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Sensory evaluation of ultrasound assisted microwave treated fruit (*Haematocarpus validus)* juice through fuzzy logic approach

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Abstract

Khoonphal (Haematocarpus validus) is an underutilised fruit with a delicately flavoured juice considered to have therapeutic properties. The present work aimed to evaluate the overall acceptability of the juice after different treatments using the fuzzy logic approach. The effects of ultrasound, microwave and conventional thermal treatment on sensory attributes were studied. Twenty trained panellists were considered for the sensory evaluation of the juice samples. Results from the fuzzy modelling showed that sample 4 (ultrasound assisted microwave treated sample) was the most acceptable and ranked as "very good" as compared to the other samples. The ranking of the juice samples in the increasing order of acceptability was $T_4 > T_3 > T_1 > T_2$ while the rank order of the quality attributes was colour > taste > flavour > mouth Feel. The results of the quality attributes showed that the highest importance was obtained for colour while the least was for mouth feel.

Introduction

Haematocarpus validus Bakh.f. (Menispermaceae), locally called *tehpattang* / *khoonphal* / blood fruit / *garo* grapes, is a wild edible fruit commonly consumed by the tribal people of Meghalaya when ripen (Rahim *et al*., 2015). *Khoonphal* is endangered and was rediscovered after a long gap in Indo-Myanmar bordering areas (Singh and Bedi, 2016). *Khoonphal* only grow in specific parts of India, Indo-Bangladesh, and Indo-Myanmar border areas while their main distribution lies in West Garo Hills, Meghalaya, in North-Eastern India. This region is located at latitude 25°34' N and longitude 90°13' E at an elevation of 1,394 feet. *Khoonphal* is reservoir to functional phytochemicals, which are used as ethno-medicines by different tribes of Meghalaya. *Khoonphal* is commonly used to treat jaundice, cancer, hypertension, arthritis, neurological problems and many other ailments (Biswas *et al*., 2010). Owing to the lack of scientific exploration of *khoonphal*, there is little being done for the development of value-added products by using *khoonphal* juice / concentrate / extract. The post-harvest losses are huge when it comes to *khoonphal*, which is a great waste in terms of its nutrition, medicinal and therapeutic values, and food security for the local society.

Preliminary research has been conducted on *khoonphal* in India (Meghalaya; Andaman and Nicobar Island) and Bangladesh in order to study the morphology, and nutritional and phytochemical characterisation (Singh *et al*., 2014). The effect of ultrasound treatment on post-harvest quality parameters have been studied from ripe *khoonphal* of Meghalaya (Sasikumar *et al*., 2017). Other studies have shown that *khoonphal* is a rich source of vitamin C and minerals (Singh *et al*., 2014; Rahim *et al*., 2015). Ripe *khoonphal* is dark purple in colour, and its juice is dark purple or blackish in colour and has an acceptable flavour, sweet acidic taste and smooth mouth feel. *Khoonphal* is a rich source of anthocyanins (3, 4-dihydroxyphenyl), hydroxycitric acid, iron, and other anti-cancer properties. Anthocyanins are known to show antioxidant, anti-inflammatory, and anti-carcinogenic activities. *Khoonphal* extract may

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be used in the preparation of natural food colourant, therapeutic drinks for anaemic people and lipsticks (Ikram *et al*., 2009; Haque *et al*., 2009).

Khoonphal juice has gained importance due to their nutritional composition and health promoting effects. However, there are no reported studies for the preparation of therapeutic beverages from *khoonphal* juice and no sensory quality studies have been carried out to evaluate their acceptability. Alternative to conventional thermal processes like pasteurisation and sterilisation, other emerging technologies such as ultrasound, microwave and pulsed electric field for the enhancement of shelf life, better sensory score, retention of nutritionally rich juice and original functional properties have been explored (Baysal and İçier, 2010; Gonzalez and Barrett, 2010). Various new innovative technologies such as radiation processing and hydrothermal treatments have allowed for the improvement of shelf life and to preserve the nutritional and sensory qualities of fresh fruits or their derived products. Among these technologies, the sonication (ultrasound) treatment is an emerging technology which is reliable, cheap and effective in achieving microbial decontamination. (Valero *et al*., 2007; Tiwari *et al*., 2009; Raju and Deka, 2018). Recent trends aim on minimal processing for modern food preservation in order to obtain safe and durable food products with high nutritional and sensory value (Jiménez-Sánchez *et al*., 2017; Petruzzi *et al*., 2017).

