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The use of fuzzy logic to determine the concentration of betel leaf essential oil and its potency as a juice preservative

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ABSTRACT

The present study was attempted to determine organoleptically acceptable concentration of betel leaf essential oil (BLEO) in raw apple juice using fuzzy logic approach, and to evaluate the efficacy of the acceptable concentration in the juice under refrigerated storage. The presence of BLEO components in treated juice was confirmed by FTIR spectroscopy. Based on similarity values, the acceptable concentration in the juice was found to be 0.19 μl/ml of BLEO. Total antioxidant capacity of untreated juice was found to be 16% less than treated juice at the end of storage. The treated juice exceeded total aerobic plate count of 2 $\log_{10}$ (cfu/ml) on 15th day of storage. Based on safe limits of microbial load, the shelf life of treated juice was extended by 6 days as compared to untreated juice under refrigerated storage. BLEO contributes to green consumerism and its application as food preservative will add value to the product.

1. Introduction

Raw apple juice (RAJ) is unfiltered, cloudy, high soluble solids, low acid (pH < 4.5), unpasteurized non-alcoholic beverage that has shorter shelf life of 2–3 weeks (Dock, 1999). Despite several foodborne illness associated with unpasteurized apple juice, it has always been preferred over thermally pasteurized apple juice by the consumers (Parish, 1997). Thermal processing is one of the most common practices, but it has adverse effects on sensory, nutritional and functional properties of food (Mañas & Pagán, 2005; Raso & Barbosa-Cánovas, 2003).

The demand of minimally processed food has escalated with emergence of green consumerism, which in turn has promoted the use of naturally occurring antimicrobials (Juneja, Dwivedi, & Yan, 2012). Essential oils are secondary metabolites of plants which can be extracted from herbs and spices. Antimicrobial properties of essential oils can be attributed to the presence of bioactive phenolic compounds (Tepe, Daferera, Sokmen, Sokmen, & Polissiou, 2005). Basak and Guha (2015) have identified chavibetol, estragole, β-cubebene, chavicol, and caryophyllene as the major chemical compounds of betel leaf essential oil (BLEO) of the cultivar Tamluk Mitha. And estragole of the five BLEO components has restricted use in the European Union, whereas all five chemical compounds of BLEO have GRAS status in US FDA.

Alfonzo et al. (2016) have investigated the biopreservative effect of lemon essential oil micro-emulsion while improving safety and sensory attributes of salted sardines. Use of essential oil is also limited due to its ability to make undesirable alteration in sensory attributes of food (Hyldgaard, Mygind, & Meyer, 2012). Therefore, detailed sensory evaluation of any product treated with essential oil forms the basis of its marketability. Sensory evaluation is a scientific method to decide acceptance and rejection of food by the evaluator upon consumption (Kemp, Hollowood, & Hort, 2009). Fuzzy logic is an important tool which can draw an important conclusion regarding acceptance, rejection, ranking, strong and weak attributes of food using vague and imprecise data in linguistic form filled in by single or multiple experts (Zimmermann, 1991). Fuzzy sets provide the mathematical method that represents the fuzziness of human expressions (Lazim & Suriani, 2009) using linguistic variables instead of numerical values (Zadeh & Kacprzyk, 1999).

Comparison and choice is fundamental to consumers (Imm, Lee, & Lee, 2011) so is the market risk of any food products. Alongside organoleptic acceptability, the quality of any food products over storage period is determined by their physical and chemical characteristics, microbiological and toxicological safety, and sensory attributes, packaging and labelling (Molnár, 1995). From industrial point of view, consumer acceptability of BLEO treated unpasteurized apple juice and its potency in shelf life extension of the selected food product should be studied. In view of the above research gap, this study was taken up to conduct sensory analysis of raw apple juice treated with betel leaf essential oil using fuzzy logic followed by evaluation of antimicrobial efficacy of organoleptically acceptable concentration of BLEO in the unpasteurized juice during refrigerated storage at 4 °C.

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2. Materials and methods

2.1. Essential oil

BLEO was extracted from fresh betel leaves of cv. Tamluk Mitha (Guha, 2007), and the essential oil based microemulsion (BLEO-ME) using Tween 20 (SRL Chem., India) as emulsifier and water as the continuous phase was formulated according to Basak and Guha (2017a).

2.2. Preparation of raw apple juice

Apples (cv. Red delicious) at commercial maturity were purchased and surface sterilization of the apples was performed according to Buchanan, Edelson, Miller, and Sapers (1999). Briefly, apples were dipped in 2 µl/ml sodium hypochlorite for 1 min, followed by rinsing them in autoclaved distilled water for another 1 min. Each apple was cut and made into pulpy juice using mixer grinder followed by filtration using two layers of muslin cloth to obtain raw apple juice.

Based on the previous study by Basak and Guha (2015), 0.14, 0.19, 0.28, 0.37 and 0.56 µl/ml of BLEO in the juice were selected for sensory evaluation that corresponds to RAJ-S2, RAJ-S3, RAJ-S4, RAJ-S5 and RAJ-S6, respectively. RAJ-S1 was served as untreated sample throughout the evaluation process. A panel of 20 participants was selected and trained to perform the sensory evaluation.

2.3. Fuzzy logic analysis

2.3.1. Sensory evaluation

All the selected panellists were trained to familiarize the quality attributes of raw apple juice, sensory score sheets and method of scoring the samples. Quality attributes of sensory analysis were colour, flavour, taste and mouthfeel. The fuzzy scale factors were “Not satisfactory”, “Fair”, “Medium”, “Good” and “Excellent”.

