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Fuzzy Logic Based Sensory Evaluation of Black Rice Porridge: A Study of Composition for Determining Suitable Ratio of Constituents

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ABSTRACT

Black rice is widely popular variant of rice (*Oryza sativa* L.) widely consumed in India and the South Asian countries. The distinctive colour in black rice is due to the presence of anthocyanins in its bran which endows it a distinctive place in desserts. Its distinctive colour and the nutty texture make it popular as a snack and as a natural food colourant. The present study attempts to explore Advanced Fuzzy logic approach for optimized sensory evaluation of porridge vis-à-vis substitute to the popular white rice porridge, given the higher nutritional benefits of black rice. A sensory study to explore the preferred porridge with its composition was conducted with 28 samples to determine the suitable ratio of constituents in black rice porridge. The study revealed that a ratio of 60 grams of dry black rice by weight in a liter of milk is most preferred over the popular white rice counterpart. The results can serve as guidance to prospective entrepreneurs, restaurants to devise the most suitable composition of constituents for black rice porridge and for targeting the health-conscious consumers.

***Key words*:** Anthocyanin, Black rice, Fuzzy logic, Hedonic perception, Porridge, Sensory evaluation

Rice (*Oryza sativa* L.) is consumed as a primary source of complex carbohydrate and energy in the meal. Rice being a staple food for over half of the global population is consumed in different forms of food [1]. Black rice has a long history of cultivation and consumption particularly in the South East Asian countries. The rice is gaining gradual and steady popularity as being a substitute to the regular white rice owing to its food value and being the highest source of antioxidants in a natural and staple food form. Black rice bran houses the maximum of antioxidants including phytic acid, γ–oryzanol, anthocyanin and vitamin E [2-5]. Of all rice types, iron is found in highest quantities in black rice [6]. Black rice contains the highest content of total anthocyanins (327.60 mg 100 g^{-1}) among all of the studied colored grains. Black rice is also an essential source of Iron, Zinc, Phosphorus, Potassium and aids to restore the water balance in the body. The higher antioxidant presence qualifies black rice as a potent agent for reducing stress lifestyle diseases [7]. Some of the benefits of black rice include inhibition of carcinogenic cells and protection against angiogenesis, protection from osteoporosis, etc. As such black rice is a promising food component with special significance in diet platter.

The organoleptic properties in any food item is a deciding factor in its consumer acceptability. The texture, taste, aroma and appearance determine whether to consume a food product or not. As such product development is determined by sensory perceptions. Sensory evaluation aids in understanding the consumer acceptability which further aids in assessing the compositions and quality parameters in the food. As such, sensory evaluation is a tool for developing the right parameters for customer acceptability [8]. Without this the possibility of a product failing in the market rises and in many a case is annulled. Sensory evaluation relies on consumers as the base for decision making in product development [9]. Sensory data alone can represent the real-life perception of consumers towards food [10-11]. Sensory analysis differs from market research testing in that the latter is practiced for branded products whereas the former is the process for non-branded products and to evaluate the preference through sensory characteristics [10].

Human perception is more identifiable towards linguistic remarks rather than numbers, it is better to use linguistic form for obtaining responses [11]. For analyzing this linguistic form of perceptions fuzzy sets can be used which give better results compared to average scores of the attributes. The standardized fuzzy scale for sensory analysis which is linguistically

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categorized on a six-point scale is represented as not satisfactory/not at all necessary, fair/somewhat necessary, satisfactory/necessary, good/important, very good/ very important and excellent/extremely important. The membership function of each follows a triangular pattern with a maximum value of 1 [12].

Porridge is a popular sweet dish normally consumed as breakfast or a a dessert post meals. Porrdige is popularly known as payash or kheer in parts of India. Usually prepared out of polished white joha rice, is a calorie rich dish. Joha rice is a popular variety of aromatic rice grown in Northeastern India and is an intermediate of the Indica and Japonica class [13]. The variety is known for its texture and palatability which also qualifies it for desserts. It is prepared by cooking rice in milk and sugar primarily and flavours added such as saffron, lemon jest and other dry fruits for enhancing flavour and taste. The primary ingredients however are rice boiled in sweet milk. The cooking time and the proportion of rice vis-à-vis that of sugar and milk determines the taste, oral tactile texture and flavour. Though served cold while as a dessert yet is eaten warm to hot when consumed otherwise. The standard proportion is followed while preparing the control which is a porridge of normal polished rice. The popularity of porridge is a tentative qualifier for black rice porridge in being a suitable and preferred alternative to polished white rice porridge with its inherent medicinal properties. Studies have indicated the potentiality of added black rice flour in enhancing the nutritional worth of food [14-15]. Black has been proved as a suitable alternative in noodles. In fact, black rice flour in biscuits aided in reducing the blood sugar levels [16]. From the literature referred to herein, no study has been found on the preparation of porridge using black rice for enhancing its medicinal worth. As such the study aims at determing the right proportion of black rice as an additive to the porridge.