The evaluations in any field are in general according to the knowledge acquired via human senses (sight, taste, touch, smell and hearing) and in sensory evaluation, the management of the amount of uncertain knowledge in the evaluation process is an important problem, because the information acquired by human senses almost always involves imprecision (Faisal *et al*., 2017). The sensory data like colour, flavour, taste and mouth feel are generally obtained through subjective evaluation and these data are generally analysed statistically; finding out the strength and weakness of specific sensory attribute responsible for acceptance or rejection of any food product is not possible.

The implementation of the fuzzy logic approach in food quality control for the food industry has been the focus of different researchers who designed applications specific for this task, and in this case the reasoning process is expressed in linguistic terms of operators and experts (Das, 2005; Perrot *et al*., 2006). Researchers have reported fuzzy logic as a useful tool for the sensory analysis of many food products like mango drink (Jaya *et al*., 2003; Debjani *et al*., 2007) and coffee (Lazim *et al*., 2009).

The main objective of the present work was therefore to find the important sensory attributes responsible for consumer acceptance of *khoonphal* juice treated with conventional thermal process and ultrasound assisted microwave treatment. The sensory evaluation and the data obtained were analysed by fuzzy logic modelling for overall acceptability of the *khoonphal* juice samples.

Materials and methods

Preparation of khoonphal juice samples

Khoonphal was obtained from the West Garo Hills, Meghalaya, in North-Eastern India within 30 min of the laboratory. The extracted fresh *khoonphal* juice was filtered and kept aside separately. The pH (method 981.2), titratable acidity (method 942.15), and total soluble solids (method 932.12) were determined using AOAC methods (AOAC, 2010). The pH was estimated using a digital pH meter (Wensar, LMPH-12, India) and total soluble solid (TSS) was measured by a hand refractometer (Atago Pocket refractometer PAL-3) and the results was expressed in B. Titratable acidity (TA) was measured from homogenised *khoonphal* juice sample by treating with 10 N NaOH solution. and three to five drops of phenolphthalein were used as indicator. The TA was expressed in terms of citric acid percentage.

Preparation of different samples for processing

The following treatment parameters were established from previous studies (Igual *et al*., 2014; Saikia *et al*., 2016).

Sample 1 (T_1)

Ultrasonication (US): 100 mL juice sample was sonicated by a probe type sonicator (Q-1500; Qsonica, Newtown, CHR, USA). The sonicator was operated with a maximum acoustic power load of 1,500 W/cm2, maintaining a constant frequency of 20 kHz during treatment. A titanium probe of 3 mm diameter and 1/5 inch length was immersed into 20 mm of juice sample and 5 s cut-off duration was fixed for all the treatments.

Sample 2 (T_2)

Microwave processing (MW): 100 mL juice sample was subjected to microwave processing at 900 W power for 30 s by placing the juice in a glass tube in a domestic microwave oven (Samsung CE1041DSB2/TL, India). The juice sample was subjected to an adjustable powder load from 300 to 1400 W with microwave oven having workable cavity dimensions 37.3 × 23.3 × 37.0 cm (W × H × D). The apparatus was slightly modified in order to treat the juice sample with a digital control system for variable process time, temperature and power load.

Sample 3 (T_3)

Conventional thermal pasteurised juice (CT): 100 mL juice sample was heated in a glass tube in a thermostatic water bath (Voltam, India) to 78 ± 1°C for 30 s (Saikia *et al*., 2016).

Sample 4 (T_4)

Ultrasound assisted microwave treated juice (UM): 100 mL juice sample was sonicated at 200 watts at 30 kHz for 30 min followed by microwave treatment at 900 W for 30 s.

Sensory evaluation of processed khoonphal juice samples

The processed juice samples were evaluated by 20 well-trained panellists (11 males and 9 females) at NEHU, Tura Campus, Meghalaya. All panellists were instructed to fill sensory score sheets and the quality attributes like "not satisfactory", "fair", "medium", "good" and "excellent" were applied as per the fuzzy logic rating for various process treatments of juice samples (Jaya and Das, 2003; Routray *et al*., 2012).

Fuzzy logic modelling for processed khoonphal juice samples

The fuzzy logic modelling was applied for subjective evaluation of the various processes used in treating *khoonphal* juice samples thus providing data on triangular fuzzy membership distribution function with fuzzy score for juice samples (Sahu *et al*., 2017). The following steps were involved to determine sensory scores by using fuzzy logic approach:

(1) Computation of total sensory scores of processed *khoonphal* juice samples in triplets.

