

## Sustainable utilisation of surplus bread as the staple ingredient in product development and challenges in consumer acceptance.

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### Abstract

Authors propose the possibility of recycling bread waste as the main ingredient together with necessary ingredients to produce bread. Altogether five types of bread were made; a control bread with 0% waste bread flour (WBF) substitution, followed by 5%, 10%, 15% and 20% WBF. The current research study initially evaluates and compares the proximate and functional properties of bread waste flour (BWF). In addition, formulates different varieties of bread using different % of bread waste as a substitute for flour along with sensory and colour profiling of baked bread varieties. Moisture content decreased with an increase in BWF content, such that the 20% BWF sample depicted the least moisture content ( $8.97 \pm 0.08$ ). Crude protein and fat composition were influenced positively with an increase in BWF supplementation. 10% BWF sample ( $31.46 \pm 0.16$ ), 5% BWF sample ( $28.52 \pm 0.27$ ) showed the highest value of "L\*". According to consumer acceptance the BWF samples for each texture, taste and crispiness scored higher than control samples. Moreover, higher concentration BWF samples, namely 15% and 20% had higher emulsifying activity and stability. The recycled bread formulated from bread waste highlights the commercial importance of food waste as co-products in the socio-economic conditions of growing and manufacturing areas.

**Keywords:** Food waste, Recycled Bread, Proximate analysis, Sensory consumer acceptance.

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### 1. Introduction

Despite ongoing efforts, the world has an increasing surge in food waste (Kamal et al., 2021) which is causing monumental environmental and substantial economic losses (Giudice et al., 2020). Bread considered the most consumed staple food across the globe (Narisetty et al., 2021) is among the top five commonly wasted food in developed households (Immonen et al., 2020; Narisetty et al., 2021). According to Brancoli et al., (2019) and Narisetty et al., (2021) the global annual wastage of bread is dominated by Europeans households, with the United Kingdom (UK) contributing to about 32% of bread waste at the consumer level. Nevertheless, this is not a unique scenario only limited to Europe, all the same is witnessed globally. According to our integrative literature research, this is due to two significant and interdependent factors. To begin with, bread has a high water activity (0.95), therefore giving bread a relatively short shelf life (Verni et al., 2020). Followed by consumers lack of awareness and insufficient knowledge of storage conditions (Guerra-Oliveira et al., 2021). Shelf life of bread can be increased with use of preservatives, or via increment of preservatives (within limits) already added in commercial breads. However, change in consumer's behaviour is a complex and multifaceted task for instance most consumers prefer fresh bread

## ***Recycling of wasted bread as the staple ingredient***

no later than 1-2 days old (Immonen et al., 2020). Consequently, it is indispensable to first accept that bread waste can be minimized but not eliminated absolutely. It is indeed an unremitting challenge.

This research study essentially is a step forward in this reference. The authors understand that with the growing population and consumer demand, global bread production will increase. This increase will directly influence the bread waste. Accordingly, the authors propose the possibility of recycling bread waste free from any physical and microbial damage as the main ingredient together with flour and essential ingredients to produce different varieties of bread. The objective of the current research study is to (a) evaluate and compare the proximate and functional properties of bread waste flour (b) formulate different varieties of bread using different % of bread waste as a substitute for flour and (c) analyze sensory and colour profiling of baked bread varieties. The outcome of this experiment is expected to contribute towards achieving the United Nation's Sustainable Development Goals (SDGs) 12.3 by reutilising bread waste and thus reducing food waste. The recycled bread formulated from bread waste highlights the commercial importance of food waste as co-products in the socio-economic conditions of growing and manufacturing areas.

## **2. Materials and Methods**

### **2.1. Material and Chemicals**

Analytical grade reagents and chemicals were used. Hexane was purchased from Sigma-Aldrich (St. Louis, MO, USA). Sulfuric acid (H<sub>2</sub>SO<sub>4</sub>) and sodium hydroxide (NaOH) were procured from Merck KGaA, Darmstadt, Germany. Moreover, cooking grade sunflower oil for emulsifying activity and stability analysis was purchased locally from Lotus Semenyih Malaysia.