MATERIALS AND METHODS

The porridge in the study is made of polished joha rice and black rice available locally in Sivasagar, Assam and grown in the adjacent regions within Assam. Prior to preparation, both black rice and joha rice are confirmed to contain same moisture in them and to prevent any errors due to inherent moisture. The proportion of rice in the samples and control are as in (Table 1) below. The samples are prepared using black rice grown in Assam and available in the local market. The sugar used is regular polished white medium granular sugar and milk used is Amul taaza brand containing snf of 8.5% and 3% fat content. All the ingredients are initailly held at room tempertaure of 25 °C. All the rice samples are washed adequately and soaked for six hours prior to cooking to maintain uniformity in mositure. The soaked rice is initially pressure cooked to 20 minutes over medium flame with UV treated water from water purifier. The pressure cooker is of stainless steel and cylindrical with a base diameter of 14.4 cm and base thickness of 6.35 mm with capacity of 3 litres; the bottom is triple layered with one layer of aluminium between two layers of stainless steel. The pressure cooked rice is then slow cooked for 45 minutes mixed with milk and sugar on a gas stove in a cylindrical aluminium vessel of 4 litre capacity and base diameter of 15 cm. the mixture is constantly stirred to prevent the formation of lumps and to obtain a thick smooth uniform consistency. The vessels for cooking, proportion of water for pressure cooking and that of milk and sugar are kept constant alongwith cooking time. The only variable in the study is the proportion of black rice.

The porridge so obtained were used for the experiment with 28 panelists using five point scale for sensory evaluation. Sensory evaluation has been conducted using attributes of flavour, texture, colour, taste and appearance. The panelist were chosen who have had breakfast at least two hours ahead and had a prior familiarity with polished joha rice porridge and non-allergic to any of the ingredients used including lactose in milk. The panelists included teachers and students of Assam Rajiv Gandhi University, Sivasagar, Assam (India). Sensory properties of the products were evaluated by 28 semi trained panel judges who were trained about the importance of impartial assessment of sensory attributes, definition of quality attributes to be evaluated, the content of the score sheet and the procedure for scoring. The experiment was conducted during 10:30AM-12:00 noon. The panelists were provided with a briefing on the purpose of the study, the terms in the response sheet and expectations from their responses. Before the commencement of the experiment and after each sample, the panelists have been asked to rise their mouth with sufficient water [12], [17-18]. This is to prevent the influence of the preceeding sample in each case. The observations of the panelists were analysed using fuzzy approach.

Table 1 Proportion of ingredients in the rice samples

Sample	Rice	Sugar	Water	Milk	Cooking time
Control: C-Polished joha rice	2/3 cup (120 grams)	2 cups	4 cups	3 cups	20 minutes
S_1: Sample 1	1 cup (180 grams)	2 cups	4 cups	3 cups	20 minutes
S_2: Sample 2	2/3 cup (120 grams)	2 cups	4 cups	3 cups	20 minutes
S_3: Sample 3	1/3 cup(60 grams)	2 cups	4 cups	3 cups	20 minutes

RESULTS AND DISCUSSION

Fuzzy logic is a potent technique that can be used to replicate and represent uncertain multi-valued linguistic human responses. It is an extension of a crisp set providing partial membership in a set. The non-crisp nature of responses in sensory eavluations make the application of fuzzy set apt in such evaluations. Studies are plenty in this regard. Fuzzy logic has been used in sensory evaluation of tea liquor [11]; fuzzy logic was used for assesing senory characteristics of amaranth and oat based pasta noodles [12], likewise fuzzy logic has been used to determine acceptable properties of cold plasma treated tender coconut water [18]. Debjani *et al*. [11] has reported a number of studies wherein fuzzy have been used for sensory evaluation. The steps for the process as conducted in [18] and [11] are as below:

a) Determination of triplets from the dataset
b) Determination of the membership function based on the triplets
c) Calculation of of normalised fuzzy membership function
d) Determinnation of membership function matrix and
e) Attribute ranking of the samples

The triplets are a set of three numbers used to obtain the traingular membership function on the five point scale used. The scale consisted of indicators such as “not at all important, somewhat important, important, very important and extremely important”. The triangular membership functions denoted by triplets for five point scale is shown in (Table 2).

