# CHAPTER 4: RESULTS

## 4.1 RAW MATERIALS

### *4.1.1 Bran*

The composition of bran fractions obtained from a standard grist of hard bread wheat is given in Table 12.

**Table 12: Proximate composition (%) of brans**

| Bran | Moisture | Protein[a] (N×5.7) | Ash[b] | Fat[b] | Fibre[b] (acid detergent) | Starch[b] |
|---|---|---|---|---|---|---|
| Pollard | 10.5 | 17.3 | 4.1 | 6.4 | 9.5 | 28.4 |
| Heat-treated pollard | 10.0 | 17.4 | 4.2 | 6.4 | 9.8 | 28.0 |
| Select | 11.3 | 15.3 | 5.6 | 5.8 | 15.0 | 20.0 |
| Heat-treated select | 11.0 | 15.3 | 5.6 | 5.8 | 16.4 | 19.8 |
| Digestive | 12.0 | 15.4 | 6.3 | 5.6 | 18.8 | 13.5 |
| Heat-treated digestive | 11.7 | 15.4 | 6.4 | 5.6 | 19.4 | 13.2 |

[a]12% moisture basis
[b]Dry basis

From this table it is evident the Digestive bran had the highest fibre and ash content, with an accompanying low fat and starch content. Pollard had highest fat and starch content, and roughly only half of the fibre and starch of digestive bran. Select bran had values between Pollard and Digestive bran. Heat treatment did not have any significant effect on bran composition.

### *4.1.2 Base flour*

The properties of the base flour are given in Table 13.

**Table 13: Base flour properties**

| | |
|---|---|
| **Property** | |
| Moisture (%) (Brabender) | 12.2 |
| Ash (%) | 0.76 |
| Kent Jones colour units | 4.00 |
| Falling number (s) | 485 |
| Protein (%) (N×5.7 - dry basis) | 13.63 |
| Diastatic activity (%) | 2.39 |
| Damaged starch (%) | 13.61 |
| Wet gluten (%) | 31.34 |
| Baking performance | B1 (good commercial quality) |
| Bread height (cm) | 15.3 |
| **Chopin alveograph** | |
| Stability P (Height×1.1mm) | 103.4 |
| Distensibility L (mm) | 94 |
| P/L value | 1.10 |
| Strength ($cm^2$) | 28.0 |
| **Brabender farinograph (500 BU)** | |
| Water absorption | 64.5 |
| Development time (min) | 5.4 |
| Stability (min) | 12.7 |
| **Brabender extensograph** | |
| Strength ($cm^2$) | 112.0 |
| Extensibility (cm) | 21.1 |

The base flour was a fairly strong flour with a protein content of 13.6%. Water absorption was 64.5%. Dough development time and stability, as shown by the farinograph data, were good, and the extensograph proved that the dough had a fairly high resistance and extensibility.

## 4.2 IMAGE ANAYSIS

A binary image of the different brans is presented in Figure 17.

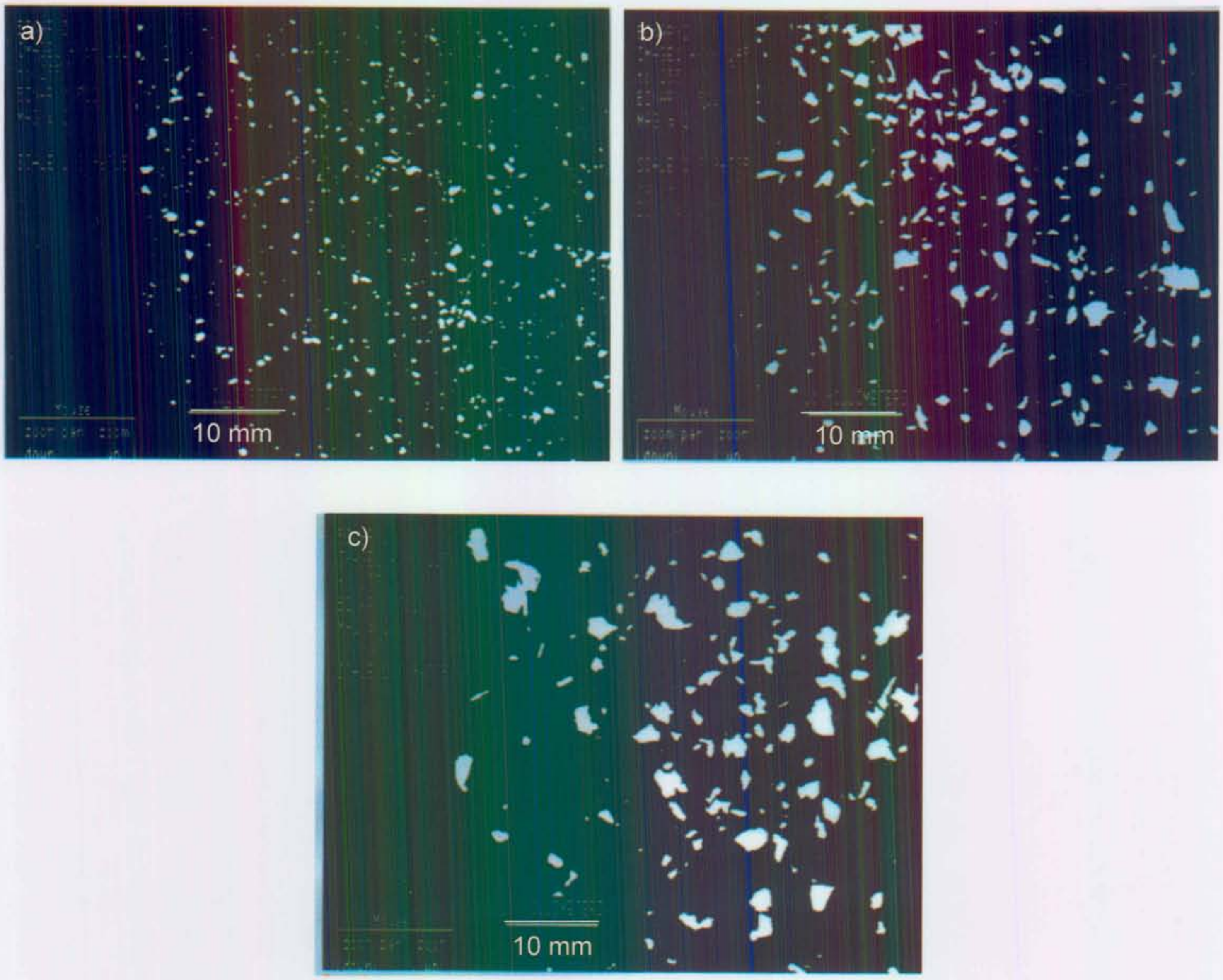
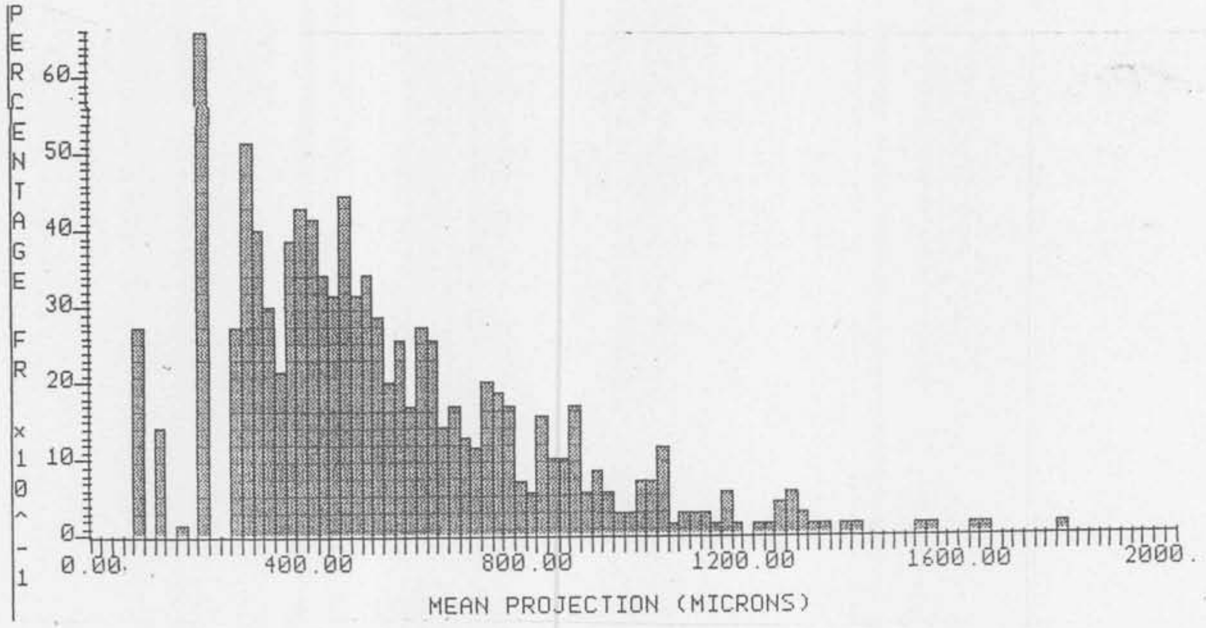


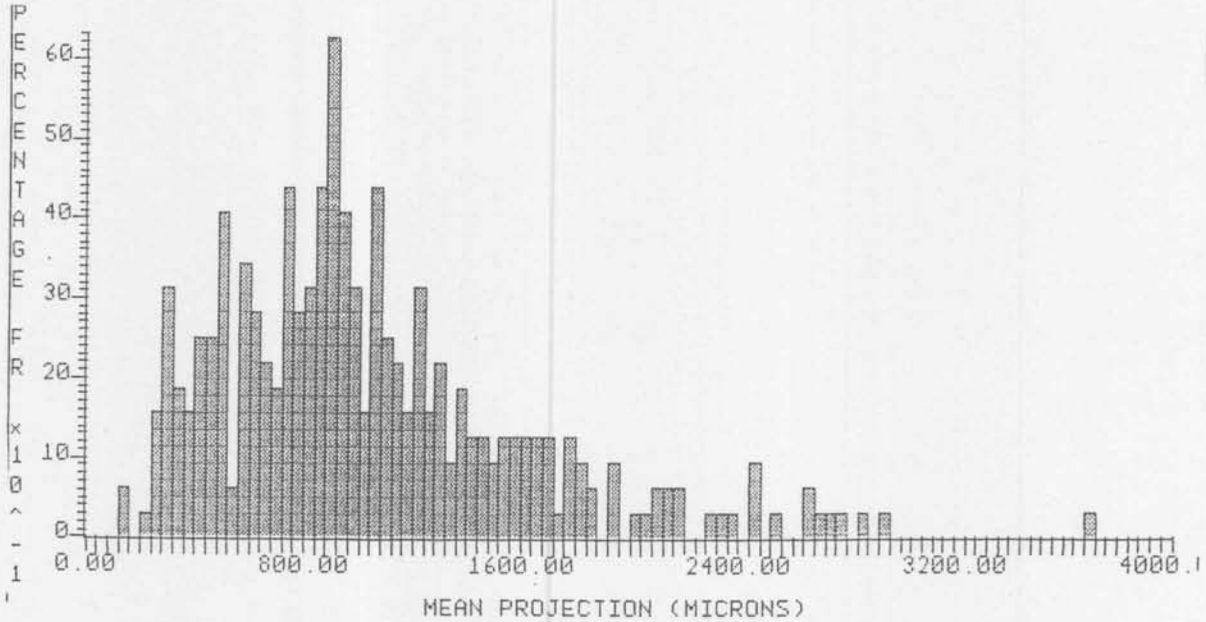

**Fig. 17:** **Image analysis of a) Pollard; b) Select bran; and c) Digestive bran**

A graphical representation of the mean projection of the different brans in a preliminary trial, as determined by IA, is given in Figure 18.

a)




b)



c)

