratory-grown animal protein (Lupton and Turner, 2016), which this material is unacceptable to most Malaysians. The usage of unfamiliar ingredients may cause dislike and repulsion among potential consumers. Although there are strong environmental and health claims that support the value of such alternative ingredients, these ingredients may still be resisted as food options by people who traditionally view insects or "fake meat" as non-food (Lupton and Turner, 2018). On the other hand, the sense of familiarity will allow consumers to be certain of what the food is and thus reducing their anxiety and suspicion of the food (Aldridge *et al.*, 2009).

3.3 Consumers' attitudes towards 3D food printing

Table 6 shows the attitude measures for both the initial and final attitudes of the respondents towards 3D food printing. Respondent's initial attitudes toward 3D food printing can be considered neutral with a mean of 3.99 ± 0.98 . They only showed slight agreement that the technology is good, to be supported and positive but is slightly unimportant. The lack of knowledge among consumers on innovative and emerging food technologies such as 3D food printing can be a barrier to their acceptance of the technology (Cardello *et al.*, 2007). Also, the lack of information and exposure will negatively impact consumers' attitudes towards 3D food printing (Brunner *et al.*, 2018). The respondents were neither very positive nor very negative about 3D food printing as they were unsure about the processing method, its potential benefits and the final product produced. After learning more about the technology through the infographic provided in the questionnaire, it can be noticed that there was a positive change in consumers' attitudes towards the technology. The overall final attitude has a mean of 4.70 ± 1.04 , indicating the respondents' positive attitude towards 3D food printing (agreed that 3D food printing is good, important, to be supported and positive).

Table 6. Measures of consumers' attitudes towards 3D food printing

Consumer Attitude	Mean	SD
Initial Attitude	3.99	0.98
I think that 3D food printing is generally...		
Good	4.00	1.06
Important	3.80	1.06
To be supported	4.06	1.07
Positive	4.10	1.05
Final Attitude	4.70	1.04
After knowing more about this technology,		
3D food printing is generally...		
Good	4.74	1.07
Important	4.52	1.12
To be supported	4.74	1.08
Positive	4.79	1.10

Results of the paired t-test showed a significant ($\alpha = 0.05$) improvement in consumers' attitude toward 3D food printing as shown in Table 7. The exposure in terms of information provided in the survey helped to improve

consumers' attitudes towards 3D food printing. The results of the present study corroborated with Brunner *et al.* (2018). There was also a positive change in attitude after the respondents were assessed a second time while taking the gained knowledge into account during the reassessment (Brunner *et al.*, 2018). The respondents had gained knowledge from the infographic included in the questionnaire, which significantly affected their attitudes and improved their overall perception of 3D food printing, with an overall attitude improvement of 0.707 ± 0.904 . The respondents were exposed to 3D food printing through information delivery using images and descriptions. The infographic displayed a 3D food printer named Foodini produced by the company Natural Machines and pictures of food printed by Foodini and a simple flowchart of how Foodini works. Moreover, brief descriptions and pictures of the benefits of 3D food printing were also shown in the infographic. The information gained allows the respondents to readjust their initial thoughts and impressions on 3D food printing before assessing their final attitude on the technology at the end of the survey.

Based on the multiple linear regression analysis results, consumers' willingness to consume 3D printed food ($B = 0.397$) and their benefit perception on 3D food printing ($B = 0.308$) are the significant factors that contributed to the positive attitude. This result revealed that the infographic information has convinced most of the respondents of the usefulness of the 3D food printing technology. The respondents also showed their willingness to consume the 3D printed product. On the other hand, food technology neophobia ($B = -0.202$) and familiarity ($B = -0.180$) are the factors that significantly contributed to the negative attitude. As 3D food printing is new and not widely known in Malaysia, it is not surprising that the respondents had some fear of such unfamiliar food technology and food product. Although the infographic contributed to the respondents' willingness to consume and benefit perception, it was not sufficient to overcome the respondents' sense of fear and unfamiliarity with the technology. This could be the reason for the low improvement in respondents' attitudes towards 3D food printing.

4. Conclusion

The present research attempts to study Malaysia's

Table 7. Changes in consumers' attitudes towards 3D food printing

Changes in Attitude	Mean	SD	Std. Error Mean	95% CI	t	df	p
Good	-0.741	1.008	0.051	(-0.841, -0.641)	-14.589	393	0.000
Important	-0.718	1.060	0.053	(-0.823, -0.613)	-13.448	393	0.000
To be Supported	-0.680	0.983	0.050	(-0.778, -0.583)	-13.736	393	0.000
Positive	-0.688	0.974	0.049	(-0.784, -0.591)	-14.022	393	0.000
Overall Attitude	-0.707	0.904	0.046	(-0.796, -0.617)	-15.521	393	0.000