Table 2 Triplets for membership functions

Not at all important	Somewhat important	Important	Very important	Extremely important
0 0 25	25 25 25	50 25 25	75 25 25	100 25 0

The sensory attributes in the study summation of individual preferences is as below:

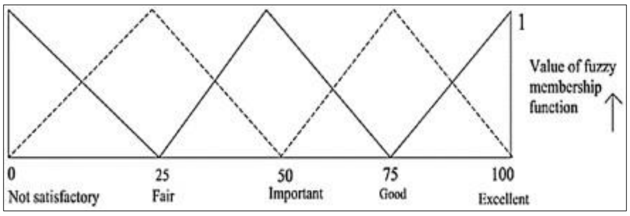

Fig 1 Sensory scale

The y axis represents the mmebership function of sensory score of the triplets with 1 being the highet value indicating full membership equivalent to a crisp set. The triplet values (a,b,c) are indicators of abscissa, the difference of the abscissa and the left value, and the difference between abscissa and the right value respectively.

The sensory evaluation for the triplets in the four samples (one control and three test samples) were calculated in due consideration of the 28 panelists' scores for sensory characteristics and is represented by matrix A in (Table 3) below:

Table 3 Responses for samples attribute wise- Matrix A

Sample attributes		Not at all important	Somewhat important	Important	Very important	Extremely important
Flavour	Control	0	0	1	17	10
	1	0	2	0	15	11
	2	1	4	5	13	5
	3	1	2	2	10	13
Texture	Control	0	6	5	12	5
	1	1	2	5	12	8
	2	2	12	5	6	3
	3	0	7	6	11	4
Taste	Control	0	1	1	14	12
	1	0	2	1	13	12
	2	0	7	3	14	4
	3	1	2	2	10	13
Colour	Control	0	1	4	12	11
	1	0	1	1	11	15
	2	0	1	3	15	9
	3	1	2	3	9	13
Appearance	Control	0	2	4	13	9
	1	0	2	0	13	13
	2	1	0	2	17	8
	3	0	3	0	15	10
Overall acceptability	Control	0	2	3	19	4
	1	0	1	2	14	11
	2	0	5	3	18	2
	3	1	2	3	11	11

The triplet set can be represented by the matrix B given by table 4 below:

Table 4 Triplet set Matrix B

Triplets		
0	0	25
25	25	25
50	25	25
75	25	25
100	25	0

For each sensory charactertics with respect of each sample the triplet values were calculated, viz., CC for colour charactericitcs of control as products of matrix multiplication of A and B. As such a 24x3 matix is obtained, where A and B is a 24x5 and 5x3 matrix respectively . The triplet values for each attribute sample wise is given by as below:

$$\frac{A \times B}{\Sigma(\textit{Sensory scale counts for each attribute sample wise})} \quad \ldots\ldots.. (1)$$

The resultant cell values are as in (Table 5).

Table 5 Triplet values attribute -sample wise as per Equation 1

Sample attributes		Triplet values for each attribute sample wise				
Flavour	Control	83.03571	25	16.07143	C Flavour	CF
	1	81.25	25	15.17857	S1 Flavour	S1F
	2	65.17857	24.10714	20.53571	S2 Flavour	S2F
	3	78.57143	24.10714	13.39286	S3 Flavour	S3F
Texture	Control	64.28571	25	20.53571	C Texture	CT
	1	58.92857	18.75	11.60714	S1 Texture	S1T
	2	33.92857	11.60714	8.035714	S2 Texture	S2T
	3	34.82143	12.5	9.821429	S3 Texture	S3T