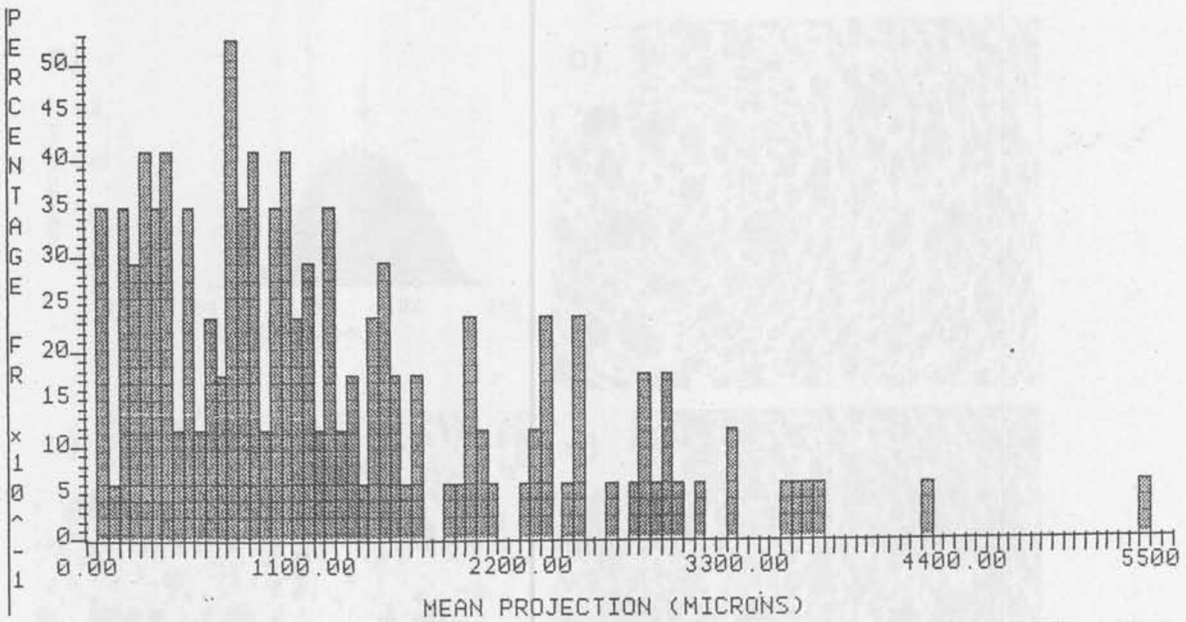



**Fig. 18: Mean projection of a) Pollard; b) Select bran; and c) Digestive bran particles**

Pollard was the smallest particles (85 % of the Pollard particles was smaller than 800 μm), followed by Select (73% was smaller than 1200 μm) and Digestive bran particles (64% was smaller than 1100 μm and 18% was lying between 1100 and 2200 μm). In a subsequent trial with bigger samples, Pollard was found to have an average mean projection of 0.6 mm, while Select and Digestive brans had average mean projections of 1.4 mm and 3.2 mm respectively. These values were consistent with the sieving range specified for the different brans. Despite the differences in size, the aspect ratios of the particles of the three types of bran were similar: Pollard 1.50, Select 1.60 and Digestive 1.46, showing that the bran types had the same general shape. Table 14 shows the complete results of IA of the different bran types that were used in the rest of this study.

**Table 14: Properties of different bran types as analysed by image analysis**

| Bran type | Parameter | Mean value | Standard deviation |
|---|---|---|---|
| Pollard | No. of particles in field | 755 | |
| | Area | $2.50 \times 10^5$ µm$^2$ | $2.19 \times 10^5$ |
| | External perimeter | 1618 µm | 898 |
| | Min. projection | 467 µm | 184 |
| | Max. projection | 692 µm | 334 |
| | Mean projection | 586 µm | 250 |
| | Aspect ratio | 1.50 | 0.38 |
| Select | No. of particles in field | 253 | |
| | Area | $1.33 \times 10^6$ µm$^2$ | $1.28 \times 10^6$ |
| | External perimeter | 4498 µm | 2651 |
| | Min. projection | 1061 µm | 521 |
| | Max. projection | 1720 µm | 911 |
| | Mean projection | 1395 µm | 705 |
| | Aspect ratio | 1.61 | 0.42 |
| Digestive | No. of particles in field | 56 | |
| | Area | $6.65 \times 10^6$ µm$^2$ | $5.67 \times 10^6$ |
| | External perimeter | 11651 µm | 7665 |
| | Min. projection | 2550 µm | 1274 |
| | Max. projection | 3848 µm | 2135 |
| | Mean projection | 3231 µm | 1747 |
| | Aspect ratio | 1.46 | 0.45 |

## 4.3 SEM

Scanning electron micrographs of the different brans are presented in Figure 19.

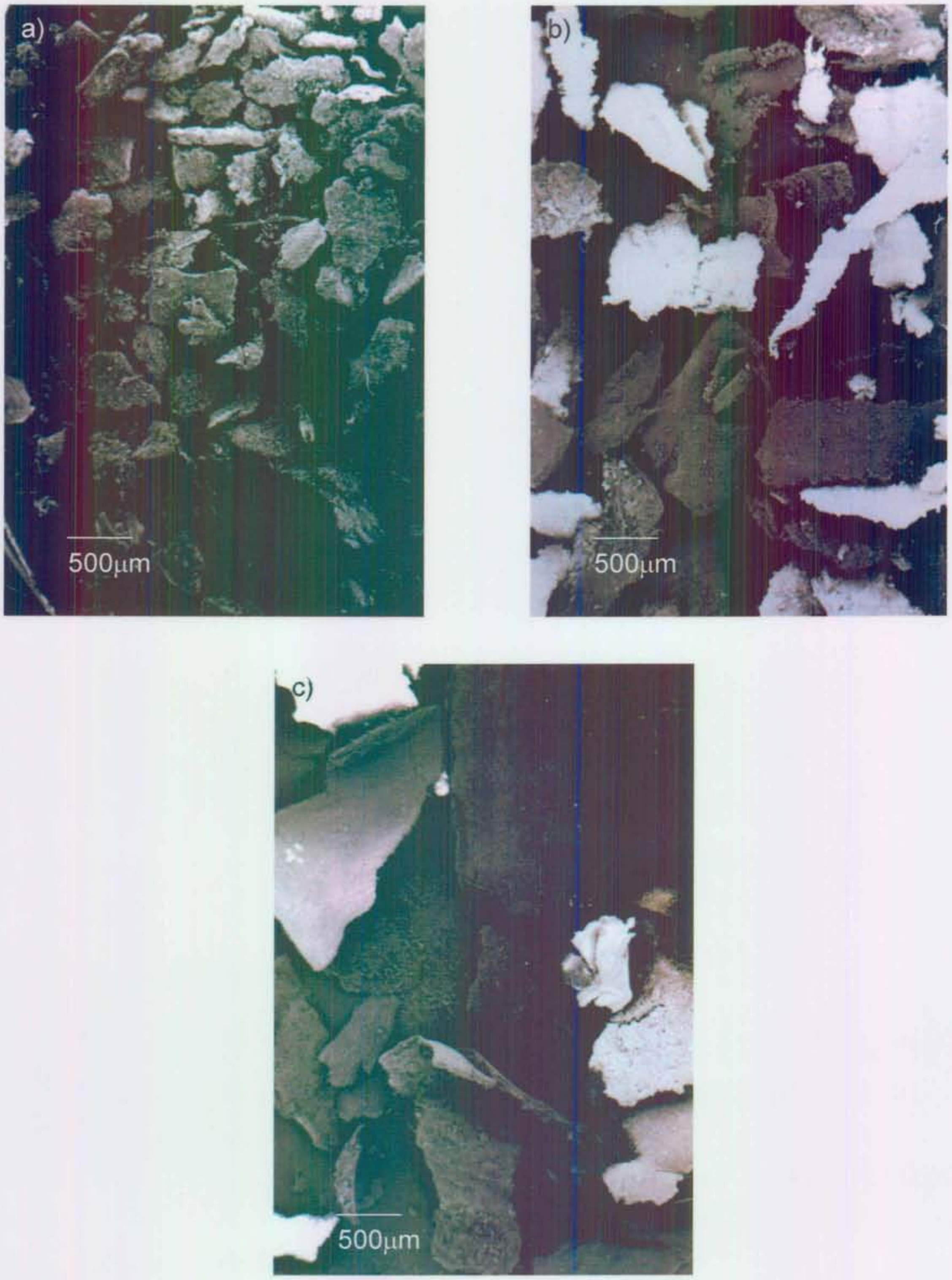



**Fig. 19: Scanning electron micrographs of a) Pollard; b) Select bran; and c) Digestive bran**

It can be seen from this figure that the Pollard particles were the smoothest and most uniform, whereas the Digestive bran particles were flaky with jagged edges.

## 4.4 HEAT TREATMENT

The lipase activities of different brans that were heat-treated for 30 and 60 minutes, are given in Table 15.

**Table 15: Effect of heat treatment (121°C) for 30 and 60 minutes on lipase activity in different bran types**

| | Lipase activity (mL 0.1 mol/L NaOH/ 5 g bran) | | |
|---|---|---|---|
| **Bran sample** | **Untreated** | **Heat-treated (30 minutes)** | **Heat-treated (60 minutes)** |
| Pollard | 307 | 136 | 85 |
| Select | 320 | 157 | 88 |
| Digestive | 340 | 91 | 71 |

Heat treatment for 30 minutes only partially inactivated the lipase. Heat treatment for 60 minutes inactivated more of the lipase. In order to ensure that all the lipase was inactivated, samples were heat-treated at 121°C for 1.5 hours.

The effect of heat treatment on the colour properties of Pollard and Digestive bran is given in Table 16.

**Table 16: Effect of a dry heat treatment (121°C, 30 minutes) on colour of Pollard and Digestive bran**

| | Hunterlab values | | | | | |
|---|---|---|---|---|---|---|
| | L | | a | | b | |
| Bran sample | Untreated | Heat-treated | Untreated | Heat-treated | Untreated | Heat-treated |
| Pollard | 66.5 | 60.0 | 2.6 | 3.5 | 13.2 | 14.8 |
| Digestive | 45.9 | 40.2 | 6.6 | 7.2 | 14.9 | 15.1 |

From this table it is evident that the L-value decreased considerably during heat treatment of both bran types. A L-value of 100 represents a total white colour and a L-value of 0 depicts a black colour. It is therefore clear that during heat treatment the bran becomes darker (more black). Heat treatment did not have a significant effect on a- (green (-) to red (+)) and b- (blue (-) to yellow (+)) values. Breads baked with heat-treated brans also had a darker colour than the breads baked with non-treated bran (Figures 23, 25 and 27).

The effect of heat treatment on moisture content and particle size is shown in Table 17.

**Table 17: Effect of heat treatment on moisture content and particle size of different bran types.**

| | Moisture content (%) | | Perimeter (mm) | |
|---|---|---|---|---|
| Bran sample | Untreated | Heat-treated | Untreated | Heat-treated |
| Pollard | 10.48 | 10.00 | 1.62 | 1.62 |
| Select | 11.30 | 10.99 | 4.50 | 4.51 |
| Digestive | 12.04 | 11.67 | 11.65 | 11.63 |

Heat treatment lowered moisture content very slightly, but did not have any significant effect on bran particle size.

## 4.5 LIPASE

Table 18 shows the lipase activities of heat-treated and untreated wheat brans of different origin.

**Table 18: Effect of heat treatment (121°C, 1.5 h) on lipase activity in brans from wheat samples of different origin**

| | Lipase activity[b] (mL 0.1 mol/L NaOH/ 5 g bran) | |
|---|---|---|
| **Bran sample[a]** | **Untreated** | **Heat-treated** |
| 1 | 315f | 7w |
| 2 | 309f | 5yx |
| 3 | 251d | 4zy |
| 4 | 275e | 5yx |
| 5 | 214a | 6xw |
| 6 | 270e | 4zy |
| 7 | 220a | 6xw |
| 8 | 234b | 3z |
| 9 | 245cd | 4z |
| 10 | 239bc | 3z |
| Mean | 257α | 5β |

[a]Origin:
1-UK; 2-Germany; 3-Canada; 4-USA; 5 Western Cape; 6-Free State; 7-Western Cape; 8-Free State; 9-Free State; 10-Mpumalanga

[b]Values with different letters in the same column are significantly different ($P<0.05$)

There was a significant variation in the level of lipase activity in most of the brans from the different samples. The highest lipase activities were in 1 (UK) and 2 (Germany), and the lowest in 5 (Western Cape) and 7 (Western Cape). Heat-treatment of the brans from different origins practically inactivated the lipase in all cases.

Table 19 shows the lipase activities of heat-treated and untreated brans of different particle size.

**Table 19: Effect of heat treatment (121 °C, 1.5 h) on lipase activity of different bran types**

| Bran type | Lipase activity (mL 0.1 mol/L NaOH/ 5 g bran) | |
|---|---|---|
| | **Untreated** | **Heat-treated** |
| Pollard | 259c | 35b |
| Select | 270d | 38b |
| Digestive | 286e | 21a |

Values with different letters are significantly different (P<0.05)

The lipase activities of the untreated brans were all of the same order of magnitude, with the highest in the Digestive bran and the lowest in the Pollard. Heat treatment reduced lipase activity by at least 85% in all cases.

## 4.6 TOTAL REDUCING SUBSTANCES

Table 20 shows the total reducing substances (TRS) of heat-treated and untreated brans of different origin.

**Table 20: Effect of heat treatment (121°C, 1.5 h) on total reducing substances in brans from wheat samples of different origin**

| | Total reducing substances[b] (mL 0.005 mol/L $S_2O_3^{2-}$/ 5 g bran) | |
|---|---|---|
| **Bran sample[a]** | **Untreated** | **Heat-treated** |
| 1 | 1.91b | 0.81t |
| 2 | 2.09a | 1.33z |
| 3 | 1.33f | 0.96y |
| 4 | 1.43de | 1.28zy |
| 5 | 1.42de | 0.71s |
| 6 | 1.66c | 1.17xw |
| 7 | 1.36ef | 1.00vu |
| 8 | 1.24g | 1.22yx |
| 9 | 1.21g | 1.09wv |
| 10 | 1.45d | 1.16xw |
| Mean | 1.51α | 1.07β |

[a]Origin:
1-UK; 2-Germany; 3-Canada; 4-USA; 5 Western Cape; 6-Free State; 7-Western Cape; 8-Free State; 9-Free State; 10-Mpumalanga

[b]Values with different letters in the same column are significantly different ($P<0.05$)

It is evident that there was a significant variation in the level of TRS in most of the brans from the different wheat samples. The lowest TRS were in samples 8 (Free State) and 9 (Free State), and the highest in sample 2 (Germany). With the exception of sample 8, heat treatment significantly reduced the level of TRS in all the brans. However, there remained significant variation in the levels of TRS in most of the heat-treated brans. The highest TRS was still in sample 2 (Germany) but the lowest in samples 1 (UK) and 5 (Western Cape).