(2) Estimation and computation of overall membership function in fuzzy standard scale.

(3) Calculation of overall similarity values and estimation of ranking order of the juice samples.

(4) Estimation of sensory quality attribute ranking of processed *khoonphal* juice samples in general.

Triplet value was used to express a triangular membership function for sensory scales in 5-point scale pattern designated as "not satisfactory / not at all important", "fair / somewhat important", "medium / important", "good / highly important" and "excellent / extremely important". The triplet value is associated with 5-point sensory scales pattern and first number of the triplet value represent the coordinate of the abscissa and the second and third numbers of the triplet denote the distance towards left and right, respectively.

Calculation of triplet value and overall sensory attributes of processed juice samples

Triplet value and overall sensory scores were calculated for the *khoonphal* juice samples. The triplets associated with a particular quality attribute for each sample were obtained from the sensory scale, number of panellists and sensory scores. Example: for colour attribute of *khoonphal* juice sample 4, when total number of panellists is ($n_1 + n_2 + n_3 + n_4 + n_5$). The n_1 panellist gives "not satisfactory", n_2 panellist gives "fair", n_3 panellist give "good", n_4 and n_5 panellists give "excellent", then the triplets value for the sensory scores of *khoonphal* colour (C*) were calculated as Equation 1:

$$C^* = \frac{n_1\,(0\ 0\ 25)+n_2(25\ 25\ 25)+n_3(50\ 25\ 25)+n_4(75\ 25\ 25)+n_5(100\ 20\ 0)}{n_1+n_2+n_3+n_4+n_5} \quad \text{(Eq. 1)}$$

The relative weightage was calculated by multiplying the sensory score with the triplets. The overall sensory scores of *khoonphal* juice samples were calculated using relative weightage and the triplets obtained for individual juice sample and quality attribute using Equation 2:

$$SO_r = S_rQA1 * QQA1_{rel} + S_rQA2 * QQA2_{rel} + S_rQA3 * QQA3_{rel} + S_rQA4 * QQA4_{rel} \quad \text{(Eq. 2)}$$

where QA1 = colour, QA2 = taste, QA3 = flavour, QA4 = mouth feel.

Membership function for standard fuzzy scale was calculated by using triangular distribution pattern (6-point scale) F_1, F_2, F_3, F_4, F_5 and F_6. The overall membership function was calculated using a triplet (a, b, c), associated with overall sensory score and is represented by Bx value using Equation 3:

$$B_x = \frac{x-(a-b)}{b}\ for\ (A - b < x < a$$
$$B_x = \frac{(a+c)-x}{c}\ for\ a < x < a + c \quad \text{(Eq. 3)}$$

The similarity values were calculated using the obtained B values on standard fuzzy scale (10 values set) by using Equation 4:

$$S_m(F,B) = \frac{F*B'}{Max\ (F*F' \text{ and } B*B')} \quad \text{(Eq. 4)}$$

The quality attribute ranking of all the processed *khoonphal* juice samples, in general, along with the individual processed juice sample were calculated using MATLAB, 2012 through fuzzy logic evaluation (Jaya and Das, 2003).

Results and discussion

In different process treatments of *khoonphal* juice samples (US, MW, CT, UM) the sensory attributes considered were colour, taste, flavour and mouth feel. The results of sensory score for selected attributes of the processed *khoonphal* juice samples are presented in Table 1. The sensory scores and quality attributes of sample 4 (Ultrasound assisted microwave) was "good / excellent" by similarity values. The triplet value associated with quality attributes like, colour, taste, flavour and mouth feel are shown in Table 2. This gives a general idea of sensory scores of samples given by 20 panellists for each sample in linguistic scale. The general quality attribute scores based on their presumption were also given for *khoonphal* juice samples.

The triplets and relative weightage of sensory attributes were calculated using Equation 5, and triplet value for overall sensory scores of Sample 1 (TO_1) were obtained as follows:

$$(a\ b\ c)*(d\ e\ f) = (a*d \quad a*e+d*b \quad a*f+d*c) \quad \text{(Eq. 5)}$$

TO_1 = (63.75 25.00 21.25) * (0.292 0.096 0.057) + (52.50 22.50 23.75) * (0.244 0.096 0.086) + (40.00 18.75 25.00) * (0.249 0.096 0.072) + (57.50 23.75 20.00) * (0.215 0.091 0.091)

Table 1. Sum of the number of panellists with different preferences and triplets associated with the sensory scores for the quality attributes of khoonphal juice samples.