Taste	Control	50	14.28571	6.25	C Taste	CS
	1	37.5	10.71429	4.464286	S1 Taste	S1S
	2	34.82143	11.60714	8.928571	S2 Taste	S2S
	3	58.03571	16.96429	8.035714	S3 Taste	S3S
Colour	Control	51.78571	16.07143	8.928571	C Colour	CC
	1	37.5	10.71429	4.464286	S1 Colour	S1C
	2	45.53571	14.28571	8.928571	S2 Colour	S2C
	3	53.57143	15.17857	4.464286	S3 Colour	S3C
Appearance	Control	55.35714	16.96429	8.928571	C Appearance	CA
	1	48.21429	13.39286	5.357143	S1 Appearance	S1A
	2	49.10714	15.17857	9.821429	S2 Appearance	S2A
	3	47.32143	13.39286	6.25	S3 Appearance	S3A
Overall acceptability	Control	72.32143	25	21.42857	C Overall	COA
	1	81.25	25	15.17857	S1 Overall	S1OA
	2	5.357143	2.678571	2.678571	S2 Overall	S2OA
	3	5.357143	2.678571	2.678571	S3 Overall	S3OA

Having obtained the triplet values for the control and samples for each attribute, the triplet values of sensory parameters for samples in general for each attribute as in the table and denoted by QFlavour, QTexture, QTaste, QColour, Qappearnce and QOverall. The sensory preference for the attributes were recorded for each panelists are as below in (Table 6).

The triplet values were recalculated with above (Table 6) and values were obtained as below in (Table 7).

Table 6 Sensory preference for the attributes

Sample attributes	Not at all important	Somewhat important	Important	Very important	extremely important
Flavour	1	2	2	14	10
Texture	1	7	5	10	5
Taste	1	3	2	13	10
Colour	1	1	3	12	12
Appearance	1	7	6	15	10
Overall acceptability	1	3	3	16	7

Table 7 The triplet values recalculated

Quality attributes	Triplet values for each attribute		
Q Flavour: QF	75.86207	24.1379	16.379
Q Texture: QT	59.82143	24.1071	20.536
Q Taste: QS	74.13793	24.1379	16.379
Q Colour: QC	78.44828	24.1379	14.655
Q Appearance: QA	66.66667	24.359	18.59
Q Overall: QO	70.83333	24.1667	19.167

However there is a need to reduce the first digit pertaining to the abscissae to a score out of 100; for this the table above values are multiplied by a factor Qsum, where Qsum can be calculated by using Equation (2), where

Qsum = ∑ abscissae of triplet values in table above ……... (2)

Qsum= 75.86207 + 59.82143 + 74.13793 + 78.44828 + 66.66667 + 70.83333 …………… (3)

= 425.7697

The product so obtained yields the relative weightage for each of the attributes and calculated for flavor as QF-rel = QF/QSum and accordingly for the other attributes.

Table 8 Relative weightage of the attributes recalculated

Relative weightage of attributes	Triplets for the relative weightage		
Q Flavour-rel: QF-rel	0.178176296	0.056692	0.03847
Q Texture-rel: QT-rel	0.140501844	0.05662	0.048232
Q Taste-rel: QS-rel	0.174126835	0.056692	0.03847
Q Colour -rel:QC-rel	0.184250488	0.056692	0.03442
QAppearance-rel: QA rel	0.156579169	0.057212	0.043661
Q Overall-rel: QO-rel	0.166365367	0.05676	0.045017

Determination of overall sensory scores are done by using the rule for triplet multiplication as (a,b,c) × (p,q,r). Here a, b, c are the triplets found for control, while p, q, r are the triplets for relative quality attributes. The overall sensory score is calculated using Zimmermann's triplet multiplication rule and equation as cited in [11], [19] and given in equation 4.

SOControl = CFxQF-rel +CTxQT-rel +CSxQS-rel +CCxQC-rel +CAxCA-rel +COxCO-rel ………………. (4)

And accordingly calculated for the other samples, S_1, S_2 and S_3.

