

# Effect of Wheat Bran Particle Size and Level of Substitution on the Physicochemical, Textural and Sensory Quality of Fibre-Enriched Cookies

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## Research Article

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# Abstract

Wheat bran is an abundant by-product of roller milling and a rich source of dietary fibre, minerals and B vitamins, yet its incorporation into baked goods is limited by adverse effects on texture, colour and flavour. This study examined how bran particle size and substitution level affect cookie quality. Wheat bran was fractionated using 30-, 36- and 52-mesh sieves and substituted for refined wheat flour (maida) at 5, 10 and 15% (w/w), giving nine treatments (T1–T9) plus a 100% flour control (T0). Cookies were baked at 160°C for 30 min and evaluated for diameter, thickness, spread ratio, proximate composition (moisture, fat, protein, ash, crude fibre, carbohydrate by difference), instrumental hardness (texture analyser, knife-edge cutting test) and sensory acceptability (9-point hedonic scale). Bran incorporation raised crude fibre from 2.55% (control) to 4.52–7.28% and increased moisture, fat, protein and ash slightly, while carbohydrate by difference fell from 72.59% to 66.91%. Cookies with 5% bran generally spread more than the control, whereas spread tended to fall as bran level rose. Peak cutting force rose with bran level within each mesh size (e.g. 5.66 → 10.39 → 11.70 kg for 52-mesh bran at 5, 10 and 15%). Cookies made with the finest bran (52 mesh) received the highest sensory scores, with T9 (15% bran, 52 mesh) rated highest for overall acceptability (7.85/9) and texture (8.00/9). Fine bran therefore allows a substantial fibre increase with acceptable, and in this panel preferred, sensory quality.

## 1. Introduction

Consumers increasingly look for foods that support health without sacrificing taste, and bakery products – bread, biscuits and cookies in particular – are among the most widely consumed processed foods worldwide. In India, bread and biscuits account for the large majority of the organised bakery sector. Cookies are, however, typically formulated from refined wheat flour, sugar and fat, and are therefore energy-dense but low in dietary fibre, protein and micronutrients. Their long shelf life, low production cost and convenience make them an attractive vehicle for nutritional enrichment (Akubor, 2003).

Wheat bran, the outer layers of the grain comprising pericarp and aleurone, is removed during refining and is widely available at low cost. It is rich in insoluble dietary fibre (notably arabinoxylans and cellulose), minerals, B-group vitamins and phenolic antioxidants (Pomeranz, 1988; Shewry, 2009). Dietary fibre is associated with improved bowel function, better glycaemic control, lower plasma cholesterol and increased satiety. Against these benefits, bran addition to baked goods usually darkens colour, introduces a bran flavour, and alters dough water absorption, spread and texture (Vratanina and Zabik, 1978; Sharma and Chauhan, 2002). Bran also contains phytate, which can reduce mineral bioavailability (López et al., 2002).

Particle size is a key but under-studied lever for controlling these trade-offs. Coarse bran tends to be gritty and to disrupt dough structure, whereas finer fractions have greater surface area and water-holding capacity and may be less perceptible in the mouth (Agrobio, 2010). Previous work has shown acceptable muffins with up to 30% bran (Golden et al., 1995) and acceptable cookies with 20% coconut dietary fibre (Yalegama and Chavan, 2006), and has reported reduced spread with defatted rice bran in cookies

(Sekhon et al., 1997) and biscuits (Haque and Shams-ud-din, 2002). Systematic comparisons of several bran particle sizes at several levels in the same formulation, combined with instrumental texture measurement, are scarce.

The objectives of this study were therefore: (i) to develop cookies incorporating wheat bran of three particle-size fractions at three substitution levels; (ii) to determine their physical, proximate and sensory properties; (iii) to quantify the effect of bran particle size on cookie quality; and (iv) to characterise cookie hardness with a texture analyser.

## **2. Materials and Methods**

### **2.1 Raw materials**

Refined wheat flour (maida), wheat bran, vanaspati (hydrogenated vegetable fat, used as shortening), sugar, salt, baking powder and eggs were purchased from the local market in Allahabad, India.

### **2.2 Bran fractionation**

Wheat bran was sieved through 30-, 36- and 52-mesh sieves to obtain fractions of different particle size. Sugar was ground before use.