#### **2.1.2. Sample Collection**

Commercial white waste bread (WB) samples by a local company under the name of "The Italian Baker Sdn Bhd" were collected locally from Lotus Semenyih Malaysia. WB samples were two days past the "best before" date. Control or non-expired (fresh) un-bleached flour sample under the name of Gardenia Bakeries (KL) Sdn Bhd was also bought from Lotus Semenyih Malaysia. The samples were refrigerated at 4°C till further preparation of waste bread flour (WBF).

## **2.2. Method**

### **2.2.1. Experimental Design**

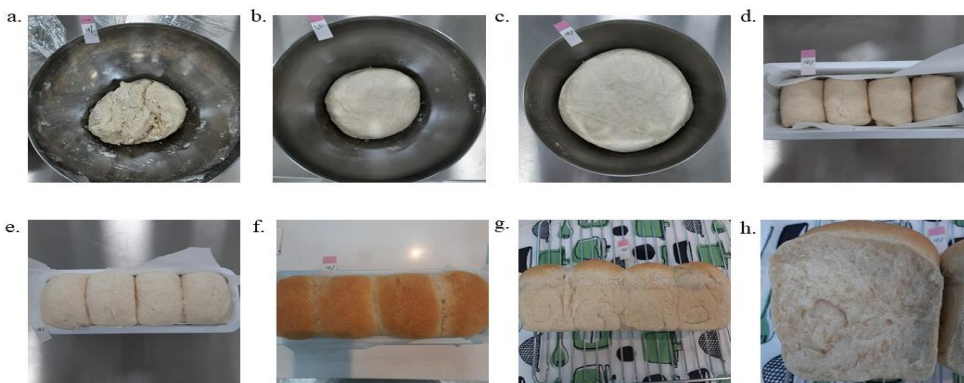
**Preparation of Waste Bread Flour (WBF) and Bread Formulation:** Commercial waste bread (WB) sample was initially oven dried at 30°C for 3 hours using a UN30 Universal Memmert Oven Unit. The dried WB sample was grounded into flour (WBF) using a commercial Conair™ Waring™ Two-speed Laboratory Blender. The particle size of powdered WBF was then passed through a 212µm sieve (US standard Mesh No.70). The sieved WBF samples were used according to Table 1 for the preparation of each bread formulation.

Each bread formulation consisted of flour, salt, oil, sugar and yeast. Altogether five types of bread were made; a control bread with 0% WBF substitution in regular bread flour (Bread A), followed with 5%, 10%, 15% and 20% WBF. The dough was mixed for 7 minutes and stored for fermentation. Small batches of dough (300gm) were baked in preheated oven at 180°C for 35 minutes and then cool down for 24 hours at room temperature.

**Recycling of wasted bread as the staple ingredient**

**Table 1.** Experimental design for bread formulation on wet basis (w/w).

Bread Type	Flour (g)	Bread Waste Flour (BWF) (g)	Water (g)	Salt (g)	Sugar (g)	Yeast (g)	Oil (g)
Control	200	0	88.01	0.55	3.27	1.09	7.09
5%	190	10	88.01	0.55	3.27	1.09	7.09
10%	180	20	88.01	0.55	3.27	1.09	7.09
15%	170	30	88.01	0.55	3.27	1.09	7.09
20%	160	40	88.01	0.55	3.27	1.09	7.09



**Figure 1 A.** Bread making process for control according to the formulation stated in Table 1.



**Figure 1 B.** Bread making process for bread waste flour (BWF) samples including 5%, 10%, 15% and 20%.

## ***Recycling of wasted bread as the staple ingredient***

### **2.2.2. Proximate Analysis**

#### **2.2.2.1. Moisture Content**

The moisture content of the WBF samples was carried out as given by the Association of Official Analytical Chemists (AOAC) (Van Soest et al., 1991). Sample weight was set at 5g and subjected to overnight drying at 100°C in a UN30 Universal Memmert Oven Unit. Difference in weight was calculated to determine moisture content.

#### **2.2.2.2. Fat Content**

Weighed 10g of WBF samples were dried overnight to remove existing moisture at 100°C in a UN30 Universal Memmert Oven Unit. After the removal of moisture, the oil was extracted in a Soxhlet apparatus for about 5 to 6 hours using n-hexane as solvent (Van Soest et al., 1991).