The values so obtained as in table below:

Table 9 Overall sensory score for sample

SO Control =	(62.77469879	41.62092	29.11886)
SOS1 =	(57.26208554	36.74965	23.7632)
SOS2 =	(39.4140247	26.68707	19.4073)
SOS3 =	(47.16897118	30.10955	18.49824)

The standard fuzzy scale as developed by Routay and Mishra is well referred to in [12], [18]. The standard sensory scale is a six-point categorised scale with represenatations as "not satisfactory / not at all necessary through excellent / extremely important". The membership function in each case of the sensory scale follows a triangular distribution with 1 as the maximum value. A comparision of the samples with the overall quality of the attributes are obtained. The overall attribute quality is represented by the triplets a,b,c as is shown in figure below:

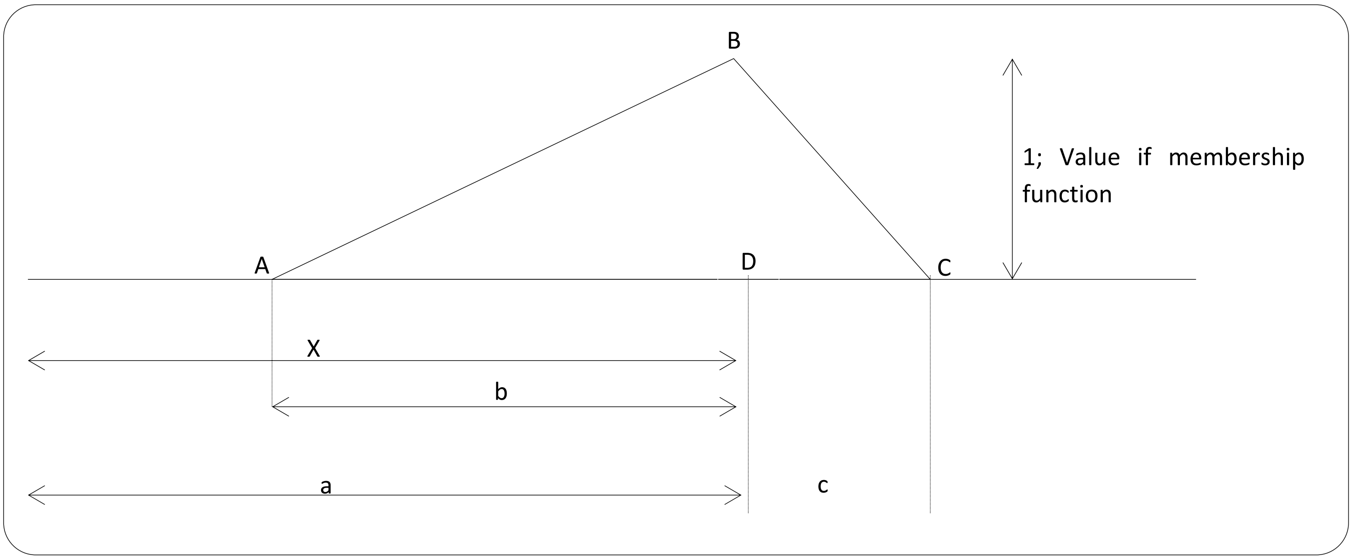

Fig 2 Sensory triplets

The overall sensory scores can be used to describe the overall prefered rank of preference of the samples. The standard fuzzy sclae is referred to here, which is a 6-point scale with not satisfactory at one extreme and excellent/extremely important at other end.; the membership function follows a traingular distribution with 1 as the maximum mebership value in the sets and 0 as the lowest value [12], [18-19]. The overall quality of the samples is being ranked with the aid of the centroid of the traingle ABC given by the triplet (a,b,c). Since triangles ABD and BDC are right angled, the centroids shall be located 1/3 space apart form the base. As such area of traingles ABC, ABD and BDC are respectively 0.5(b+c), 0.5b and 0.5c. In such a case the distance xof the centroid is as per Equation 5.

$$X=\frac{a-(b-c)}{3}\text{……………………..(5)}$$

Calculating x for each sample under study yields the following values as below:

Table 10 Distance x from the centroid

XC	16.75755
Xs1	14.75855
XS2	10.71142
XS3	11.85255

As such the overall ranking of the samples is as in the order below.