## 4.7 BAKING TESTS

### *4.7.1 Effect of bran origin and heat treatment on loaf volume*

The effect of bran origin and heat treatment on loaf volume is shown in Table 21.

**Table 21: Effect of brans from wheat samples of different origin and their heat treatment on loaf volume and loaf height when brans were used to bake brown bread (15% bran) using a common base flour**

| | Loaf volume[b] (% of white bread control) | | Loaf height[b] (% of white bread control) | |
|---|---|---|---|---|
| **Bran sample[a]** | **Untreated** | **Heat-treated** | **Untreated** | **Heat-treated** |
| 1 | 86.9a | 93.3zy | 87.3a | 93.3zy |
| 2 | 90.7bcd | 93.3zy | 90.7bc | 94.5zyx |
| 3 | 91.9d | 93.1zy | 91.8bcd | 92.9z |
| 4 | 90.3bcd | 92.8z | 90.0b | 93.7zy |
| 5 | 90.2bcd | 95.2yxw | 90.1b | 95.8yxw |
| 6 | 91.5cd | 93.6zyx | 93.7d | 94.4zyx |
| 7 | 90.1bcd | 93.0zy | 90.2b | 93.9zyx |
| 8 | 89.9bc | 96.0w | 92.3cd | 97.6w |
| 9 | 89.5b | 92.8z | 91.2bc | 93.1zy |
| 10 | 91.5cd | 95.7xw | 92.2bcd | 96.7xw |
| Mean | 90.2α | 93.9β | 91.0α | 94.6β |

[a]Origin:
1-UK; 2-Germany; 3-Canada; 4-USA; 5 Western Cape; 6-Free State; 7-Western Cape; 8-Free State; 9-Free State; 10-Mpumalanga

[b]Values with different letters in the same column are significantly different ($P<0.05$)

There were significant differences in loaf volume and loaf height between breads produced from a common base flour, with brans from different origins. In other words, different brans varied in their effect of depressing loaf size. Highest loaf volumes were obtained with bran samples 2, 3, 4, 5, 6, 7 and 10 (90.1-91.5% of white bread control), and the highest loaf heights with bran samples 3, 6, 8 and 10 (91.8-93.7% of control). The lowest loaf volume and height were obtained with bran sample 1 (86.9 and 87.3%, respectively of the control).

Heat-treatment of the brans from different origins increased both loaf volume and height. However, heat-treatment did not result in the brans all producing loaves of the same volume and height. There were still some significant differences between the samples. Heat-treated bran samples 5, 8 and 10 gave the highest loaf volumes (95.2-96.0% of control) and heights (95.8-97.6% of the white bread control). Samples 1, 2, 3, 4, 6, 7 and 9 gave the lowest loaf volume (92.8-93.6% of the control) and height (92.9-94.4% of the control).

### *4.7.2 Effect of bran type, level of addition and heat treatment on loaf volume*

The effect of bran type, level of addition and heat treatment on loaf volume is given in Table 22 and Figures 20 to 29.

**Table 22: Effect of different bran types, heat treatment and level of addition on loaf volume**

| Bran type | Level of addition (%) | Loaf volume[a] (% of white bread control) | |
|---|---|---|---|
| | | Untreated | Heat-treated |
| Pollard | 9 | 96.3 de | 97.7 efg |
| | 12 | 93.1 bc | 96.9 def |
| | 15 | 89.7 a | 91.6 ab |
| Select | 9 | 100.2 hij | 102.2 ijk |
| | 12 | 95.9 de | 99.7 gh |
| | 15 | 93.1 bc | 95.2 cd |
| Digestive | 9 | 102.4 jk | 102.6 k |
| | 12 | 97.1 def | 98.8 fgh |
| | 15 | 91.99 b | 92.6 b |

[a]Values with different letters are significantly different ($P<0.05$)

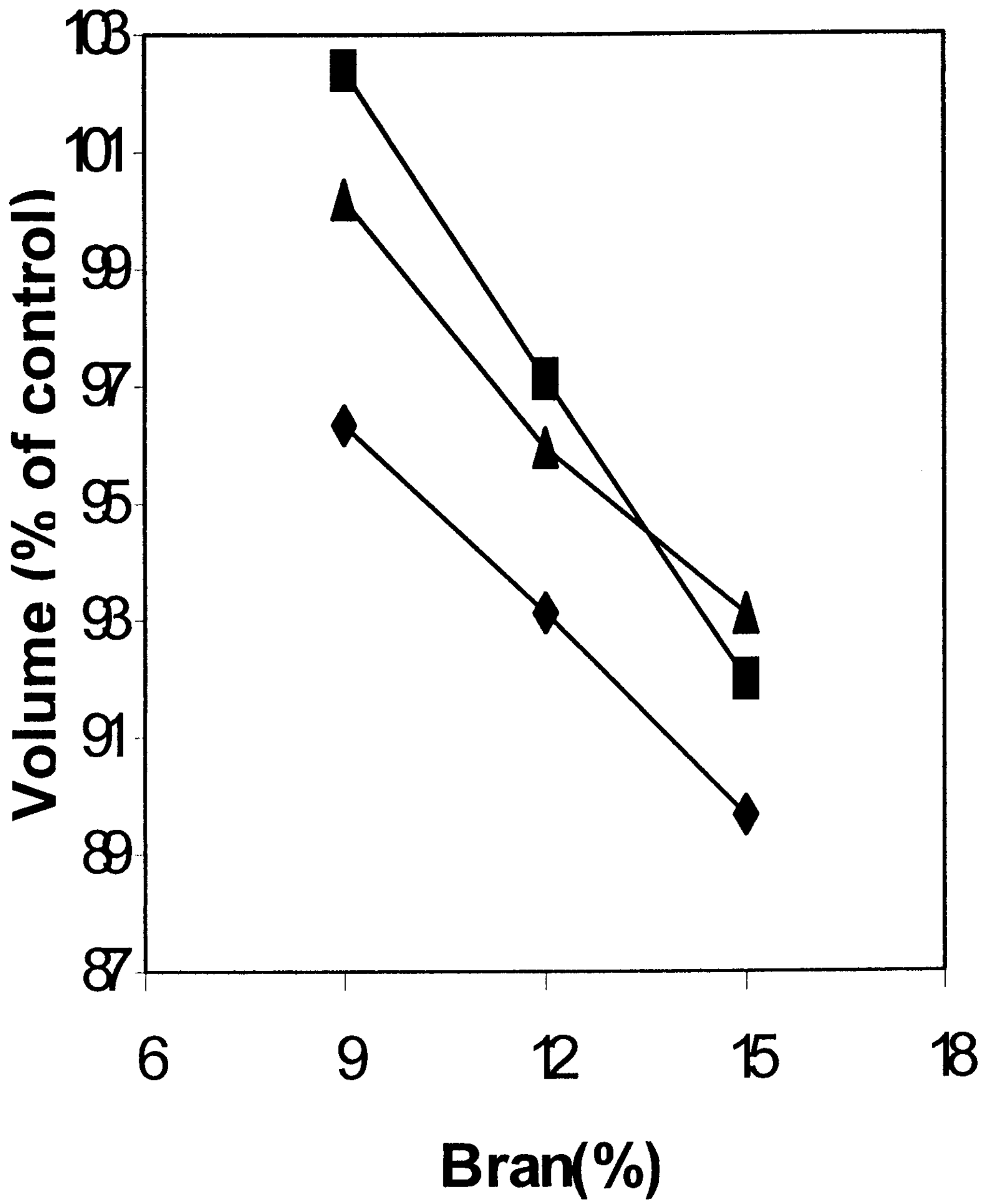
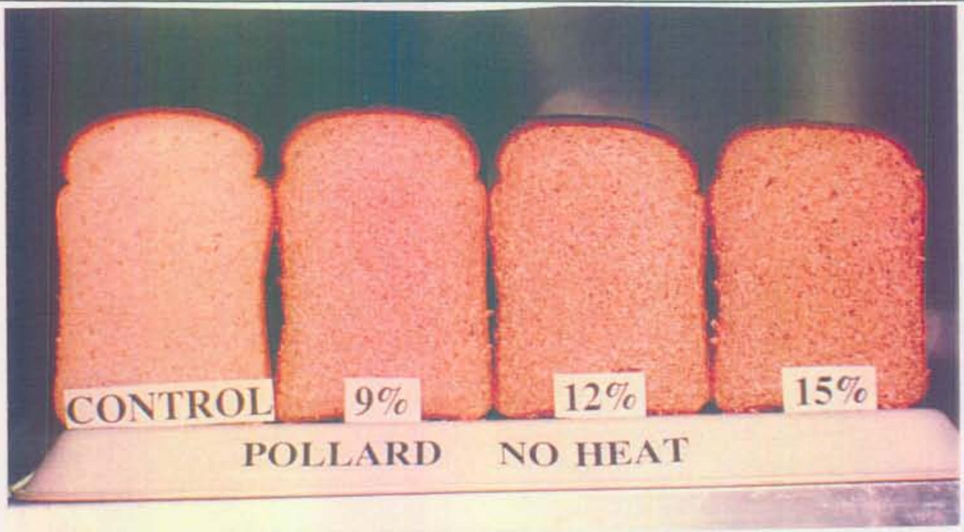
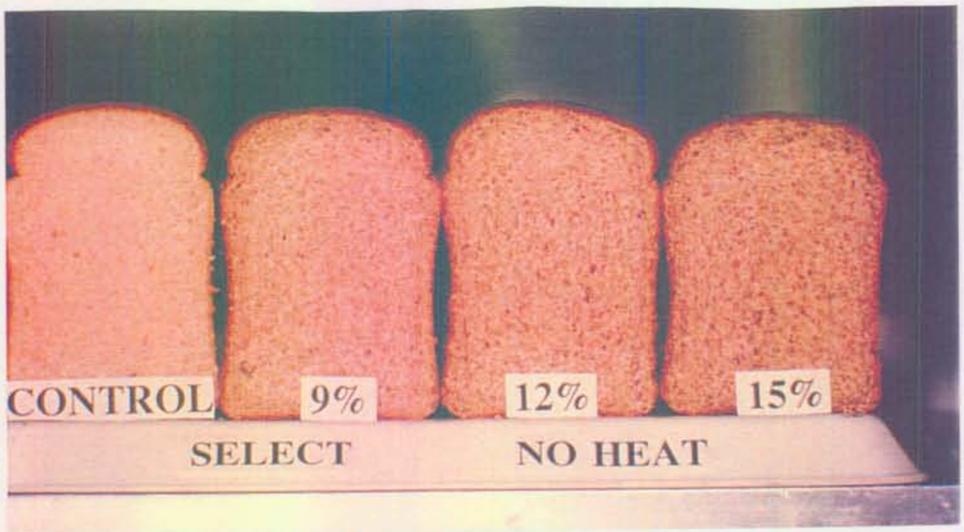



**Fig. 20:** **Effect of bran type and level of addition on loaf volume (results expressed as percent of a white bread control). ◆ - ◆ = Pollard; ▲ - ▲ = Select; ■ - ■ = Digestive**

a)




b)




c)

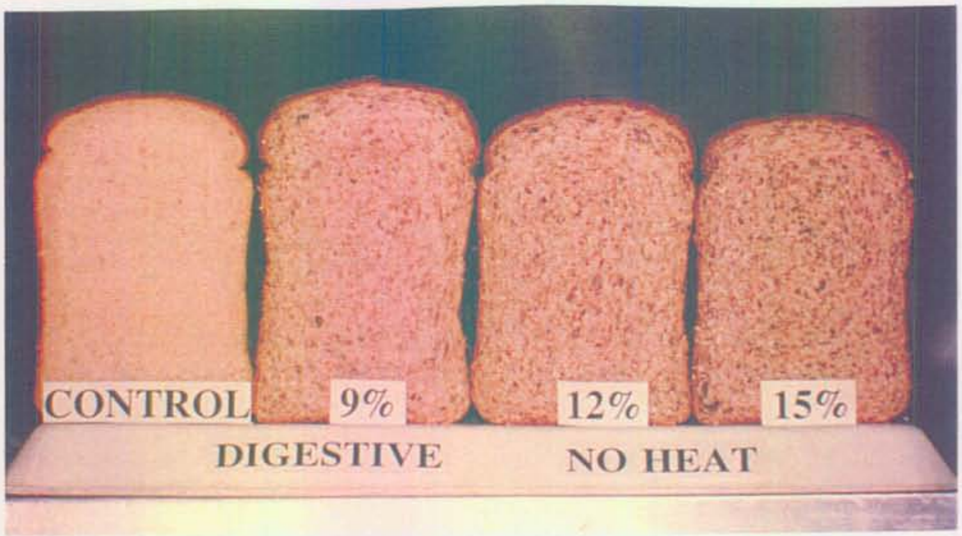



**Fig 21: Breads baked with different levels of addition of a) Pollard; b) Select bran; and c) Digestive bran, compared to a white bread control**