#### **2.2.2.3. Protein Content**

Kjeldahl method was applied to estimate the protein content. Sample weight was set at 5g with a nitrogen factor i.e., 6.25 to calculate protein content as described by Van Soest et al., (1991).

#### **2.2.2.4. Ash Content**

Weighed 10g sample of each of the respective bread was oven dried overnight to remove existing moisture at 100°C in a UN30 Universal Memmert Oven Unit. Then the sample was ignited in a R-1905 Srefo Programmable Muffle Furnace Unit at 550°C for nearly 5 hours (Van Soest et al., 1991). Difference in weight was calculated to determine ash content.

#### **2.2.2.5. Fiber Content**

Fiber content of each of the respective bread was subjected to digestion with 1.25M H<sub>2</sub>SO<sub>4</sub> followed with 1.25M of NaOH under specific conditions (Van Soest et al., 1991). The weight loss residue post digestion was calculated to evaluate the fiber content per 5g of sample weight respectively.

### **2.2.3. Quality Analysis**

#### **2.2.3.1. Colour Profile**

Hunter colorimeter model Colour-Flex (Hunter Associates Laboratory, Reston, VA, USA) was used to conclude the L (lightness), a (redness and greenness), and b (yellowness and blueness) according to the method described by Habib et al., (2014).

#### **2.2.3.2. Sensory Profile**

Participant's (consumer) perceptions were evaluated using the hedonic consumer sensory profile and ranking sensory tests at the Food, Nutrition and Health Science Department's sensory analysis laboratory at University of Nottingham Malaysia. Consumers including 69% females and 31% males aged between 18-39 years old (61%), 40-59 years old (21%) and over 60 years old (18%) were screened using a questionnaire. The main selection criterion for consumers was that they were the ones who consumed bread regularly. No prior information about the samples was provided to the consumers. Moreover, in order to prevent consumers from being biased, they did not receive any monetary incentive for their participation. Altogether 80 participants were included in the sensory evaluation panel. Each bread sample including control, 0%, 5%, 10%, 15% and 20% WBF with dimensions measuring 10 x 3 cm was presented in a disposable black dish with a 3 digit code. Evaluation took place at room temperature

## ***Recycling of wasted bread as the staple ingredient***

using a hedonic taste sheet. Visual appearance, texture, odour, taste, freshness and overall acceptance were evaluated on a structured 9-point hedonic scale. The 9-point hedonic scale ranged from: “1- dislike extremely, 2- dislike very much, 3- dislike, 4- dislike slightly, 5- neither like nor dislike, 6- like slightly, 7- like, 8- like very much and 9- like extremely”. Special instructions were provided to consumers to cleanse their palates between samples. The samples were presented in a sequential monadic way with two repetitions per sample in two different sessions. Each session ranged between 45 minutes to 90 minutes.

### **2.2.4. Functional Modifications**

Evaluation of functional properties included water absorption capacity (WAC, %), emulsifying activity (EA, %), emulsifying stability (ES, %), foam capacity (FC, %) and foam stability (FS, %). The water absorption capacity of the waste bread flour (WBF) was according to Chandra et al., (2015) with minor variation. One gram of WBF was mixed with 20 mL of distilled water for 15 minutes. The WBF slurry was then allowed to stand for 30 minutes at room temperature, followed by centrifugation for 20 minutes at 25°C and 6000 x g. Difference in weight resulted in water absorption per gram WBF.

On the other hand, emulsifying activity (EA) and stability (ES) were analyzed by a method described by Maqsood et al., (2019) with minor modifications. One gram of WBF was homogenized with 20 mL distilled water and sunflower oil in 1:1 ratio. The homogenized WBF slurry was then subjected to centrifugation for 5 minutes at 25°C and 3500 x g. Emulsifying activity (EA) was measured by calculating the ratio of the volume of emulsion layer to the total volume of the WBF slurry mixture in percentage. However, stability of the emulsion (ES) was evaluated by heating the emulsion for 30 minutes at 80°C. After 30 minutes, samples were centrifuged for 5 minutes at 25°C and 3500 x g and the ratio of the volume of emulsion layer to the total volume of the WBF slurry mixture in percentage were noted as the stability of emulsion.