Sensory Quality Attributes of Khoonphal Juice	NS	FR	MD	GD	EX	Triplets for Sensory Scores
Colour						
Sample 1 (T_1) US	0	5	2	10	3	T_1-C = (63.75 25.00 21.25)
Sample 2 (T_2) MW	2	1	11	5	1	T_2-C = (45.00 21.25 25.00)
Sample 3 (T_3) CT	5	3	7	5	0	T_3-C = (46.25 22.50 22.50)
Sample 4 (T_4) UM	1	4	7	4	4	T_3-C = (63.75 21.25 18.75)
Taste						
Sample 1 (T_1) US	3	4	7	6	0	T_1-T = (52.50 22.50 23.75)
Sample 2 (T_2) MW	2	5	7	5	1	T_2-T = (47.50 22.50 23.75)
Sample 3 (T_3) CT	2	4	8	5	1	T_3-T = (71.25 25.00 20.00)
Sample 4 (T_4) UM	0	4	8	2	6	T_4-T = (48.75 20.00 20.00)
Flavour						
Sample 1 (T1) US	2	5	9	2	2	T_1- F = (40.00 18.75 25.00)
Sample 2 (T_2) MW	0	1	5	10	4	T_2- F = (48.75 22.50 23.75)
Sample 3 (T_3) CT	4	1	5	9	1	T_3- F = (52.50 20.00 23.75)
Sample 4 (T_4) UM	0	0	12	2	6	T_4- F = (43.75 21.25 22.50)
Mouth Feel						
Sample 1 (T_1) US	3	0	5	7	5	T_1-M = (57.50 23.75 20.00)
Sample 2 (T_2) MW	4	5	3	4	4	T_2-M = (62.50 25.00 17.50)
Sample 3 (T_3) CT	3	5	8	2	2	T_3-M = (67.50 25.00 17.50)
Sample 4 (T_4) UM	2	5	6	4	3	T_4-M = (51.25 22.50 21.25)

EX = excellent; FR = fair; GD = good; MD = medium; NS = not satisfactory; T_1-C = triplet associated with the quality attribute colour of sample 1; T_2-C = triplet associated with the quality attribute colour of sample 2; T_3-C = triplet associated with the quality attribute colour of sample 3; T_4-C = triplet associated with the quality attribute colour of sample 4; T_1-T = triplets associated with the quality attribute taste of sample 1; T_2-T = triplets associated with the quality attribute taste of sample 2; T_3-T = triplets associated with the quality attribute taste of sample 3; T_4-T = triplets associated with the quality attribute taste of sample 4; T_1-F = triplets associated with the quality attribute flavour of sample 1; T_2-F = triplets associated with the quality attribute flavour of sample 2; T_3-F = triplets associated with the quality attribute flavour of sample 3; T_4-F = triplets associated with the quality attribute flavour of sample 4; T_1-M = triplets associated with the quality attribute mouth feel of sample 1; T_2-M = triplets associated with the quality attribute mouth feel of sample 2; T_3-M = triplets associated with the quality attribute mouth feel of sample 3; T_4-M = triplets associated with the quality attribute mouth feel of sample 4.

Table 2. Sum of the number of panellists with different preference, triplets associated with scores and scores and the relative weightage for quality attributes of the *khoonphal* juice samples.

Quality Attributes of the *Khoonphal* Juice	Sensory Scales					Triplets for sensory scores	Triplets for relative weightage
	NI	SI	IM	HI	EI		
Colour	0	2	3	7	8	QC = (76.25 25.00 15.00)	QCrel = (0.292 0.096 0.057)
Flavour	0	1	9	8	2	QT = (63.75 25.00 22.50)	QFrel = (0.244 0.096 0.086)
Taste	0	2	9	4	5	QF = (65.00 25.00 18.75)	QTrel = (0.249 0.096 0.072)
Mouth Feel	1	3	7	8	1	QM = (56.25 23.75 23.75)	QMrel = (0.215 0.091 0.091)

NI = not at all important; SI = somewhat important, IM = important; HI = highly important; EI = extremely important; QC = triplet for sensory score of quality attribute colour; QT = triplet for sensory score of quality attribute taste; QF = triplet for sensory score of quality attribute flavour; QM = triplet for sensory score of quality attribute mouth feel; QCrel = triplet for relative weightage of quality attribute colour; QFrel = triplet for relative weightage of quality attribute flavour; QFrel = triplet for relative weightage of quality attribute flavour; QMrel = triplet for relative weightage of quality attribute mouth feel.