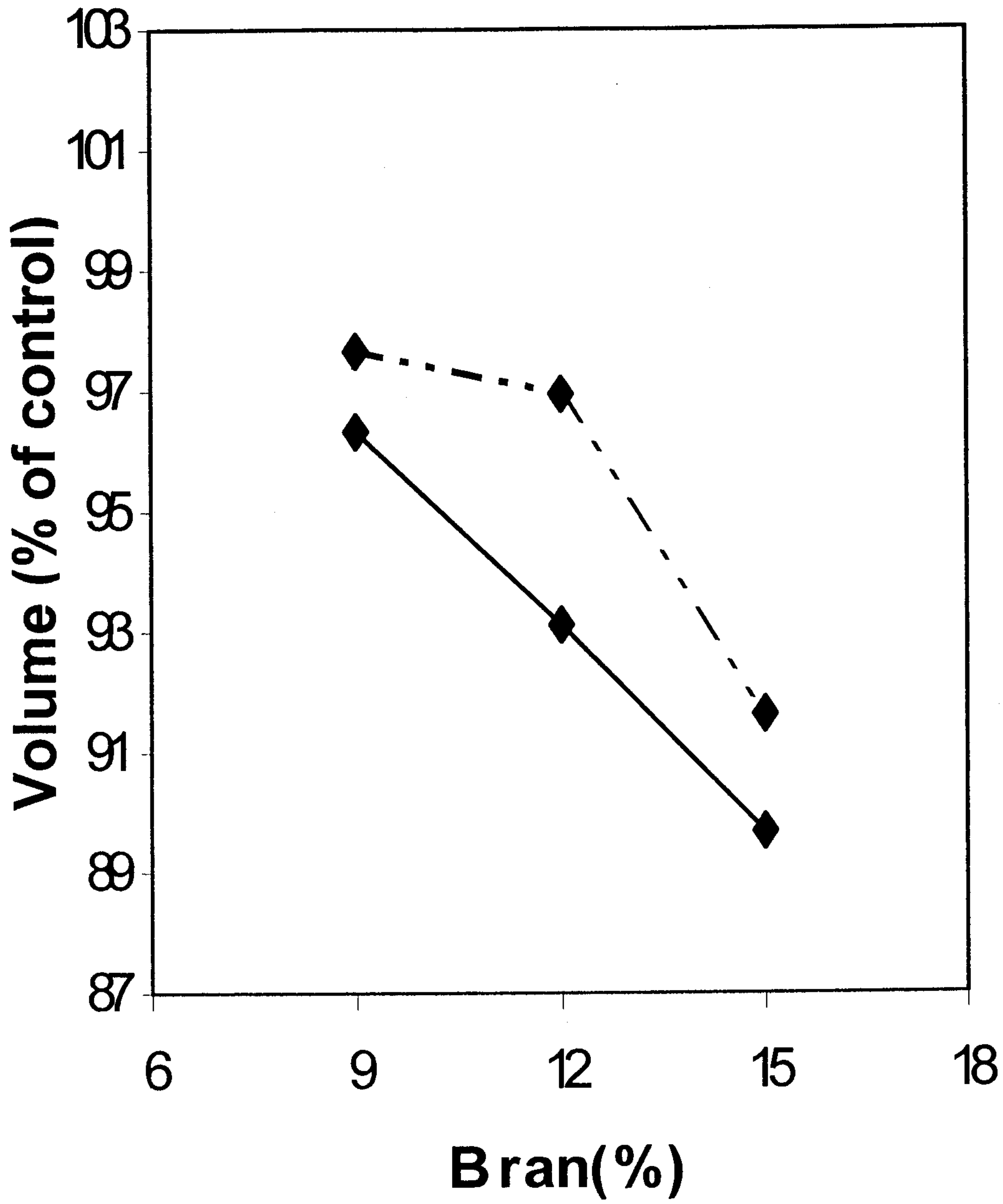



Fig. 22: Effect of heat treatment and level of addition of Pollard on loaf volume (results expressed as percent of a white bread control). ◆ - ◆ = Pollard; ◆- - -◆ = heat-treated Pollard

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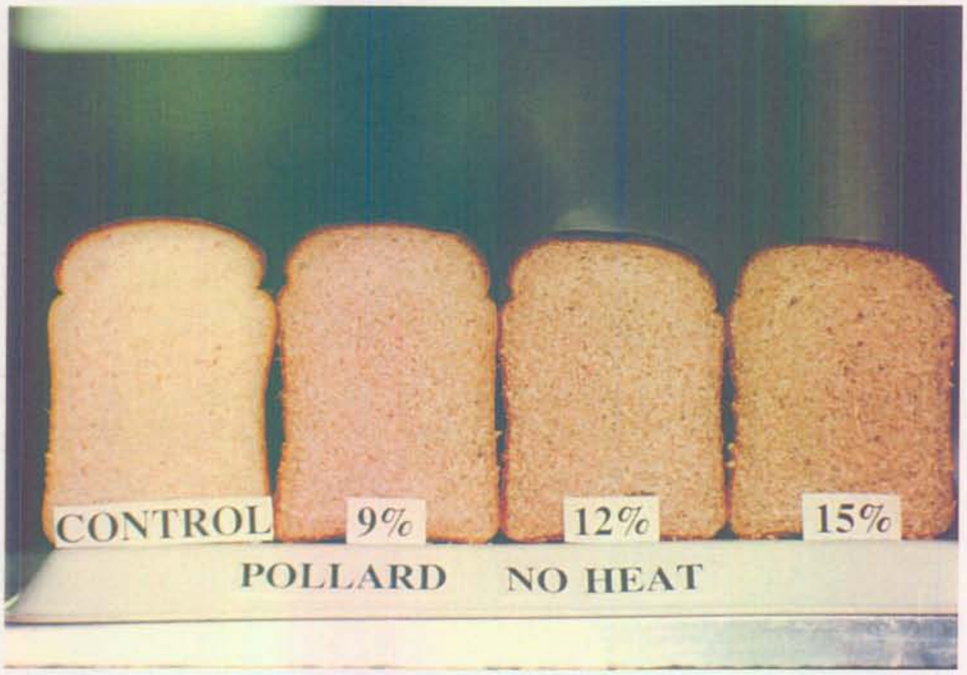
a)




b)

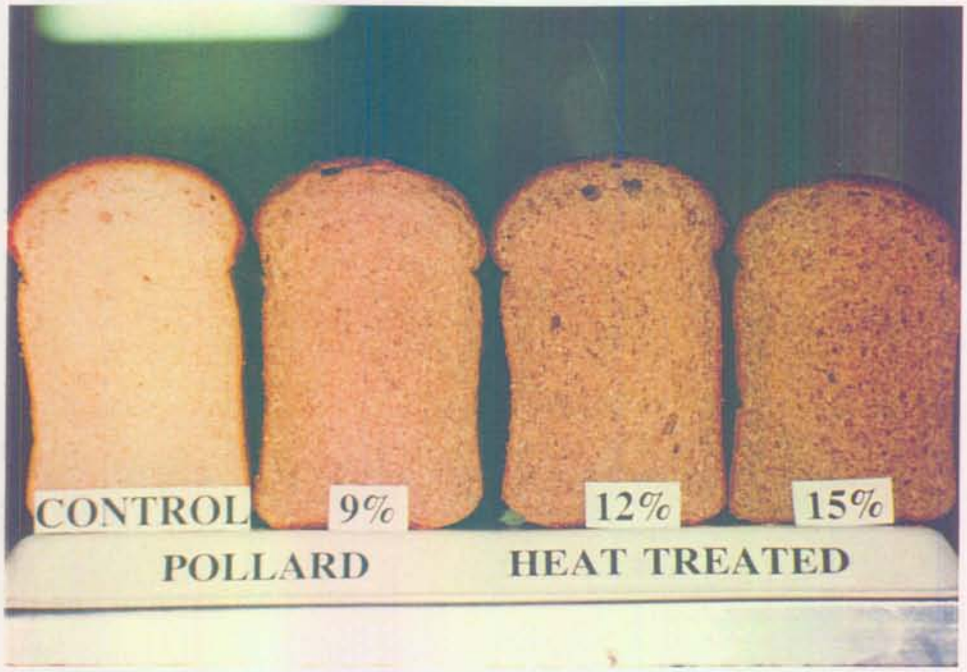



**Fig. 23: Breads baked with different levels of addition of a) Pollard and b) Heat-treated Pollard, compared to a white bread control**

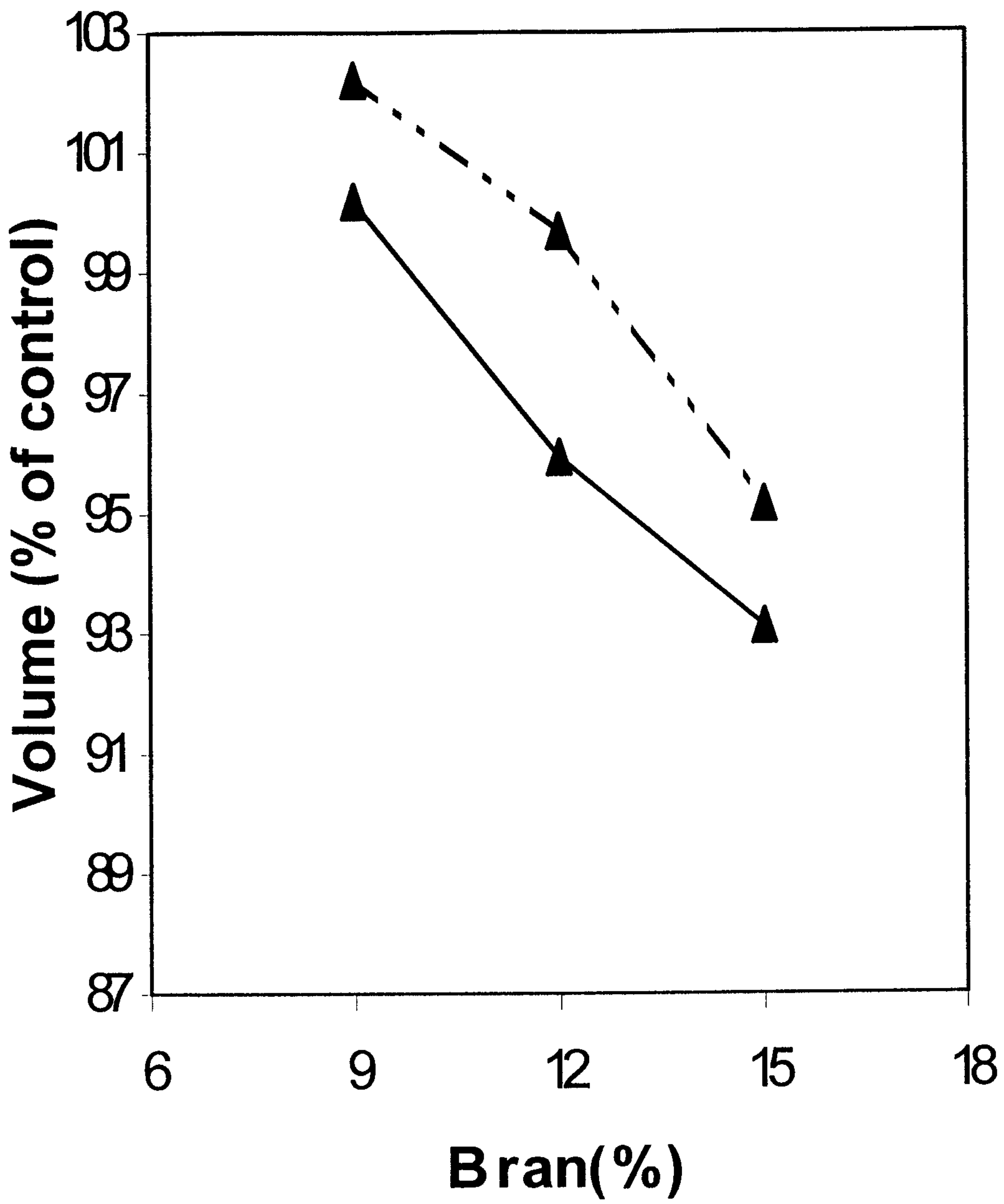
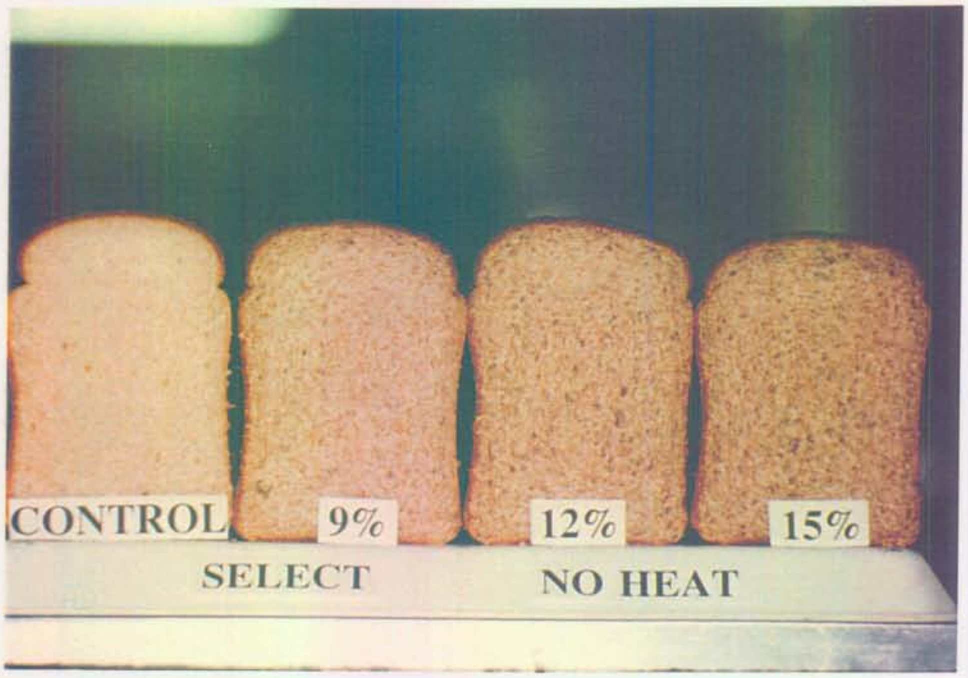