### **2.3 Experimental design and cookie preparation**

Nine treatments were prepared by replacing refined flour with bran at 5, 10 or 15% (w/w) for each of the three mesh sizes, together with a control containing 100% refined flour (Table 1). Flour and bran were mixed thoroughly to give a dry mix. Sugar and fat were creamed to a paste, and the dry mix, egg and baking powder were added and mixed into a dough. The dough was sheeted, cut with a cutter, baked at 160°C for 30 min, cooled to room temperature and packed in low-density polyethylene (LDPE) pouches, which were heat-sealed and stored at ambient temperature.

Table 1  
Treatments.

| Code         | Bran mesh | Bran (%) | Flour (%) |
|--------------|-----------|----------|-----------|
| T0 (control) | –         | 0        | 100       |
| T1           | 30        | 5        | 95        |
| T2           | 30        | 10       | 90        |
| T3           | 30        | 15       | 85        |
| T4           | 36        | 5        | 95        |
| T5           | 36        | 10       | 90        |
| T6           | 36        | 15       | 85        |
| T7           | 52        | 5        | 95        |
| T8           | 52        | 10       | 90        |
| T9           | 52        | 15       | 85        |

## 2.4 Physical characteristics

Weight was measured on an electronic balance (0.01 g). Diameter and thickness followed AACC (2000). For diameter, six cookies were placed edge to edge, measured with a ruler, rotated 90° and re-measured; the mean was taken. For thickness, six cookies were stacked and the total height measured; this was repeated five times. Spread ratio was calculated as (width/thickness) × 10

## 2.5 Proximate composition

Moisture was determined by oven drying at  $130 \pm 1^\circ\text{C}$  for 1 h (Kent-Jones, 1962). Protein was determined by micro-Kjeldahl ( $\text{N} \times 6.25$ ; AOAC, 1984). Fat was determined by Soxhlet extraction with petroleum ether (b.p. 60–80°C) (AOAC, 1990). Ash was determined by incineration at  $550 \pm 5^\circ\text{C}$ . Crude fibre was determined by sequential digestion with 1.25%  $\text{H}_2\text{SO}_4$  and 1.25% NaOH (AOAC, 1975). Carbohydrate was calculated by difference:  $100 - (\text{moisture} + \text{fat} + \text{protein} + \text{ash} + \text{fibre})$ .

## 2.6 Texture analysis

Hardness was measured with a texture analyser fitted with a Warner-Bratzler blade (knife edge, slotted insert) and a 25 kg load cell, in compression mode with return-to-start. Pre-test, test and post-test speeds were 1.5, 2.0 and 10.0 mm/s, travel distance 5 mm and auto trigger force 25 g. Cookies were placed centrally under the blade, and peak force (the first major peak, at which the cookie fractured) was taken as hardness.

## 2.7 Sensory evaluation

Cookies were evaluated for colour, taste, aroma, flavour, texture, appearance and overall acceptability on a 9-point hedonic scale (1 = dislike extremely, 9 = like extremely) (Ranganna, 1986).

## **2.8 Statistical analysis**

The experiment followed a completely randomised design.

## **3. Results and Discussion**

### **3.1 Physical characteristics**

Cookie diameter ranged from 46.2 to 50.0 mm and thickness from 8.3 to 9.4 mm (Table 2). The control (47.0 mm, 9.2 mm) was exceeded in diameter by 5% bran cookies of every mesh size, with 30-mesh bran giving the greatest value (T1, 50.0 mm). Diameter then declined with increasing bran level within each mesh size, to 46.2–48.0 mm at 15%. This biphasic pattern – an initial increase followed by a decrease – agrees with the report of Haque and Shams-ud-din (2002) for bran-supplemented biscuits.

Spread ratio is an established quality indicator for cookies, with larger spread generally preferred (Finney and Morris, 1950). Reported spread ratios were higher than the control (51.08) in all bran treatments and decreased as bran level rose within each mesh size (e.g. 56.32 → 54.88 → 52.47 for 36-mesh bran). Reduced spread at higher bran levels is consistent with the greater water absorption of bran, which increases dough viscosity and limits flow during baking (Vratanina and Zabik, 1978; Sekhon et al., 1997). The initial increase at 5% may reflect incomplete hydration of coarse particles at low inclusion levels, although this was not tested here.