Similarly, triplet value for overall sensory scores of Sample 2 (TO_2), Sample 3 (TO_3) and Sample 4 (TO_4) were calculated and the following results were obtained:

TO_1 = 54.821 43.283 38.589
TO_2 = 55.138 43.403 38.660
TO_3 = 46.053 38.008 38.086
TO_4 = 59.862 46.699 37.220

Overall membership functions and similarity values of processed *khoonphal* juice samples

Six-point sensory scale (F_1, F_2, F_3, F_4, F_5 and F_6) was used for calculating overall membership function and similarity values according to Equations 3 and 4. The overall sensory scores for Sample 1 (TO_1) were (54.821 43.283 38.589), i.e., a = 54.821, b = 43.283, c = 38.589, the value of B_x at x = (0, 10, 20, 30, 40, 50, 60, 70, 80, 90, 100) was found out as B_1 = (0.0681, 0.3085, 0.5489, 0.7894, 1.0000, 0.9695, 0.7230, 0.4766, 0.2301, 0.0000), (Table 3):

F_1 = 1,0.5,0,0,0,0,0,0,0,0,0
F_2 = 0.5,1,1,0.5,0,0,0,0,0,0,0
F_3 = 0,0,0,5,1,1,0.5,0,0,0,0
F_4 = 0,0,0,0,0.5,1,1,0.5,0,0
F_5 = 0,0,0,0,0,0,0.5,1,1,0.5
F_6 = 0,0,0,0,0,0,0,0,0.5,1

The membership functions on standard fuzzy scale were then used to calculate the similarity values. For example, the membership function of Sample 1 was B_1, F_1*B_1', F_1*F_1' and B_1*B_1' which was calculated by applying rules of matrix multiplication. The similarity values like F_2 (fair), F_3 (satisfactory), F_4 (good), F_5 (very good) and F_6 (excellent) were represented for processed *khoonphal* juice samples (Table 4). For Sample 4 (T_4), the highest similarity value was "very good" (0.6611) as compared to the other samples. So, their ranking was T_4 (very good) > T_3 (good) > T_1 (good) > T_2 (satisfactory). Thus, the combined effect on process treatment of ultrasound and microwave treated *khoonphal* juice sample

Table 3. Values of overall membership function of the *khoonphal* juice samples.

Overall Membership Function	Values									
B1	0.0000	0.1955	0.4266	0.6576	0.8886	1.0000	0.8658	0.6066	0.3475	0.0883
B2	0.0000	0.1904	0.4208	0.6512	0.8816	1.0000	0.8742	0.6156	0.3569	0.0982
B3	0.0515	0.3146	0.5777	0.8408	1.0000	0.8964	0.6338	0.3871	0.1087	0.0000
B4	0.0000	0.1464	0.3605	0.5747	0.7888	1.0000	0.9963	0.7277	0.4590	0.1904

Table 4. Similarity values of the *khoonphal* juices samples and ranking.

Scale factors	Sample-1	Sample-2	Sample-3	Sample-4
Not satisfactory, F_1	0.0265	0.0258	0.0595	0.0189
Fair, F_2	0.2578	0.2536	0.3814	0.2051
Satisfactory, F_3	0.6126	0.6071	0.7346	0.5277
Good, F_4	0.7085	0.7098	0.6337	0.7112
Very good, F_5	0.3880	0.3948	0.2316	0.4596
Excellent, F_6	0.0711	0.0749	0.0155	0.1084
Ranking	III	II	IV	I

resulted as the most acceptable process for better sensory scores then other process treatments.

The results obtained revealed that sensory attributes were not affected by non-conventional process methods (ultrasound and microwave) but there was poor overall sensory score in the case of conventional thermal process. This could be due to the disappearance or reduction in pigments i.e. anthocyanins and carotenoids (Saikia *et al*., 2016). Anthocyanins are responsible for the bright red colour thus improving the sensory score for ultrasound assisted microwave treated samples (Chen *et al*., 2013; Jimenez-Aguilar *et al*., 2015). This treatment showed appreciable change in sensory score of *khoonphal* juice samples. The presence of readily oxidisable molecules and ascorbic acid indicated that sonication had no effect on the ascorbic acid content in *khoonphal* juice sample (Salazar-González *et al*., 2014; Rodríguez-Roque *et al*., 2015). Sample 4 (T_4) showed superior flavour as compared to the other samples; the main reason could be due to the production of substantial amounts of hydroxyl radicals in competition (different reaction rates) between hydroxyl groups and all the other oxidisable substrates available in the sample (i.e. proteins or sugars). Similar result was reported in tomato juice (Walkling-Ribeiro *et al*., 2009; Lee *et al*., 2016).