Fig 24: Effect of heat treatment and level of addition of Select bran on loaf volume (results expressed as percent of a white bread control). ▲ - ▲ = Select; ▲- - -▲ = heat treated Select

a)




b)

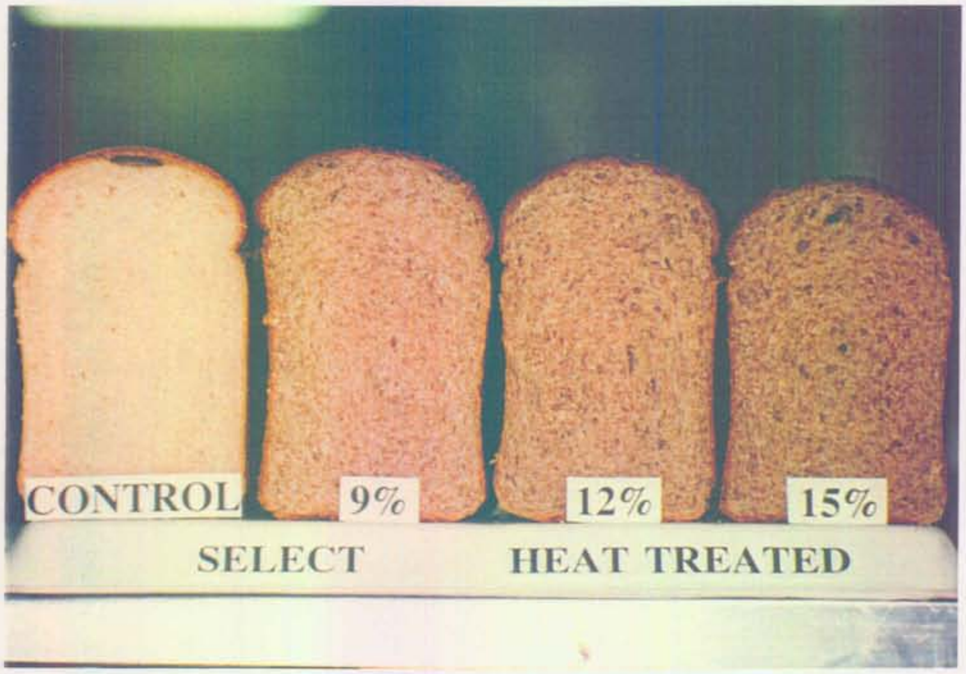



**Fig. 25: Breads baked with different levels of addition of a) Select bran and b) Heat-treated Select bran, compared to a white bread control**

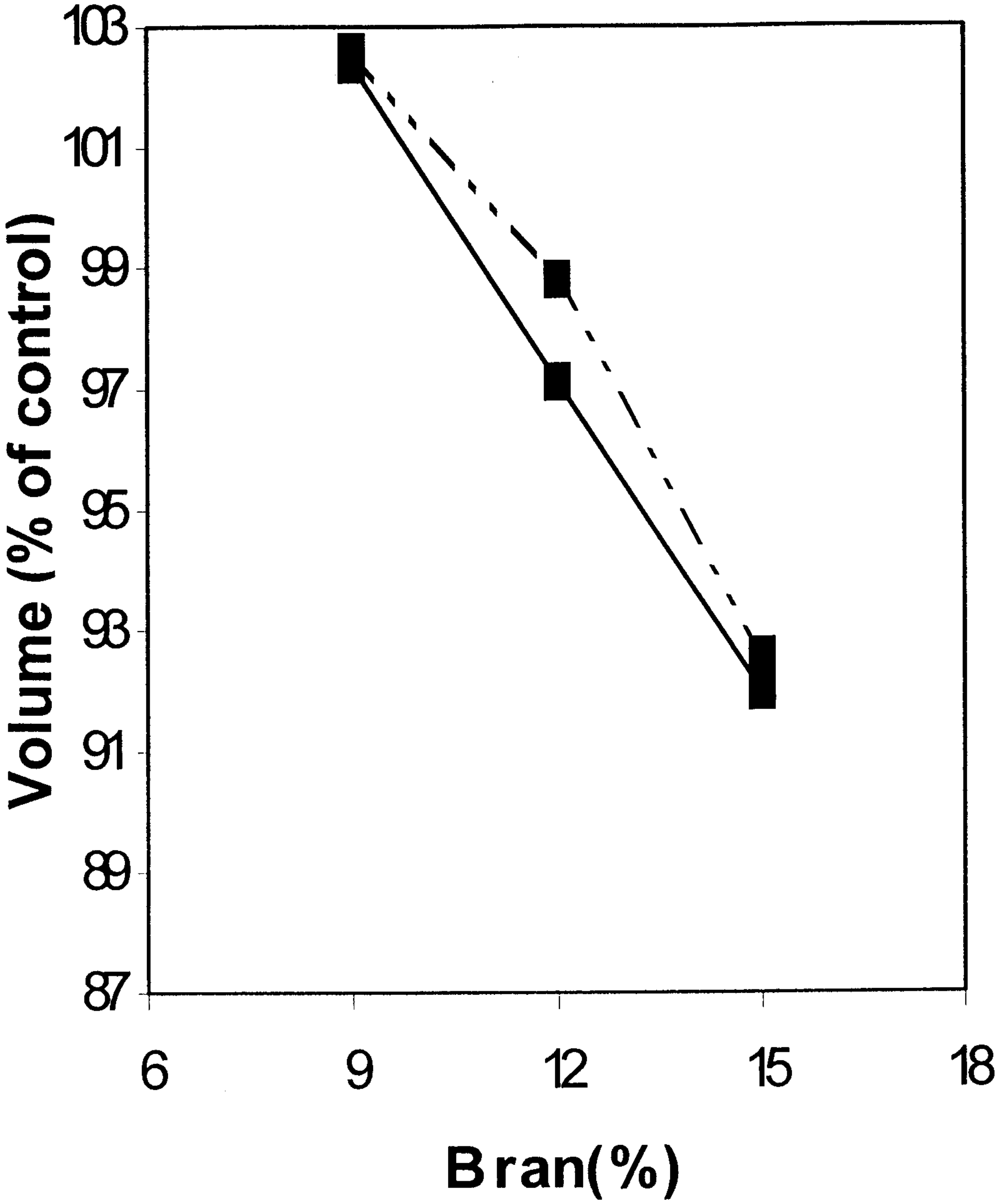
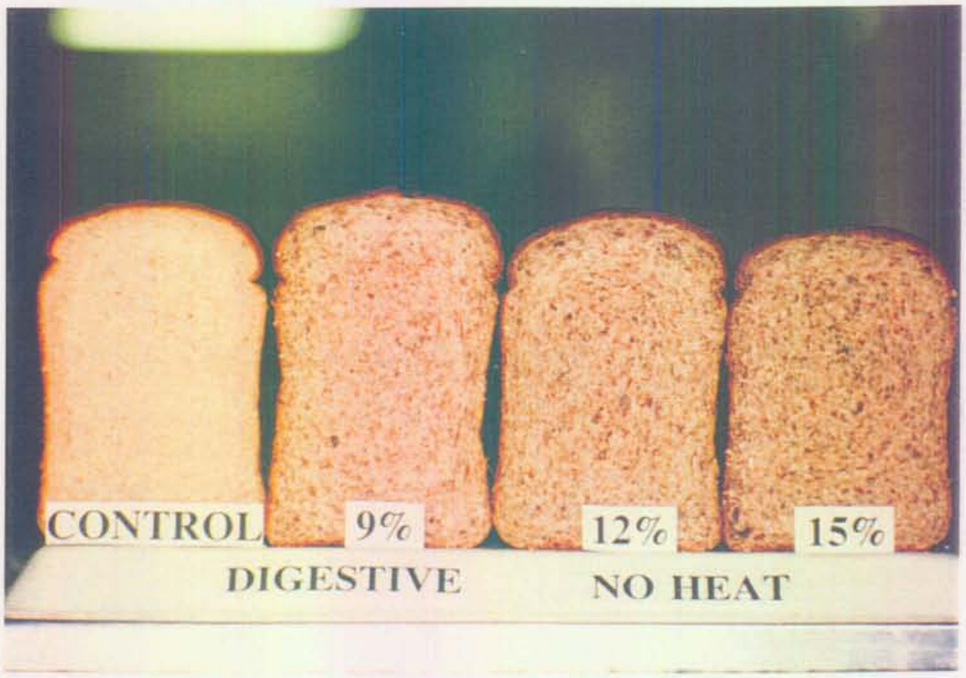



Fig 26: Effect of heat treatment and level of addition of Digestive bran on loaf volume (results expressed as percent of a white bread control). ■ - ■ = Digestive; ■- - - ■ = heat-treated Digestive

a)




b)

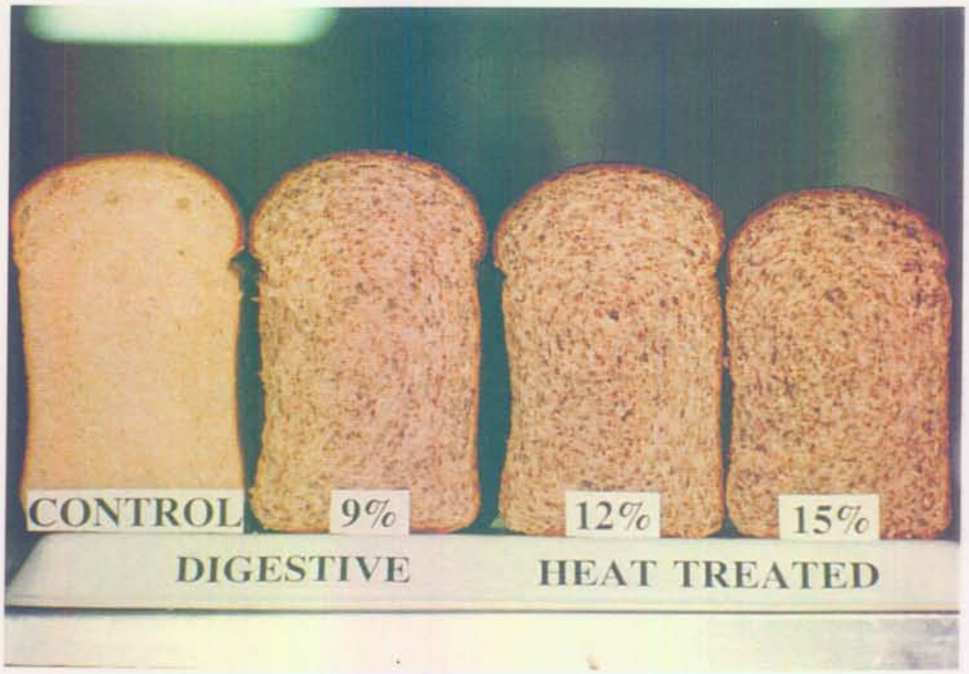



**Fig. 27: Breads baked with different levels of addition of a) Digestive bran and b) Heat-treated Digestive bran, compared to a white bread control**