Table 2  
Diameter, thickness and spread ratio of cookies.

| Treatment | Diameter (mm) | Thickness (mm) | Spread ratio (as reported) | Spread ratio (recalculated, W/T × 10) |
|-----------|---------------|----------------|----------------------------|---------------------------------------|
| T0        | 47.0          | 9.2            | 51.08                      | 51.09                                 |
| T1        | 50.0          | 9.4            | 55.83                      | 53.19                                 |
| T2        | 48.0          | 8.9            | 53.93                      | 53.93                                 |
| T3        | 48.0          | 8.3            | 52.86                      | 57.83                                 |
| T4        | 49.0          | 8.7            | 56.32                      | 56.32                                 |
| T5        | 48.3          | 8.8            | 54.88                      | 54.89                                 |
| T6        | 46.2          | 9.4            | 52.47                      | 49.15                                 |
| T7        | 47.8          | 8.6            | 55.58                      | 55.58                                 |
| T8        | 47.6          | 8.6            | 54.23                      | 55.35                                 |
| T9        | 46.4          | 8.5            | 52.90                      | 54.59                                 |

## 3.2 Proximate composition

Proximate results are summarised in Table 3. Moisture rose slightly with bran level (3.39% in the control to 3.52% in T9), consistent with the high water-binding capacity of bran fibre (Vratanina and Zabik, 1978). All values are low enough to be consistent with the crisp texture and extended shelf stability expected of cookies (Wade, 1988).

Crude fibre was the attribute most affected by bran addition, rising from 2.55% (control) to 4.52–4.58% at 5% bran, 6.55–6.63% at 10% and 6.80–7.28% at 15%. T9 (15% bran, 52 mesh) had the highest fibre (7.28%), nearly three times the control. Increases of this kind with wheat bran have been reported in biscuits (Rauf, 2004). Differences between mesh sizes within a level were small ( $\leq 0.08$  percentage points at 5 and 10%) and not consistent at 15% (T3 6.92 > T6 6.80), so a particle-size effect on measured crude fibre cannot be asserted from these data. Increases in protein (7.055 → 7.075–7.089%), fat (13.45 → 13.48–13.56%) and ash (0.919 → 0.923–0.944%) were similarly modest. Although each rose with bran level and was numerically highest in the finest fraction, the particle-size differences are within the range of ordinary analytical variation and should be confirmed with replicated data and post-hoc tests before any mechanistic interpretation (such as greater concentration of nutrients in fine fractions) is offered.

Carbohydrate by difference decreased from 72.59% (control) to 66.91% (T9), an expected consequence of replacing starch-rich flour with fibre- and protein-rich bran in a difference-based calculation.

Table 3  
Proximate composition of cookies (%).

| Treatment | Moisture | Fat   | Protein | Ash   | Crude fibre | Carbohydrate (by difference) |
|-----------|----------|-------|---------|-------|-------------|------------------------------|
| T0        | 3.39     | 13.45 | 7.055   | 0.919 | 2.55        | 72.59                        |
| T1        | 3.42     | 13.48 | 7.075   | 0.923 | 4.52        | 70.53                        |
| T2        | 3.43     | 13.50 | 7.077   | 0.930 | 6.55        | 68.51                        |
| T3        | 3.45     | 13.52 | 7.082   | 0.935 | 6.92        | 68.12                        |
| T4        | 3.49     | 13.50 | 7.078   | 0.926 | 4.55        | 70.45                        |
| T5        | 3.50     | 13.52 | 7.081   | 0.931 | 6.59        | 68.33                        |
| T6        | 3.51     | 13.54 | 7.084   | 0.938 | 6.80        | 68.13                        |
| T7        | 3.46     | 13.52 | 7.082   | 0.929 | 4.58        | 70.43                        |
| T8        | 3.48     | 13.54 | 7.086   | 0.935 | 6.63        | 68.33                        |
| T9        | 3.52     | 13.56 | 7.089   | 0.944 | 7.28        | 66.91                        |

### 3.3 Instrumental hardness

Peak cutting force (Table 4) was lowest for 5% bran cookies made with 36- and 52-mesh bran (T4, 5.55 kg; T7, 5.66 kg) and 30-mesh bran (T1, 6.78 kg), all below the control (10.21 kg), indicating more brittle, easily fractured cookies at low inclusion. Force then increased with bran level within every mesh size: 6.78 → 7.72 → 11.29 kg (30 mesh), 5.55 → 9.95 → 12.97 kg (36 mesh) and 5.66 → 10.39 → 11.70 kg (52 mesh). Bran fibre dilutes and interrupts the gluten–starch matrix while binding water, which is likely to produce a denser, harder crumb at higher inclusion; the lower hardness at 5% may reflect the greater spread and thinner structure observed at this level.

At 15% bran the 52-mesh cookies (T9, 11.70 kg) were softer than 36-mesh cookies (T6, 12.97 kg) but harder than 30-mesh cookies (T3, 11.29 kg), so a consistent benefit of finer bran for hardness is not evident from the instrumental data alone. Hardness is also influenced by cookie thickness and dimensions; the dimensions of tested samples should be reported.