The foam capacity (FC) and stability (FS) was calculated by the methods described by Guo et al., (2015) with minor modifications. One gram of WBF was added to 50 mL and whipped using an Ultra-Turrax homogenizer (Ultra-Turrax T25, IKA, Staufen im Breisgau, Germany) at 16000 rpm for 2 minutes. The total volume was determined at two time intervals (0 and 30 minutes). The volume of foam after whipping was expressed in percentage as FC (Equation 1) as follows:

$$FC (\%) = \frac{\text{Volume of foam after whipping} - \text{Volume of foam before whipping}}{\text{Volume of foam before whipping}} \times 100 \quad (1)$$

The volume of foam was noted 30 minutes after whipping to determine FS (Equation 2) as per percent of initial foam volume as follows:

$$FS (\%) = \frac{\text{Volume of foam 30 minutes after whipping} - \text{Volume of initial foam after whipping}}{\text{Volume of initial foam after whipping}} \times 100 \quad (2)$$

### **2.2.5. Statistical analysis**

All the parameters for proximate analysis, colour profiling and functional modifications were analyzed in triplicate. Analysis of variance (ANOVA) and Tukey's test were used to study the data. Means separation using Tukey's test ( $P < 0.05$ ) was carried out when a significant difference was detected. However, for the sensory profile evaluation, samples were presented in a sequential monadic way with two repetitions per sample per session ( $n = 4$ ). In addition multiple factor analysis was performed in order to relate the consumer's acceptance in hedonic terms with the descriptive sensory profile. All statistical analysis was carried out using SPSS version 28 (SPSS INC., Chicago, IL, USA, 2021).

### **3. Results and discussion**

#### **3.1. Proximate Analysis**

Crucial understanding of the nutritional content is vital initially in formulating balanced rations and accordingly in waste management. Besides, for decades enhancing nutrition (fortification) in bread has been an embryonic opportunity. Consequently, proximate nutritional composition of the BWF supplemented breads; including moisture, fat, protein, fiber and ash content were evaluated (Table 2).

The comparison between control bread and BWF samples show significant differences specifically concerning moisture, fat and protein contents. Moisture content was observed highest in the control sample ( $16.84 \pm 0.08$ ) and decreased with an increase in BWF content. Thus, producing “low moisture content breads” with 20% BWF sample depicting the least moisture content ( $8.97 \pm 0.08$ ). In commercial bread making lower moisture content breads (e.g., bagels and certain sandwich loaves) are characterized by dough with lower flour to water ratio (typically 50-60%) (Chen et al., 2021). Aside customized product development, a lower moisture content can be a contributing factor in increasing the shelf life of bread (Oliveira et al., 2021).

Table 2. Proximate analysis of bread waste flour (BWF) samples in comparison with control.

Bread Type	Moisture (%)	Crude Protein (%)	Crude Fat (%)	Ash (%)	Crude Fiber(%)
Control	$16.84 \pm 0.08^c$	$11.41 \pm 0.81^a$	$4.02 \pm 0.11^a$	$3.64 \pm 0.81^f$	$2.86 \pm 0.10^a$
5%	$14.13 \pm 0.21^a$	$11.97 \pm 0.81^a$	$4.11 \pm 0.81^a$	$3.66 \pm 0.11^a$	$2.96 \pm 0.09^a$
10%	$11.61 \pm 0.33^{ab}$	$14.27 \pm 0.81^{ab}$	$4.09 \pm 0.81^a$	$3.01 \pm 0.40^a$	$3.09 \pm 0.08^a$
15%	$11.42 \pm 0.14^{ab}$	$14.31 \pm 0.06^{ab}$	$4.57 \pm 0.81^b$	$3.12 \pm 0.12^a$	$3.09 \pm 0.11^a$
20%	$8.97 \pm 0.08^b$	$16.11 \pm 0.03^{bc}$	$5.01 \pm 0.81^{bc}$	$3.25 \pm 0.09^b$	$3.01 \pm 0.01^a$

On the contrary, crude protein and fat composition were influenced positively by increase in BWF supplementation.

Crude protein was significantly higher in 20% BWF samples ( $16.11 \pm 0.03$ ). An increase in protein content can be contributed due to the addition of 40g of additional BWF. The same concept is applied to the increment of crude fat. However, since the second most primary component of wheat flour is protein (a complex mixture of gliadins and glutenins), the protein percentage increase is more profound (Platat et al., 2015). Ash and fiber content were observed to be fairly constant with almost negligible differences. Overall the results showed that from a nutritional standpoint the supplementation of bread flour with BWF, fortifies the end product with higher macronutrients, mainly protein and fat.