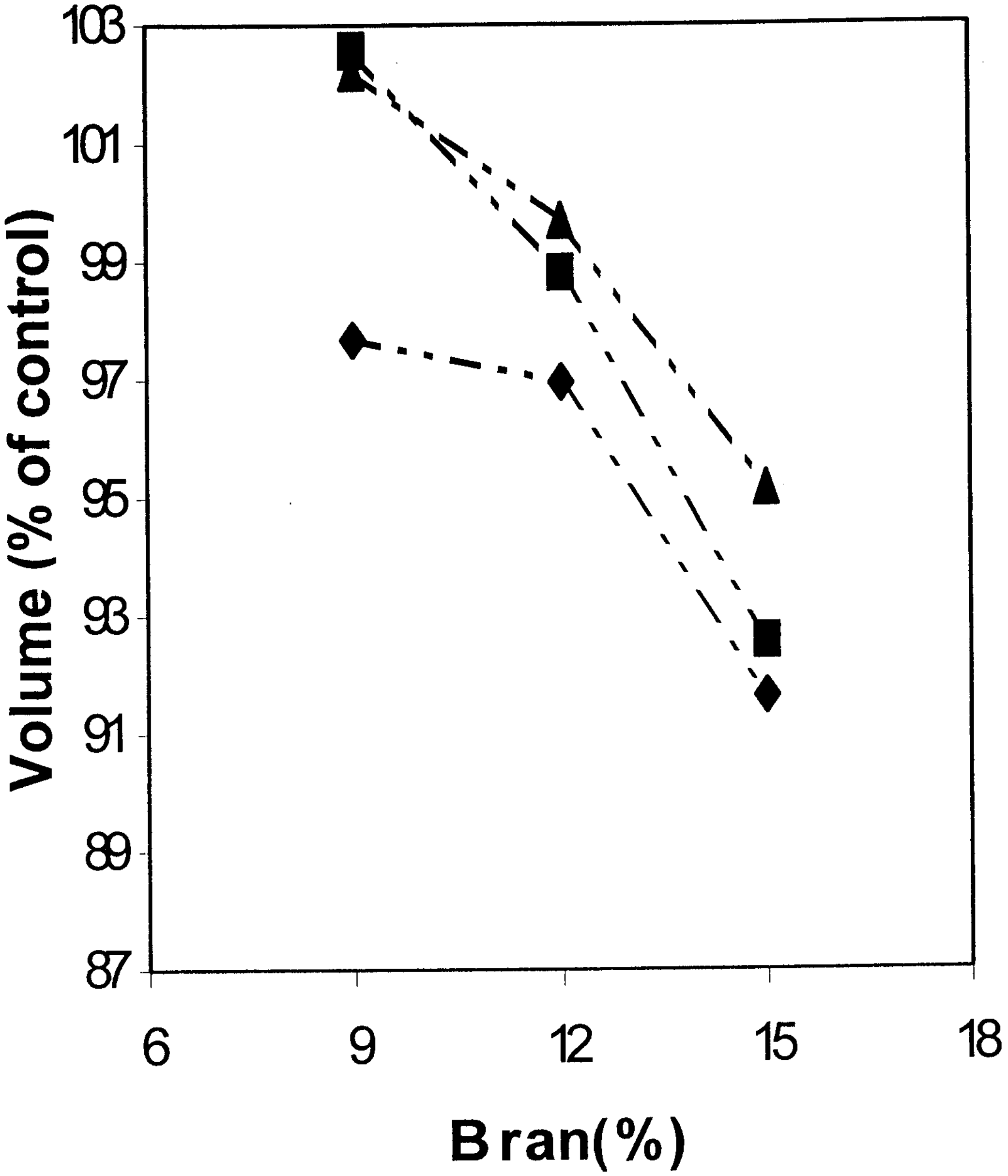



Fig. 28: Effect of heat-treated bran type and level of addition on loaf volume (results expressed as percent of a white bread control). ◆- - -◆ = heat-treated Pollard; ▲- - -▲ = heat treated Select; ■- - - ■ = heat-treated Digestive

a)

b)

c)

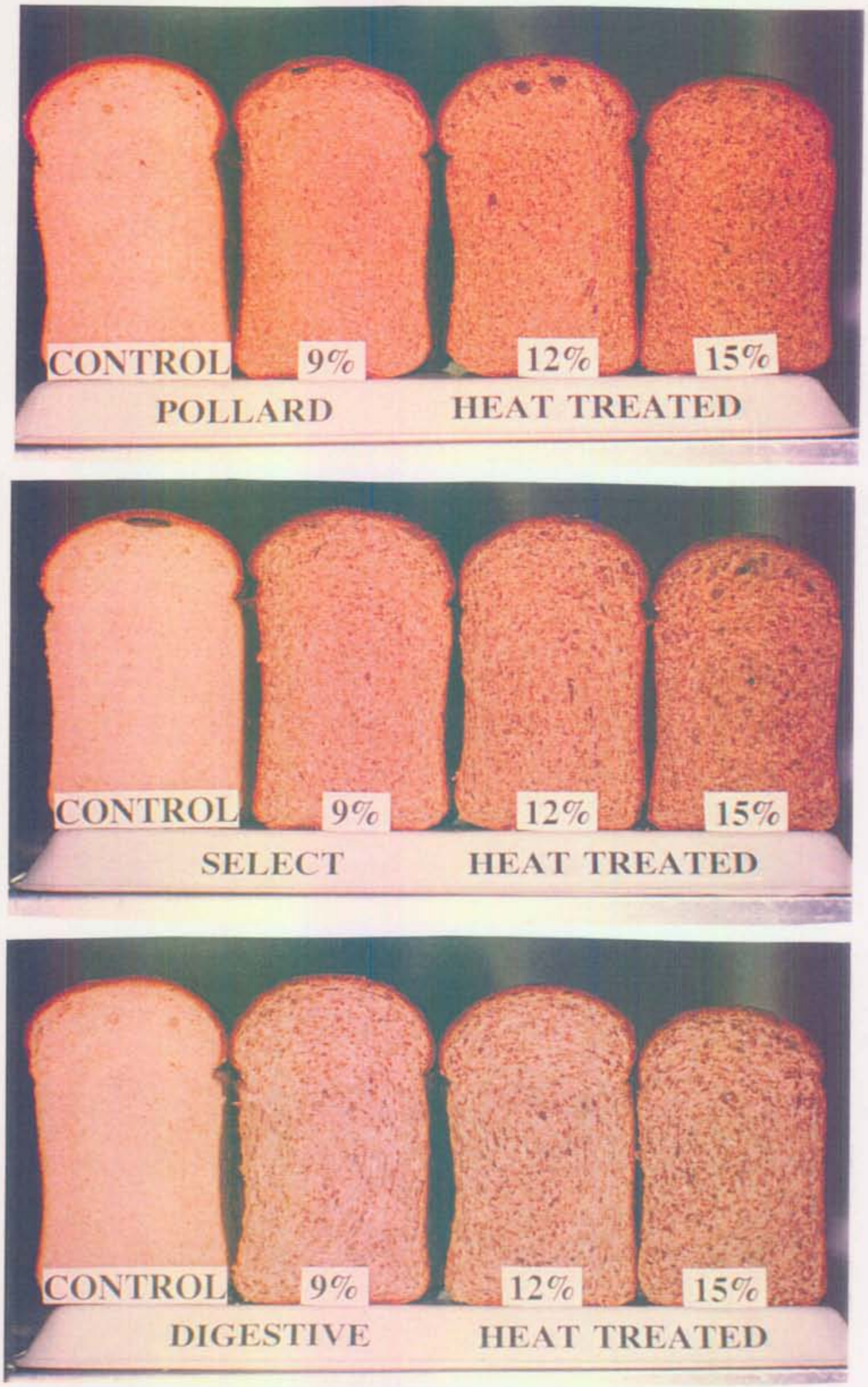



**Fig. 29: Breads baked with different levels of addition of a) Heat-treated Pollard; b) Heat-treated Select bran; and c) Heat-treated Digestive bran, compared to a white bread control**

Pollard caused the largest depression in loaf volume and Digestive bran the least. Select bran produced intermediate loaf volumes. Increased levels of addition caused loaf volumes to be more depressed. With heat-treated bran there was a clear trend for loaf volumes to be less depressed when compared to the loaves that were baked with the untreated bran. After heat-treatment of the brans, loaves baked with Pollard still gave the smallest volume, whereas the loaves baked with Select bran were at least as large as those baked with Digestive bran. At low levels of addition of Select and Digestive bran, loaf volumes of bread with untreated and heat-treated bran were as big or bigger than the white bread control. It is also evident that heat treatment had the greatest effect on decreasing loaf volume depression in breads baked with Pollard and the least effect on breads baked with Digestive bran.

Photographs of cubes of the control white bread and breads baked with the different bran types and different levels of addition are shown in Figures 30 to 33.

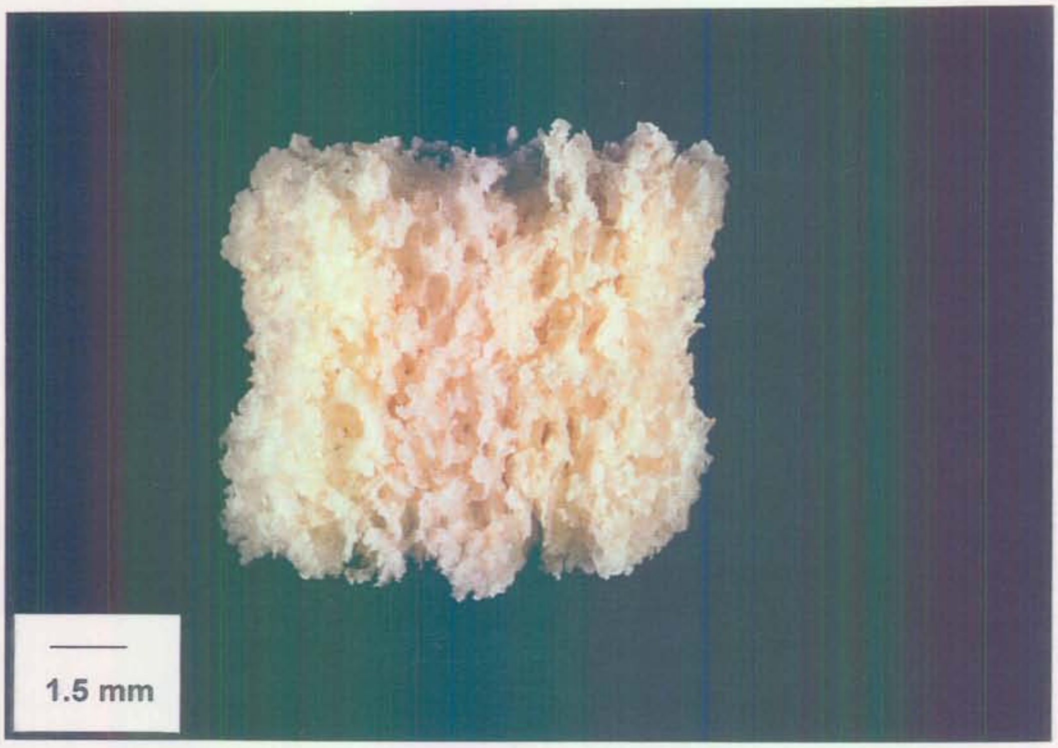



**Fig. 30: Cube of a white bread control**

a)
b)
c)