According to the explanation provided by Das (2005), ranking of raw apple juice samples were done using triangular fuzzy membership distribution function. Sensory scores of the juice samples obtained using fuzzy scores given by the panellists were converted into triplets and similarity analysis were performed in order to rank the samples. A program was coded in Matlab® 2015a (The Mathworks™; McGarrity, 2008) to perform calculations involved in aforementioned steps. As shown in Fig. S1 (supplementary materials), the distribution pattern of 5-point sensory scales comprises “Not satisfactory/Not at all important, (0, 0, 25)”, “Fair/Somewhat important, (25, 25, 25)”, “Medium/Important, (50, 25, 25)”, “Good/Highly important, (75, 25, 25)” and “Excellent/Extremely important, (100, 25, 0)”. The first number in the triplets denote coordinate of the abscissa where the value of the membership function is 1, whereas the second and third number represents distance to left and right of the first number where the membership function is zero, respectively (Chakraborty, Das, & Das, 2011).

2.3.2. Triplets for sensory score of samples

Quality attributes of the samples in form of triplets were calculated using sum of sensory scores, triplets associated with sensory scale and number of panellists as given below:

$$\begin{aligned}&\text{Quality attribute of RAJ samples}=[\{\text{no. of panellist}\times(0\ 0\ 25)\}+\\&\{\text{no. of panellist}\times(25\ 25\ 25)\}+\{\text{no. of panellist}\times(50\ 25\ 25)\}+\\&\{\text{no. of panellist}\times(75\ 25\ 25)\}+\{\text{no. of panellist}\times(100\ 25\ 0)\}]\\&/(\text{Total no of panellist})\end{aligned}\tag{1}$$

Accordingly, values of triplets for colour, flavour, taste and mouthfeel of all samples were obtained using Eq. (1).

2.3.3. Triplets for panellists’ preference to importance of quality attributes

Preference of individual panellist to the importance of quality attributes of raw apple juice in general was calculated using sum of sensory scores, triplets associated with sensory scales, and number of panellists as given below:

$$\begin{aligned}&\text{Quality attributes of RAJ in general}=[\{\text{no. of panellist}\times(0\ 0\ 25)\}\\&+\{\text{no. of panellist}\times(25\ 25\ 25)\}+\{\text{no. of panellist}\times(50\ 25\ 25)\}\\&+\{\text{no. of panellist}\times(75\ 25\ 25)\}+\{\text{no. of panellist}\times(100\ 25\ 0)\}]\\&/(\text{Total no of panellist})\end{aligned}\tag{2}$$

Similarly, triplets for all quality attributes, viz. colour (*QC*), flavour (*QF*), taste (*QT*) and mouthfeel (*QM*) of RAJ in general were calculated according to Eq. (2).

2.3.4. Triplet for relative weightage of quality attributes

Relative weightage of quality attributes were calculated so as to determine the triplets for overall sensory scores of the juice using Eq. (3):

$$Q_{\text{sum}} = \text{sum of first digit of triplets of } QC, QF, QT \text{ and } QM \tag{3}$$

Triplet for relative weightage of colour (QC_{rel}) attribute was calculated using Eq. (4):

$$QC_{\text{rel}} = \frac{QC}{Q_{\text{sum}}} \tag{4}$$

Accordingly, relative weightage for all four quality attributes of raw apple juice was calculated.

2.3.5. Triplets for overall sensory scores of the juice samples

The values of triplets for colour, flavour, taste and mouthfeel of all samples are tabulated in Table S1 (supplementary material). Similarly, the triplets for sensory score of quality attributes of RAJ in general was calculated based on the preferences of panel members (Table S2, supplementary material). Overall sensory scores for every sample were calculated according to Eq. (5):

$$\text{SO1} = (\text{S1 C}\times \text{QC}_{\text{rel}}) + (\text{S1 F}\times \text{QF}_{\text{rel}}) + (\text{S1 T}\times \text{QT}_{\text{rel}}) + (\text{S1 M}\times \text{QM}_{\text{rel}}) \tag{5}$$

where, SO1 is the overall sensory score for RAJ-S1; S1C, S1F, S1T and S1M represent the triplets corresponding to the colour, flavour, taste and mouthfeel of RAJ-S1; QC_{rel}, QF_{rel}, QT_{rel} and QM_{rel} represents the triplets corresponding to the relative weightage of quality attributes of RAJ in general. Multiplication of triplet (*a, b, c*) with (*d, e, f*) was performed using the rule given in Eq. (6):

$$(a,b,c)\times(d,e,f) = [(a\times d),(a\times e + d\times b),(a\times f + d\times c)] \tag{6}$$

Using the above triplet multiplication rule, overall sensory score for all RAJ samples were calculated.

2.3.6. Standard fuzzy scale and ranking of the samples

Standard fuzzy scale following triangular distribution pattern of 6-point sensory scale is shown in Fig. S2 (supplementary material). The linguistic expression of the standard fuzzy scale and values of membership functions for F1–F6 are mentioned in Table S3 (supplementary material).

2.3.7. Values of overall membership function of sensory scores on standard fuzzy scales

Membership function of overall sensory scores of raw apple juice samples was calculated on standard fuzzy scale. According to Fig. S3 (supplementary material), when the value of abscissa as *a*, the value of membership function become 1, and when $(a - b) <$ abscissa $< (a + c)$, the value of membership function becomes 0. For the given value of *x* on abscissa, value of membership function B_x can be expressed as,

$$B_x = \frac{x-(a-b)}{b} \text{ for } (a-b) < x < a$$