#### **3.2. Quality Attributes**

##### **3.2.1. Colour Profile Analysis**

Colour is a direct reflection of the baking process which reflects primarily on the quality, including consumer perception, brand identity, marketing and safety (García-Gómez et al., 2022). According to Platat et al., (2015) colour deviations can indicate (i) under-baking (light colour), (ii) over-baking (dark colour) or (iii) inconsistent dough fermentation process.

### Recycling of wasted bread as the staple ingredient

Table 3. systematically evaluate the evolution of colour parameters (L \*, a \*, b \*) for each variety of BWF samples to highlight deviation.

Bread Type	L*	a*	b*
Control	24.71±0.35 <sup>e</sup>	13.14±0.29 <sup>k</sup>	8.23±0.13 <sup>f</sup>
5%	28.52±0.27 <sup>hi</sup>	9.34±0.10 <sup>fg</sup>	7.23±0.14 <sup>e</sup>
10%	31.46±0.16 <sup>m</sup>	6.66±0.14 <sup>cd</sup>	4.04±0.12 <sup>b</sup>
15%	27.11±0.14 <sup>g</sup>	10.83±0.16 <sup>i</sup>	11.49±0.24 <sup>i</sup>
20%	27.78±1.23 <sup>gh</sup>	6.96±0.44 <sup>d</sup>	6.75±0.14 <sup>de</sup>

The differential distribution of colour indexes in this study is directly influenced by proximate composition mainly starch, protein and moisture contents influencing the Maillard reaction causing browning and flavour development (Shokrollahi and Taghizadeh, 2016). The results highlight significant differences ( $P < 0.05$ ) in lightness (L \*), redness (a \*) and yellowness (b \*). Among the four BWF samples analyzed, the 10% BWF sample ( $31.46 \pm 0.16$ ), 5% BWF sample ( $28.52 \pm 0.27$ ) showed the highest value of "L \*" thus being lighter than the rest of the samples. The control bread displays an unusually low L\* value ( $24.7 \pm 0.35$ ), which does not match typical white bread. This can be in accordance to Table 1, where unbleached flour is used to formulate control and other BWF breads. Similarly, the L\* values increase at 5% and 10% substitution but then decrease at 15% and 20%, which contradicts the expected progressive darkening with higher BWF levels due to Maillard browning. Authors relate this paleness as a result of insufficient yeast activity. In other words not enough sugars are produced to caramelize. As for, "a \*" and "b \*" all the values were in the positive range indicating a range of reddish-yellow colour with control and 15% BWF sample depicting the highest value for both, i.e.,  $13.14 \pm 0.29$  and  $10.83 \pm 0.16$ , respectively. Both 10% BWF and 20% BWF depicted a lower value of "a \*". On the other hand, the 10% BWF sample ( $4.04 \pm 0.12$ ) due to lower values of "b \*" represented a less yellow colouration in comparison to the other samples. Conversely, 15% BWF ( $11.49 \pm 0.24$ ) had the highest values of "b \*".

#### 3.2.2. Sensory Profile Analysis

According to Upadhyay et al., (2023) characteristics in bread, such as texture, odour, colour, taste and freshness are important parameters to consumer's acceptance. Our current research focussing on generating a nutrition enhancement process via addition of surplus bread as "flour" impacts the overall acceptance of bread. For this reason, the four BWF samples, along with the control sample were subjected to a panel of 80 participants using a 9-point Hedonic rating scale (Lim et al., 2009). Sensory attributes calculated via colour, flavour, taste, crispiness, texture are shown in Table 4, where different addition of BWF samples impact bread quality. Overall acceptability was calculated by taking average of all the scores of sensorial attributes (Table 4). The highest colours score was awarded for both 15% and 20% BWF samples from 8.87 to 8.89 respectively. The collected data highlighted that in comparison to the control sample, all the BWF samples scored higher.

Table 4. Differences in sensory profile of bread waste flour (BWF) samples in comparison with control.