Table 4  
Hardness (peak cutting force) of cookies.

| Treatment | Peak force (kg) |
|-----------|-----------------|
| T0        | 10.208          |
| T1        | 6.776           |
| T2        | 7.715           |
| T3        | 11.285          |
| T4        | 5.550           |
| T5        | 9.947           |
| T6        | 12.967          |
| T7        | 5.657           |
| T8        | 10.393          |
| T9        | 11.70           |

### 3.4 Sensory evaluation

Sensory scores are given in Table 5. Control and 30-/36-mesh cookies were rated in the ‘like slightly’ to ‘like moderately’ range (mostly 5.3–6.6), whereas 52-mesh cookies, particularly T8 and T9, scored substantially higher (7.4–8.0, ‘like very much’). T9 had the highest overall acceptability (7.85) and texture score (8.00), followed by T8 (7.71). The pattern is consistent with the expectation that finer bran gives a smoother mouthfeel and less visible speckling than coarse bran. Within the 52-mesh series, acceptability rose with bran level (6.42, 7.71, 7.85), contrary to most reports in which flavour response declines as bran level rises (Sharma and Chauhan, 2002). This unusual result may reflect the cookie base, the small panel, or the control being rated low; panel size and any sample-order effects should be reported so readers can evaluate it. The authors observed slightly darker colour at 15% bran, which remained within acceptable limits.

Table 5  
Sensory scores (9-point hedonic scale; means).

| Treatment | Colour | Taste | Aroma | Flavour | Texture | Appearance | Overall acceptability |
|-----------|--------|-------|-------|---------|---------|------------|-----------------------|
| T0        | 6.28   | 6.14  | 5.85  | 5.57    | 6.00    | 5.42       | 5.57                  |
| T1        | 6.71   | 6.42  | 7.42  | 6.00    | 6.00    | 5.57       | 5.57                  |
| T2        | 6.42   | 6.57  | 7.42  | 6.42    | 6.00    | 5.57       | 5.42                  |
| T3        | 6.14   | 6.57  | 5.57  | 6.00    | 5.57    | 6.14       | 6.00                  |
| T4        | 5.85   | 6.42  | 5.71  | 6.42    | 6.00    | 6.14       | 5.28                  |
| T5        | 6.42   | 6.57  | 6.42  | 6.28    | 6.28    | 6.42       | 6.28                  |
| T6        | 6.28   | 6.57  | 6.14  | 6.57    | 6.14    | 6.28       | 6.28                  |
| T7        | 7.71   | 7.57  | 7.42  | 7.42    | 7.42    | 6.14       | 6.42                  |
| T8        | 7.57   | 7.42  | 7.71  | 7.57    | 7.57    | 7.42       | 7.71                  |
| T9        | 7.71   | 7.71  | 7.57  | 7.71    | 8.00    | 7.71       | 7.85                  |

### 3.5 Statistical analysis

### 3.6 Nutritional and practical implications

A 15% substitution with 52-mesh bran raised crude fibre by about 4.7 percentage points relative to the control, a substantial improvement for a snack item, while remaining the most acceptable formulation to the panel. Because fibre content is on a fresh-weight basis, a typical 30 g serving would contribute a meaningful fraction of daily fibre intake. Claims regarding health benefits should be confined to the established benefits of dietary fibre, as the present study did not include any physiological or clinical measurements. Phytate content and mineral bioavailability were not assessed and warrant investigation, as bran-rich products may reduce zinc, iron and calcium availability (López et al., 2002).

## 4. Conclusions

Substituting refined flour with wheat bran at 5–15% increased the fibre content of cookies up to about 2.9-fold and produced modest increases in moisture, protein, fat and ash. Higher bran levels reduced spread and increased cutting force. Cookies made with the finest bran fraction (52 mesh) were the most acceptable to the sensory panel, and the 52-mesh, 15% bran formulation (T9) scored highest for overall acceptability, texture and fibre content. Fine bran therefore appears to be the better choice for fibre-enriched cookies. Future work should include replicated data with variance estimates, bran particle-size distribution by laser diffraction, water absorption and dough rheology, measured shelf-life, phytate and mineral bioavailability, and consumer testing.

# Declarations

## Conflict of interest:

none

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none

## Author Contribution

Sagar Rahul Mane: Conceptualization, methodology, investigation, formal analysis, data curation, writing – original draft preparation, and writing – review & editing.

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