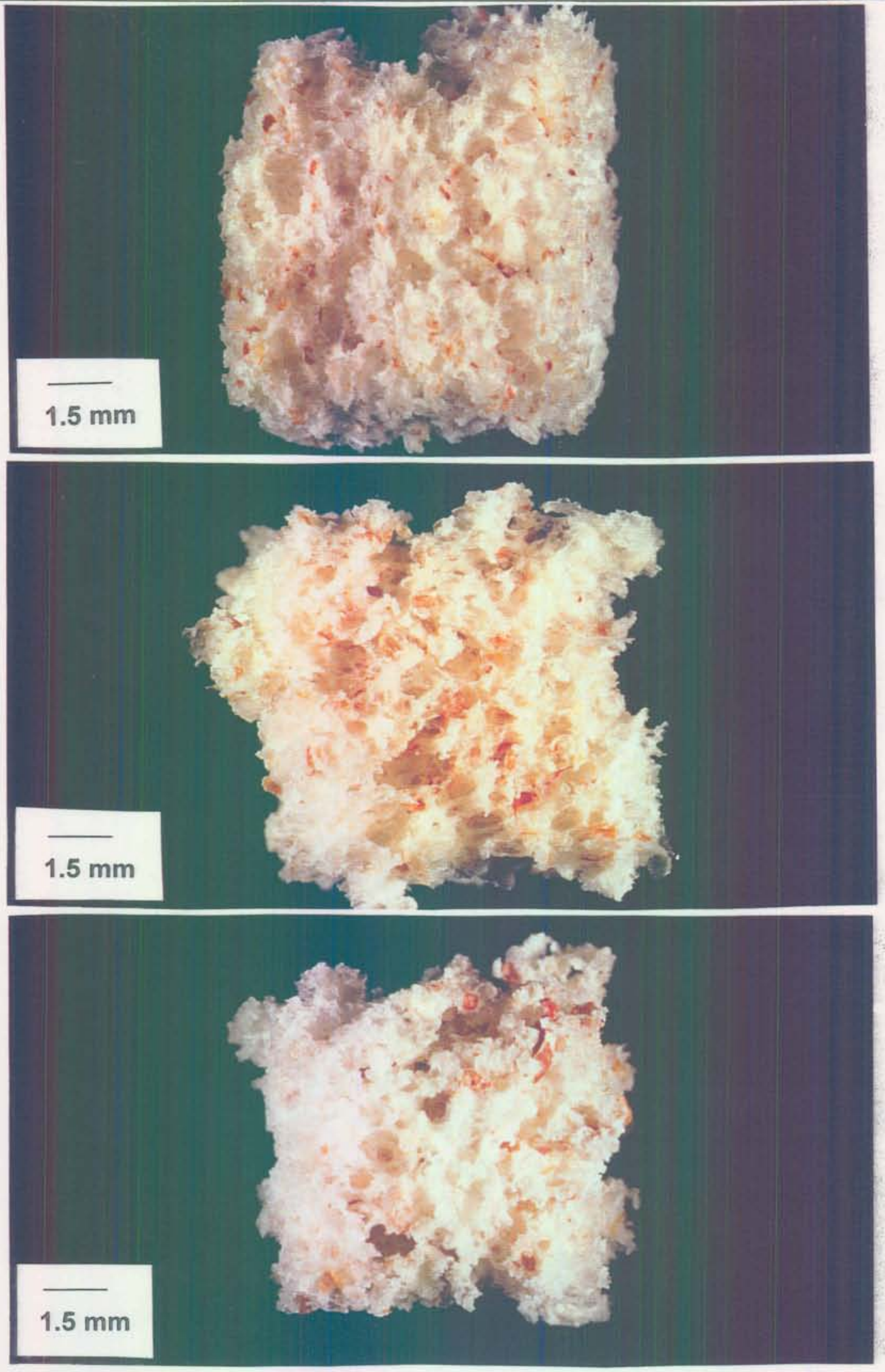
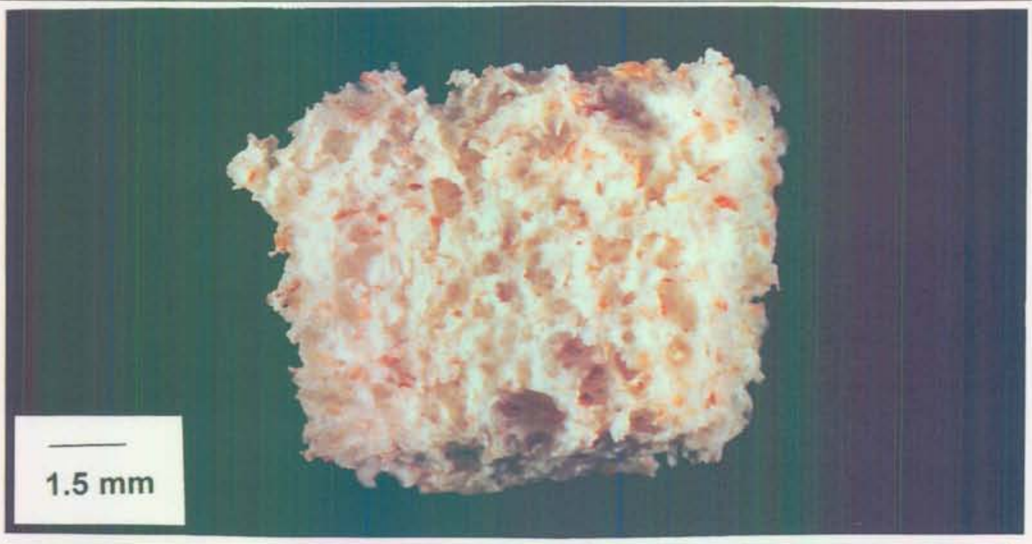
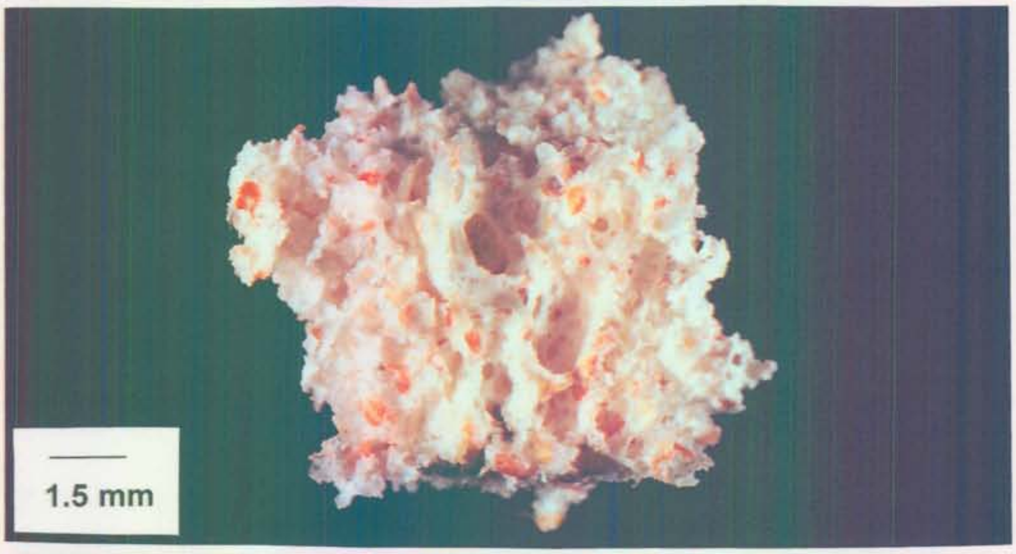



**Fig. 31: Cubes of bread baked with a 9% level of addition of a) Pollard; b) Select bran; and c) Digestive bran**

a)




b)




c)

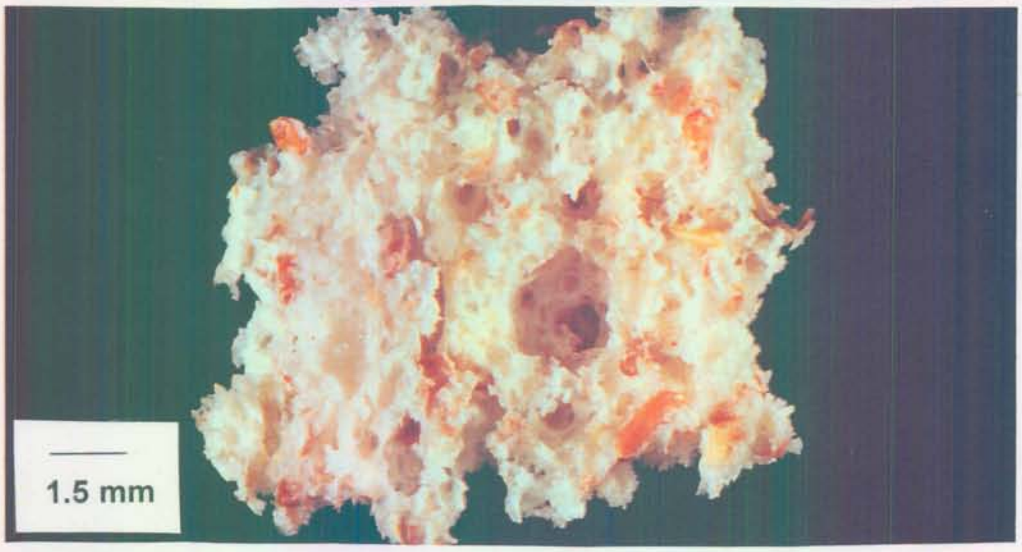



**Fig. 32: Cubes of bread baked with a 12% level of addition of a) Pollard; b) Select bran; and c) Digestive bran**

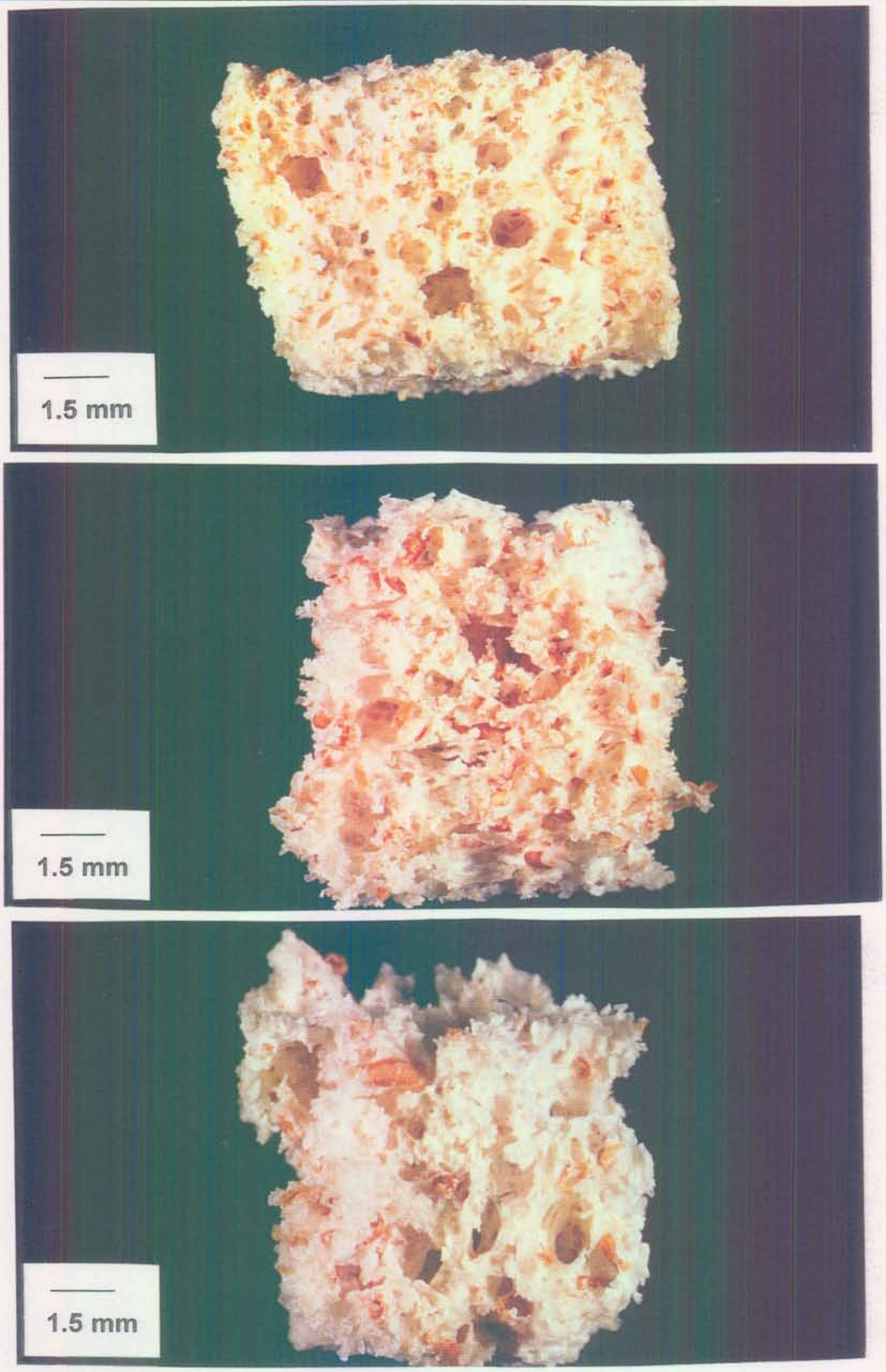



**Fig. 33: Cubes of bread baked with a 15% level of addition of a) Pollard; b) Select bran; and c) Digestive bran**

It is evident from these figures that the crumb of the bread baked with Digestive bran had a much more open structure than the bread baked with Pollard, which was more dense. Select bran gave an intermediate crumb structure. Increasing the level of addition disrupted the crumb structure.

### *4.7.3 Effect of size reduction and heat treatment on loaf volume*

Tables 23 and 24 show the effect of bran size, heat treatment and milling on loaf volumes and loaf heights.

**Table 23: Effect of bran size, heat treatment and milling on loaf volume when brans were used to bake brown bread (12% bran) using a common base flour**

| Treatment | Pollard[a] | Select[a] | Digestive[a] | Overall mean[a] |
|---|---|---|---|---|
| None | 90.8 b | 91.7 b | 92.6 ab | 91.7 b |
| Milled | 85.6 a | 86.1 a | 90.4 a | 87.4 a |
| Heat-treated | 90.7 b | 98.1 c | 93.0 ab | 94.0bc |
| Heat-treated then milled | 93.0 b | 94.7 bc | 95.6 b | 94.4 c |
| Overall mean[b] | 90.0 x | 92.7 y | 93.0 y | |

[a]Values with different letters in the same column are significantly different (P<0.05)

[b]Values with different letters in the same row are significantly different (P<0.05)

**Table 24: Effect of bran size, heat treatment and milling on loaf height when brans were used to bake brown bread (12% bran) using a common base flour**

| Treatment | Pollard[a] | Select[a] | Digestive[a] | Overall mean[a] |
|---|---|---|---|---|
| None | 90.9 ab | 94.1 b | 94.0a | 93.0 b |
| Milled | 87.2 a | 88.5 a | 92.7 a | 89.4 a |
| Heat-treated | 94.4 b | 98.6 b | 94.0 a | 95.7 c |
| Heat-treated then milled | 93.3 b | 94.8 b | 94.0a | 94.7 bc |
| Overall mean[b] | 91.5 x | 94.0 y | 96.0 y | |

[a]Values with different letters in the same column are significantly different (P<0.05)

[b]Values with different letters in the same row are significantly different (P<0.05)

It is evident that, overall, Pollard gave the lowest loaf volumes. It can also be seen that significantly smaller loaf sizes were obtained with the milled bran. Overall, as found previously, heat treatment increased loaf size. Overall, similar loaf volumes and heights were obtained in breads produced with bran which was heat-treated and then milled, and breads produced with bran that had only been heat-treated.