Bread Type	Colour	Flavour	Taste	Crispiness	Texture	Overall Acceptability
Control	7.91±0.01 <sup>ef</sup>	6.29±0.10 <sup>d</sup>	8.23±0.11 <sup>hi</sup>	8.18±0.75 <sup>j</sup>	6.43±0.13 <sup>d</sup>	7.23±0.13 <sup>f</sup>
5%	8.43±0.02 <sup>f</sup>	8.25±0.15 <sup>g</sup>	8.51±0.05 <sup>e</sup>	8.15±0.24 <sup>c</sup>	7.40±0.29 <sup>b</sup>	7.23±0.14 <sup>e</sup>
10%	8.22±0.23 <sup>ab</sup>	8.43±0.01 <sup>a</sup>	6.21±0.07 <sup>bc</sup>	8.44±0.34 <sup>f</sup>	8.70±0.54 <sup>k</sup>	7.04±0.12 <sup>b</sup>
15%	8.87±0.08 <sup>a</sup>	8.69±0.49 <sup>l</sup>	8.48±0.06 <sup>l</sup>	8.49±0.19 <sup>f</sup>	8.29±0.10 <sup>d</sup>	7.49±0.24 <sup>i</sup>
20%	8.89±0.17 <sup>gh</sup>	8.14±0.16 <sup>b</sup>	7.31±0.31 <sup>a</sup>	8.52±4.62	8.25±0.15 <sup>g</sup>	7.75±0.14 <sup>de</sup>

### Recycling of wasted bread as the staple ingredient

This could be due to an increase in the incorporation of BWF resulting in a direct increment of browning colour due to maillard reaction during baking (García-Gómez et al., 2022). Similarly, the highest flavour score was obtained by supplemented BWF samples, namely 15% and 10% respectively. The flavour score for the control sample was significantly lower (6.29). These results are contrary to other research studies (Chandra et al., 2015; García-Gómez et al., 2022; Shokrollahi and Taghizadeh, 2016). A decrease in flavour concerning increase in BWF% was not observed in this research study, which can be reasoned with “flavour” being “perceptive”. In other words, colour can be identified and accepted in a tangible manner. However, flavour is a more complex multisensory experience that goes beyond just taste and is co-dependent on attributes such as texture, taste and crispiness. Keeping this in view and comparing the results of texture, taste and crispiness with flavour, a similar perceptive can be observed. BWF samples for each texture, taste and crispiness scored higher than control samples. According to authors this highlights a significant issue in sensory evaluations, such that the use of the same set of labels in different studies is not a guarantee that the same sensory concept is measured. Moreover, the sensorial for overall acceptability data revealed negligible change between control and 5% BWF samples. The increased incorporation of BWF in 10% and onward samples coincided in the range of “light slightly” to “like moderately” with 20% BWF sample ranking significantly higher.

### 3.3. Functional Attributes

Functional properties are explicitly associated with the molecular structure, particle size, composition and type of applied processing and unit operation (Bußler et al., 2016; Kamal et al., 2023; Ly et al., 2018). Correspondingly, the current section identifies a dependent functional relationship with an increase in BWF supplementation. According to Table 5, no particular trend was observed in evaluating water holding capacity (WHC) such that the control and 5% BWF sample were almost similar in value, followed by 10% BWF sample with the lowest recorded WHC ( $2.06 \pm 0.19$ ). The decrease in WHC with an increase in flour constituents has been reported in literature as lower availability of polar amino acids and hydrophilic polysaccharides (Chandra et al., 2015). However, in the current study, authors observed a sudden increment in WHC at 15% ( $5.19 \pm 0.11$ ) followed by a major decrement at higher concentrations. Keeping in view the dependant factors including molecular structure, particle size, composition and type of applied processing and unit operation, for the given experimental design optimum WHC occurs at 15%. Higher WHC is a result of (a) increase in availability of polar amino acids and (b) increase in amylose leaching, resulting in higher solubility and loss of starch crystalline structure, thus increasing the hydrophilic constituents and viscosity (Boye et al., 2010; Hojilla-Evangelista et al., 2009). Another functional property creating electrostatic repulsion on oil droplet surface, essential in salad dressings, meat products and various frozen desserts etc is discussed here as “Emulsion activity and stability (EA and ES) respectively.

Table 5. Functional properties of bread waste flour (BWF) samples in comparison with control.