Quality ranking of processed khoonphal juice samples

The quality attributes play main role for better consumer acceptability for different food products. The sensory quality attributes considered for *khoonphal* juice samples were colour (C), taste (T), flavour (F) and mouth feel (M). Table 5 represents similarity values of chosen sensory quality attributes of processed *khoonphal* juice samples. The important quality attribute resulted was colour (0.8873) which was "highly important" out of other sensory factors - taste (0.9643), flavour (0.9573) and mouth feel (0.9467) which were considered "important". But, similarity ranking value of flavour was found to be less than taste. Thus, taste was the second most important quality attribute and flavour was the third most important quality attribute for the overall acceptability of processed *khoonphal* juice samples. The order of preference of quality attributes for the processed *khoonphal* juice samples was colour > taste > flavour > mouth feel.

The other quality attributes i.e. taste and mouth feel of *khoonphal* juice samples, following ultrasound and microwave treatments, were compared with conventional heat treatment. Higher consistency and initial apparent viscosities were observed for the ultrasound and microwave treated samples. The effect could be due to the interaction or entanglement of cell particles (mostly cell walls), soluble proteins or due to pure pectin solutions that yielded molecules with lower apparent viscosities due to a size reduction. A similar result was observed by Abid *et al*. (2013). The reason behind the improved taste of the *khoonphal* juice samples might be due to the modification of pectin properties in gels derived from pectin. Longer molecules show higher resistance to flow but shorter ones can interact in a different way with suspended particles, also leading to an increased resistance to flow (Bhat *et al*., 2011; Sinija and Mishra, 2011).

The combined effect of ultrasound assisted microwave treatment in sample (T_4) was that the flavour factor was obtained as "important" and this could be due to an increase in polyphenolic compounds. This includes flavonoids generated by enhanced disruption of cell wall with mechanical forces as a result of the shear forces exerted on the fruit cell due to rapid change in pressure during the processing (Rodríguez-Roque *et al*., 2016). The creation of hydroxyl radicals during sonication which generates the aromatic ring of phenolic compounds might be the main reason for the improvement in flavour, taste and moth feel in the *khoonphal* juice samples. Similar results were reported in sonicated *kasturi* lime juice (Bhat *et al*., 2011). Therefore, it can be concluded that the ultrasonic assisted microwave treated *khoonphal* juice can be highly acceptable in the commercial market as well as safe and healthy for consumption.

Table 5. Similarity values of the *khoonphal* juices samples and their attributes ranking.

Scale factors	Colour	Taste	Mouth Feel	Flavour
Not at all necessary	0.0000	0.0000	0.0000	0.0000
Somewhat necessary	0.0000	0.0099	0.0000	0.0624
Necessary	0.0700	0.3662	0.3200	0.6139
Important	0.6400	0.9643	0.9467	0.9573
Highly important	0.8667	0.5938	0.5733	0.3330
Extremely important	0.2033	0.0550	0.0421	0.0000
Ranking	I	II	IV	III

Conclusion

The present work revealed the effectiveness of ultrasound assisted microwave to process *khoonphal* juice in the laboratory to obtain better overall sensory score by using the fuzzy logic approach. This technology can be commercialised for better utilisation of *khoonphal*. The present work concluded that sample 4 (T_4), processed by ultrasound assisted microwave treatment, was ranked first. The processed *khoonphal* juice was ranked according to its sensory attributes; colour > taste > flavour > mouth feel. The present work also revealed that the combined effect of ultrasound assisted microwave treatment had an influence on overall acceptability of sensory quality scores / attributes of *khoonphal* juice as compared to other processing methods. Sample 4 (T_4) showed higher sensory score and overall attributes. Ultrasound assisted microwave process is new hurdle technology and has advantages like short time, less temperature, high nutrition and acceptability. Therefore, the combined processing of ultrasound assisted microwave treatment could be used in place of thermal pasteurisation. For the future, the present work could be applied to a greater number of fruit juice samples to determine their consumer acceptability.

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