Control > S1 > S3 > S2

Using the same equation, the importance of the attributes of the samples can be assessed. Thus, with the triplets the values obtained are as below:

Table 11 Overall ranking of samples

Flavour	22.70114943
Texture	18.75
Taste	22.12643678
Colour	22.98850575
Appearance	20.2991453
Overall Acceptability	21.94444444

The values are indicative of the relative importance of the attribute which is found as:

Colour>Flavour>Taste>Overall acceptability>Appearance

For the sensory scores obtained, similarity analysis is used for distributing the same in the standard fuzzy scale represented in linguistic form. The values of the membership function F_1 through F_6 are represented by a set of 10 numbers which are indicative of maximum membership of fuzzy membership in each interval as maximum membership value of fuzzy membership function between 0 and 10 and so on through maximum membership of fuzzy membership function between 90 and 100. The membership values are indicated as:

Not satisfactory F_1	:	[1 0.5 0 0 0 0 0 0 0 0]
Fair F_2	:	[0.5 1 1 .5 0 0 0 0 0 0]
SatisfactoryF_3	:	[0 0 0.5 1 1 0.5 0 0 0 0]
Good F_4	:	[0 0 0 0 0.5 1 1 0.5 0 0]
Very good F_5	:	[0 0 0 0 0 0 0.5 1 1 0.5]
Excellent F_6	:	[0 0 0 0 0 0 0 0 0.5 1]

These values of F_1 through F6 are used to obtain the standardized fuzzy scale membership for the overall scores of the samples under study. For values of x ranging from the values in the abscissae, the membership Function Bx is calculated [12], [18] as Equation 6 below:

$$Bx = \frac{X-(a-b)}{b} \text{ or } (a-b) < x < a \;\ldots\ldots\ldots\ldots\ldots (6)$$

$$= \frac{(a+c)-X}{c} \text{ for } a < x < (a + c) \;\ldots\ldots\ldots\ldots\ldots (7)$$

$$= 0 \text{ for all other values } \ldots\ldots\ldots\ldots (8)$$

The values of the fuzzy membership function for the samples and control with varied proportion of rice for x ranging from 0 through 90 and are obtained using equations 6, 7 and 8 above as resultant values. The membership values of the overall sensory values as identified by 10 numbers as given by B_1 through B_{10} in the interval of 0 through 100 is as below:

Table 12 Membership function values

B_1 = (0	0	0.21254266	0.452806	0.69307	0.933334	0.751868679	0.408449	0.065029)
B_2 = (0	0	0.25816748	0.530279	0	0.884783	0.463964682	0.043146	0)
B_3 = (0	0.272531	0.64724398	0.969806	0.454536	0	0	0	0)
B_4 = (0	0.097663	0.4297832	0.761904	0.846957	0.306365	0	0	0)

In the list above, B_1 through B_4 represent the overall sensory scores distribution of control and the samples S_1, S_2, S_3.

Similarity values

For each the samples and control, the membership function is depicted in the values of F_1 through F_6. Upon comparing the membership value functions of B_1 through B_4 with the values of F_1 through F_6, the similarity TSn values for control and the samples were obtained using the equation below:

$$Sn = \frac{F \times BT}{\Sigma(\text{Sensory scale counts for each attribute sample wise})} \;\ldots\ldots.\ (9)$$

The values so obtained are placed in the table below

Table 13 Similarity values for black rice samples

	Scale factors	Control	S_1	S_2	S_3
	Not satisfactory	0	0	0.058284	0.020886
	Fair	0.187743	0.223825	0.600804	0.388532
Sn =	Satisfactory	0.735148	0.471251	0.747637	0.84554
	Good	0.95636	0.586091	0.097206	0.31216
	Very good	0.363301	0.117676	0	0
	Excellent	0.013907	0	0	0

Having obtained the values corresponding to the equation, the relative priority for the samples and control are as:

Control	:	0.95636
S_1	:	0.586091
S_1	:	0.747637
S_1	:	0.84554

The ranks so obtained for the priority in preference of the samples are as:

$S_3 > S_2 >$ Control $> S_1$

Sample S_3 as is evident is the most preferred sample which was prepared using 60 grams of black rice, 400 grams of sugar, 1 liter of water and 1 liter of milk.

CONCLUSION

The study has made interesting reveals about the porridge prepared of black rice. Sample S_3 containing 60 grams of black rice in 1 liter of milk and water each is the most preferred one over the control. The suitable ratio for rice, sugar, milk and water is thus 3:20:51.6:50 and for milk and water is 1:1. This is indicative that black rice porridge with the specified composition is more preferred and hence is a prospective food product with properties of preference and health benefits together. The finding shall be instrumental in serving as guidance to restaurants desirous of substituting white rice in porridge with black rice. This shall further aid in targeting health-conscious consumers.

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