consumer response to 3D food printing technology. In this study, the respondents displayed a low awareness of 3D food printing, which led to an initial neutral attitude towards the technology. This is due to the lacking of knowledge and no exposure to that technology. Respondents' willingness to consume 3D printed food and their benefit perception towards the technology indicated a positive attitude, while a negative attitude was contributed by food technology neophobia and unfamiliarity. Interestingly, the respondents' attitudes improved significantly with the aid of the infographic included in the survey as the medium for the respondents to have an idea about 3D food printing. This shows that information delivery is important in developing consumers' responses to 3D food printing. An appropriate communication strategy can build a positive attitude among the target consumers. For instance, the information delivered should focus on enhancing the target market's benefit perception on 3D food printing and increasing their willingness to consume 3D printed food and providing assurance to dismiss their sense of fear and unfamiliarity with 3D food printing. Therefore, the information will be able to influence the consumers in accepting 3D food printing. Also, it is suggested that a real-life representation such as a display of 3D food printers and 3D printed food samples and 3D printed food tasting could be utilised to further inform the respondents in the public domain.

Conflict of interest

The authors declare no conflict of interest.

References

- Aldridge, V., Dovey, T.M. and Halford, J.C. (2009). The Role of Familiarity in Dietary Development. *Developmental Review*, 29(1), 32-44. <https://doi.org/10.1016/j.dr.2008.11.001>
- Bruhn, C.M. (2007). Enhancing Consumer Acceptance of New Processing Technologies. *Innovative Food Science and Emerging Technologies*, 8(4), 555-558. <https://doi.org/10.1016/j.ifset.2007.04.006>
- Brunner, T.A., Delley, M. and Denkel, C. (2018). Consumers' Attitudes and Change of Attitude toward 3D-printed Food. *Food Quality and Preference*, 68, 389-396. <https://doi.org/10.1016/j.foodqual.2017.12.010>
- Cardello, A.V., Schutz, H.G. and Leshner, L.L. (2007). Consumer Perceptions of Foods Processed by Innovative and Emerging Technologies: A Conjoint Analytic Study. *Innovative Food Science and Emerging Technologies*, 8(1), 73-83. <https://doi.org/10.1016/j.ifset.2006.07.002>
- des Aufsatzes, V., Gebharfdt, A. and Fateri, M. (2013). 3D Printing and its Applications. *Journal für Rapid Technologien*, 2013, 0009-2-35626
- Dick, A., Prakash, S. and Bhandari, B. (2021). 3D Printing. In Pathania, S. and Tiwari, B.J. (Eds.) *Food Formulation: Novel Ingredients and Processing Techniques*, p. 101-119. United Kingdom: John Wiley and Sons Ltd. <https://doi.org/10.1002/9781119614760.ch6>
- Dijksterhuis, G. (2016). New Product Failure: Five Potential Sources Discussed. *Trends in Food Science and Technology*, 50, 243-248. <https://doi.org/10.1016/j.tifs.2016.01.016>
- Frewer, L.J., Bergaman, K., Brennan, M., Lion, R., Meertens, R., Rowe, G., Siegrist, M. and Vereijken, C. (2011). Consumer Response to Novel Agri-food Technologies: Implications for Predicting Consumer Acceptance of Emerging Food Technologies. *Trends in Food Science and Technology*, 22(8), 442-456. <https://doi.org/10.1016/j.tifs.2011.05.005>
- Gaskell, G. (2000). Agricultural Biotechnology and Public Attitudes in the European Union. *AgBioForum*, 3(2 and 3), 87-96.
- Gayler, T., Sas, C. and Kalnikaite, V. (2018). User Perceptions of 3D Food Printing Technologies. In Proceedings of CHI'18: Extended Abstracts of the 2018 CHI Conference on Human Factors in Computing Systems, p. 1-6. ACM Digital Library. <https://doi.org/10.1145/3170427.3188529>
- Godoi, F., Bhandari, B.R., Prakash, S. and Zhang, M. (2019). *Fundamentals of 3D Food Printing and Applications*. London, United Kingdom: Academic Press.
- Greenhy, G., McCarthy, M.B., Henchion, M.M., Dillon, E.J. and McCarthy, S.N. (2013). Complexity and Conundrums: Citizens' Evaluations of Potentially Contentious Novel Food Technologies Using a Deliberative Discourse Approach. *Appetite*, 70(12), 37-46. <https://doi.org/10.1016/j.appet.2013.06.083>
- Jaeger, H., Knorr, D., Szabo, E., Hamori, J. and Banati, D. (2015). Impact of Terminology on Consumer Acceptance of Emerging Technologies through the Example of PEF Technology. *Innovative Food Science and Emerging Technologies*, 29, 87-93. <https://doi.org/10.1016/j.ifset.2014.12.004>
- Kulviwat, S., Brunner, I.I., Gordon, C., Kumar, A., Nasco, S.A. and Clark, T. (2007). Toward a Unified Theory of Consumer Acceptance Technology. *Psychology and Marketing*, 24(12), 1059-1084. <https://doi.org/10.1002/mar.20196>
- Lupton, D. and Turner, B. (2016). 'Both Fascinating and Disturbing': Consumer Responses to 3D Food