Bread Type	Water Holding Capacity (WHC)	Emulsifying activity (EA) %	Emulsifying Stability (ES) %	Foaming Capacity (FC) %	Foaming Stability (FS) %
Control	$3.10 \pm 0.70^a$	$22.05 \pm 0.90^a$	$45.13 \pm 0.80^a$	$5.01 \pm 0.11^a$	$22.21 \pm 0.01^a$
5%	$3.13 \pm 0.17^b$	$21.05 \pm 0.12^b$	$45.11 \pm 0.22^b$	$2.02 \pm 0.05^b$	$24.29 \pm 0.03^b$
10%	$2.06 \pm 0.19^c$	$21.05 \pm 0.18^c$	$48.22 \pm 0.18^c$	$3.90 \pm 0.03^c$	$33.13 \pm 0.01^c$
15%	$5.19 \pm 0.11^b$	$25.42 \pm 0.11^b$	$52.64 \pm 0.41^b$	$7.19 \pm 0.11^b$	$42.15 \pm 0.0^b$
20%	$3.38 \pm 0.04^b$	$26.07 \pm 0.03^b$	$56.17 \pm 0.13^b$	$5.81 \pm 0.05^b$	$24.17 \pm 0.0^b$

Table 5 clearly illustrates an increasing EA and ES development with an increase in BWF supplementation. Higher concentration BWF samples, namely 15% and 20% found to be efficient in tabulating higher EA and ES with 20% BWF samples collectively showcasing the highest EA ( $26.07 \pm 0.19$ ) and ES ( $56.17 \pm 0.13$ ). In the current study, higher EA and ES reflect a colloid where the existing emulsifying agents (mainly amphiphilic proteins and polysaccharides) adsorb at the oil-water interface reducing interfacial tension and stabilizing emulsions. Similarly proteins with good foaming capacity and stability (FC and FS) are vital in the food product development. The effect of increase in BWF supplementation was positive with 15% BWF as the optimum higher value ( $7.19 \pm 0.11$ ).

## ***Recycling of wasted bread as the staple ingredient***

Additionally, there was a direct relationship between FC and FS where increase in BWF supplementation continued to form numerous small bubbles surrounded by flexible protein film, causing a delay in collapse thus increasing stability of the foam.

### **4. Conclusion**

Two key outcomes of this study are: First surplus (wasted) bread was valorised as “bread waste flour” to formulate four different types of bread. Evaluation of proximate composition shows a direct increment in major micronutrients mainly protein and fat. The results further show improved functional properties and highlighted optimum BWF supplementation at 15%. BWF samples for each texture, taste and crispiness scored higher than control samples. Moreover, the sensorial for overall acceptability data revealed negligible change between control and 5% BWF samples. The increased incorporation of BWF in 10% and onward samples coincided in the range of “light slightly” to “like moderately” with 20% BWF sample ranking significantly higher. Secondly, authors wanted to map the valorisation potential of surplus bread using circular management pathway for human consumption. According to food waste hierarchy, under priority of action for policy and action against food waste, the alternate management pathway for surplus bread include (a) food donations, (b) reduced prices, (c) ethanol production or (d) animal feed. Incorporation of BWF as an ingredient in bread making supports a more sustainable alternative pathway for production and consumption of food. It is crucial to prevent losses and valorise surpluses for human consumption. To abridge, authors via this study believe in the application of a circular system which reduces the devastating environmental impact and is also efficient from a social and economic point of view.

**Author agreement:** We the undersigned declare that this manuscript is original, has not been published before and is not currently being considered for publication elsewhere.

**CRedit authorship** contribution statement: Hina Kamal: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data, along with writing the original draft. Tan Kah Ee: Contributed reagents, materials, analysis tools, along with performing the experiments. Asgar Ali: Supervision; Validation; Project administration; Funds acquisition; Writing - review and editing.

**Competing Interests:** The authors declare that they have no competing interests.

**Ethical concern:** The sensory experiments conducted in this research study were in accordance with the established ethical guidelines and informed consent obtained from the participants. The current study received no objection from the ethical committee of research in University of Nottingham Malaysia (Ref. N° 2023-000071/MS/MESRS/CERS, January 11<sup>th</sup>, 2023).

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## ***Recycling of wasted bread as the staple ingredient***

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