- Printing and Implications for Food Activism. In Schneider, T., Eli, K., Dolan, C. and Ulijaszek, S. (Eds.) *Digital Food Activism*. London, United Kingdom: Routledge. <https://doi.org/10.4324/9781315109930-8>
- Lupton, D. and Turner, B. (2018). Food of the Future? Consumer Responses to the Idea of 3D-Printed Meat and Insect-Based Foods. *Food and Foodways*, 26(4), 269-289. <https://doi.org/10.1080/07409710.2018.1531213>
- Manstan, T. (2018). The Future is Now: Consumer Perceptions Towards 3D Printed Foods and Technology. Canada: Acadia University, BSc. Thesis.
- Manstan, T. and McSweeney, M.B. (2020). Consumers' Attitudes towards and Acceptance of 3D Printed Foods in Comparison with Conventional Food Products. *International Journal of Food Science and Technology*, 55(1), 323-331. <https://doi.org/10.1111/ijfs.14292>
- Mantihal, S., Kobun, R. and Lee, B.B. (2020). 3D Food Printing as the New Way of Preparing Food: A Review. *International Journal of Gastronomy and Food Science*, 22, 100260. <https://doi.org/10.1016/j.ijgfs.2020.100260>
- Mantihal, S., Prakash, S. and Bhandari, B. (2019). Texture Modified 3D Printed Dark Chocolate: Sensory Evaluation and Consumer Study. *Journal of Texture Studies*, 50(5), 386-399. <https://doi.org/10.1111/jtxs.12472>
- Martin, Y. and Pliner, P. (2006). "Ugh! That's Disgusting!": Identification of the Characteristics of Foods Underlying Rejections based on Disgust. *Appetite*, 26(1), 75-85. <https://doi.org/10.1016/j.appet.2005.09.001>
- Mohr, S. and Khan, O. (2015). 3D Printing and its Disruptive Impacts on Supply Chains of the Future. *Technology Innovation Management Review*, 5(11), 20-25. <https://doi.org/10.22215/timreview/942>
- Pallottino, F., Hakola, L., Costa, C., Antonucci, F., Figorilli, S., Seisto, A. and Menesatti, P. (2016). Printing on Food or Food Printing: A Review. *Food Bioprocess Technology*, 9(5), 725-733. <https://doi.org/10.1007/s11947-016-1692-3>
- Pant, A., Lee, A.Y., Karyappa, R., Lee, C.P., An, H., Hashimoto, M. and Zhang, Y. (2021). 3D Food Printing of Fresh Vegetables using Food Hydrocolloids for Dysphagic Patients. *Food Hydrocolloids*, 114, 106546. <https://doi.org/10.1016/j.foodhyd.2020.106546>
- Popa, M.E. and Popa, A. (2012). Consumer Behaviour: Determinants and Trends in Novel Food Choice. In McElhatton, A. and Sobral, P.J.D.A. (Eds.) *Novel Technologies in Food Science: Their Impacts on Products, Consumer Trends and the Environment*, p. 137-156. New York, USA: Springer. https://doi.org/10.1007/978-1-4419-7880-6_6
- Rollin, F., Kennedy, J. and Willis, J. (2011). Consumers and New Food Technologies. *Trends in Food Science and Technologies*, 22(2-3), 99-111. <https://doi.org/10.1016/j.tifs.2010.09.001>
- Savini, A. and Savini, G.G. (2015). A Short History of 3D Printing, a Technological Revolution Just Started, presented at the International History of High-technologies and their Socio-cultural Contexts Conference, 18 – 19 August., p. 1-8. Israel: Tel-Aviv University. <https://doi.org/10.1109/HISTELCON.2015.7307314>
- Seur, H., Odongo, W. and Gellynck, X. (2015). Applying the Food Technology Neophobia Scale in a Developing Country Context: A Case-Study on Processed Mattoke (Cooking Banana) Flour in Central Uganda. *Appetite*, 96, 391-398. <https://doi.org/10.1016/j.appet.2015.10.009>
- Siegrist, M. (2008). Factors Influencing Public Acceptance of Innovative Food Technologies and Products. *Trends in Food Science and Technology*, 19(11), 603-608. <https://doi.org/10.1016/j.tifs.2008.01.017>
- Tuorila, H. and Hartmann, C. (2020). Consumer Responses to Novel and Unfamiliar Foods. *Current Opinion in Food Science*, 33, 1-8. <https://doi.org/10.1016/j.cofs.2019.09.004>