## 4.8 CAT SCANS

Figures 34 to 37 represent CAT scans of proofing loaves with different bran types. Figures 38 to 53 show the frequency distribution of bubble size (area, length and perimeter) and shape (roundness or aspect ratio) at different stages of proofing.

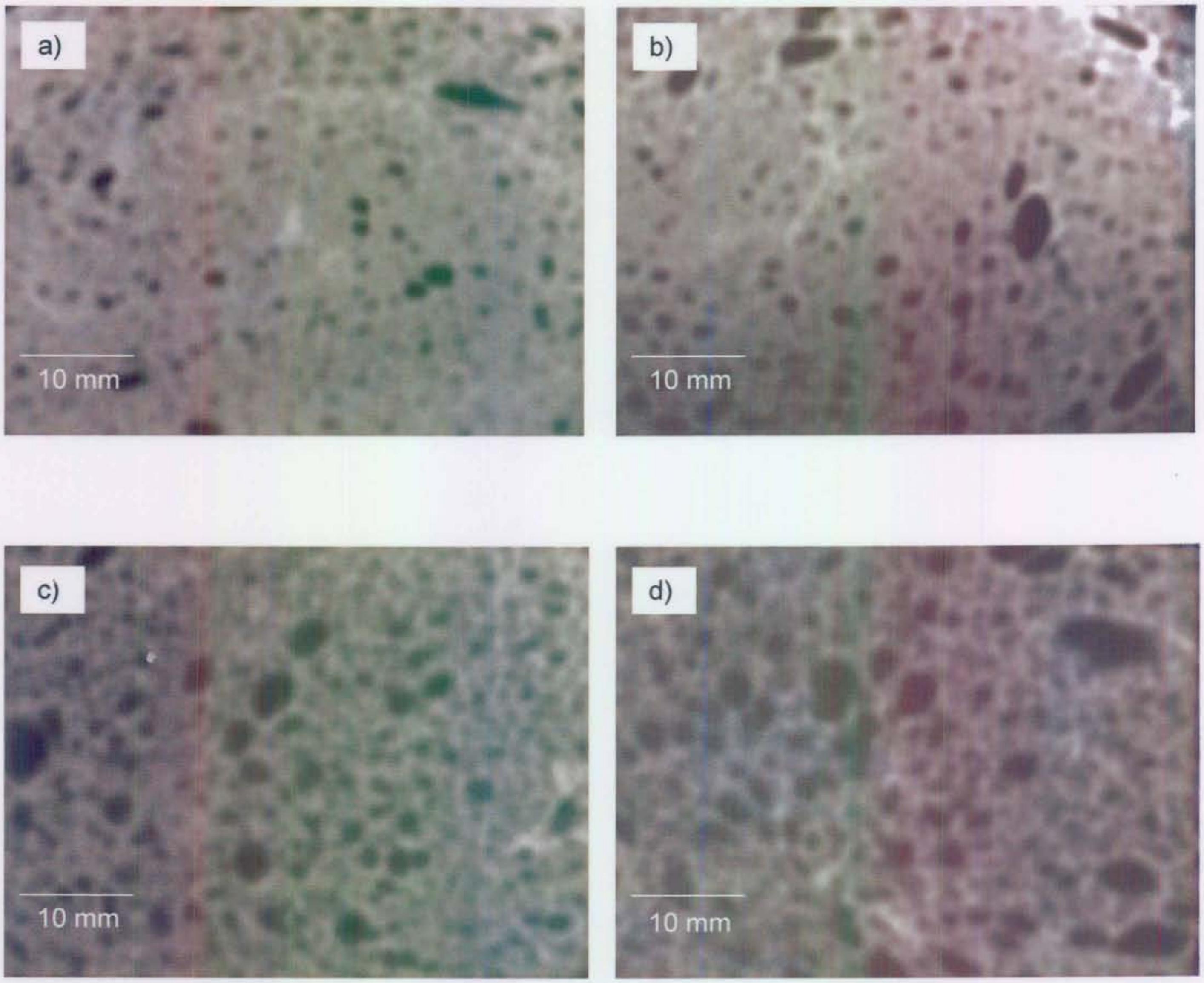



**Fig. 34: CAT scans of a white bread control after a) 0 min.; b) 20 min.; c) 40 min.; and d) 60 min. of proofing at 40°C**

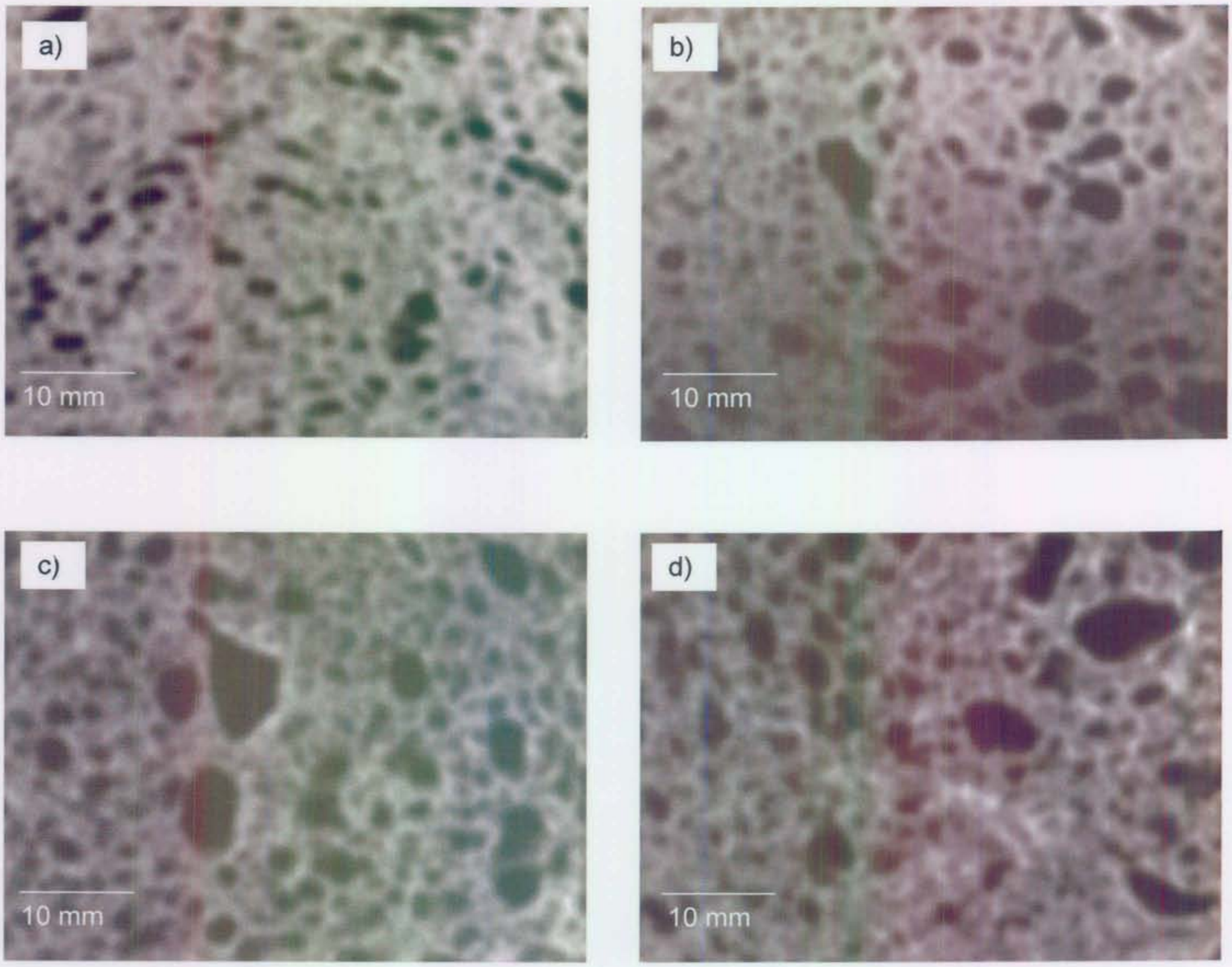



**Fig. 35: CAT scans of loaves with Pollard (15%) after a) 0 min.; b) 20 min.; c) 40 min.; and d) 60 min. of proofing at 40°C**

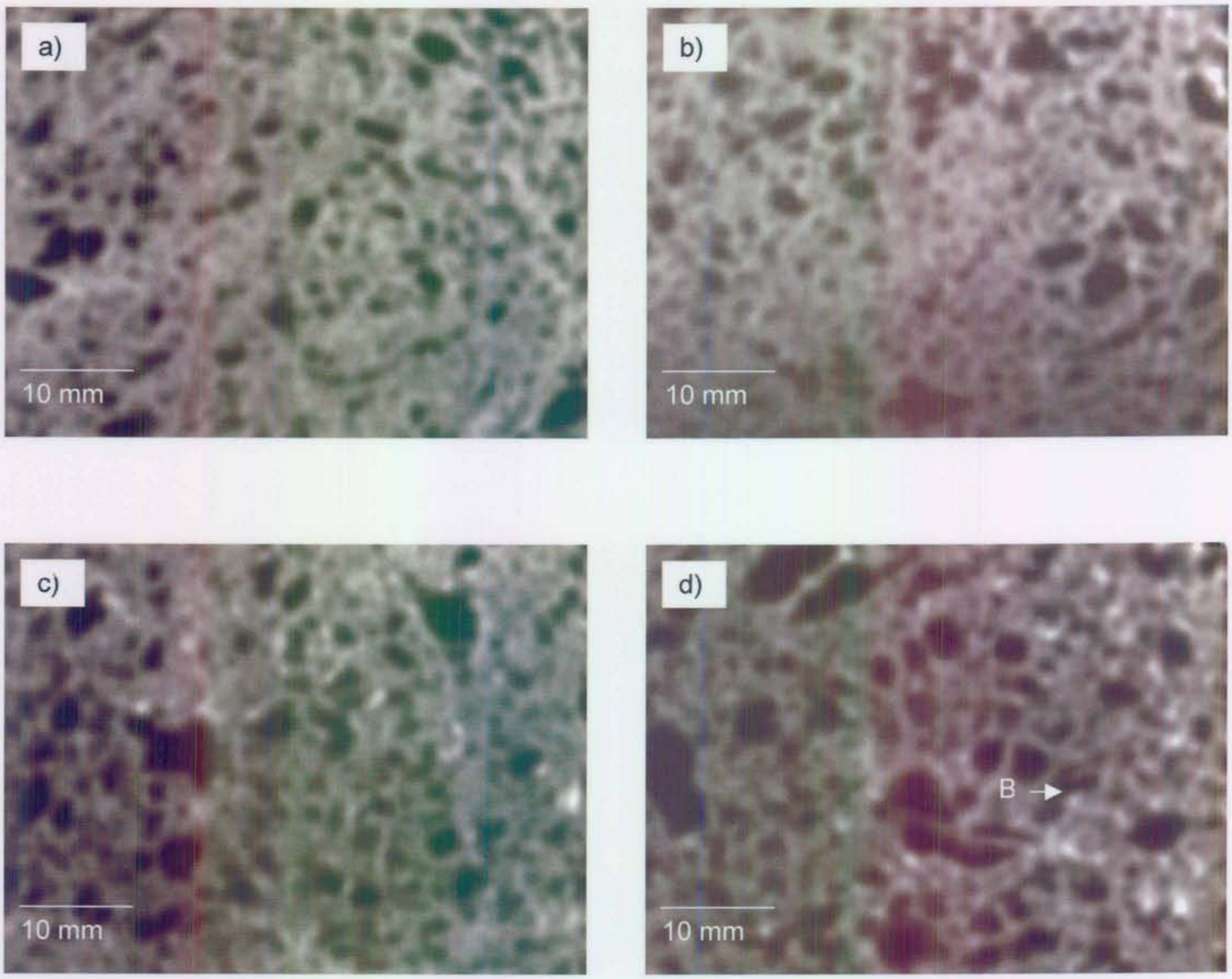



**Fig. 36: CAT scans of loaves with Select bran (15%) after a) 0 min.; b) 20 min.; c) 40 min.; and d) 60 min. of proofing at 40°C. B = bran particle protruding bubble**

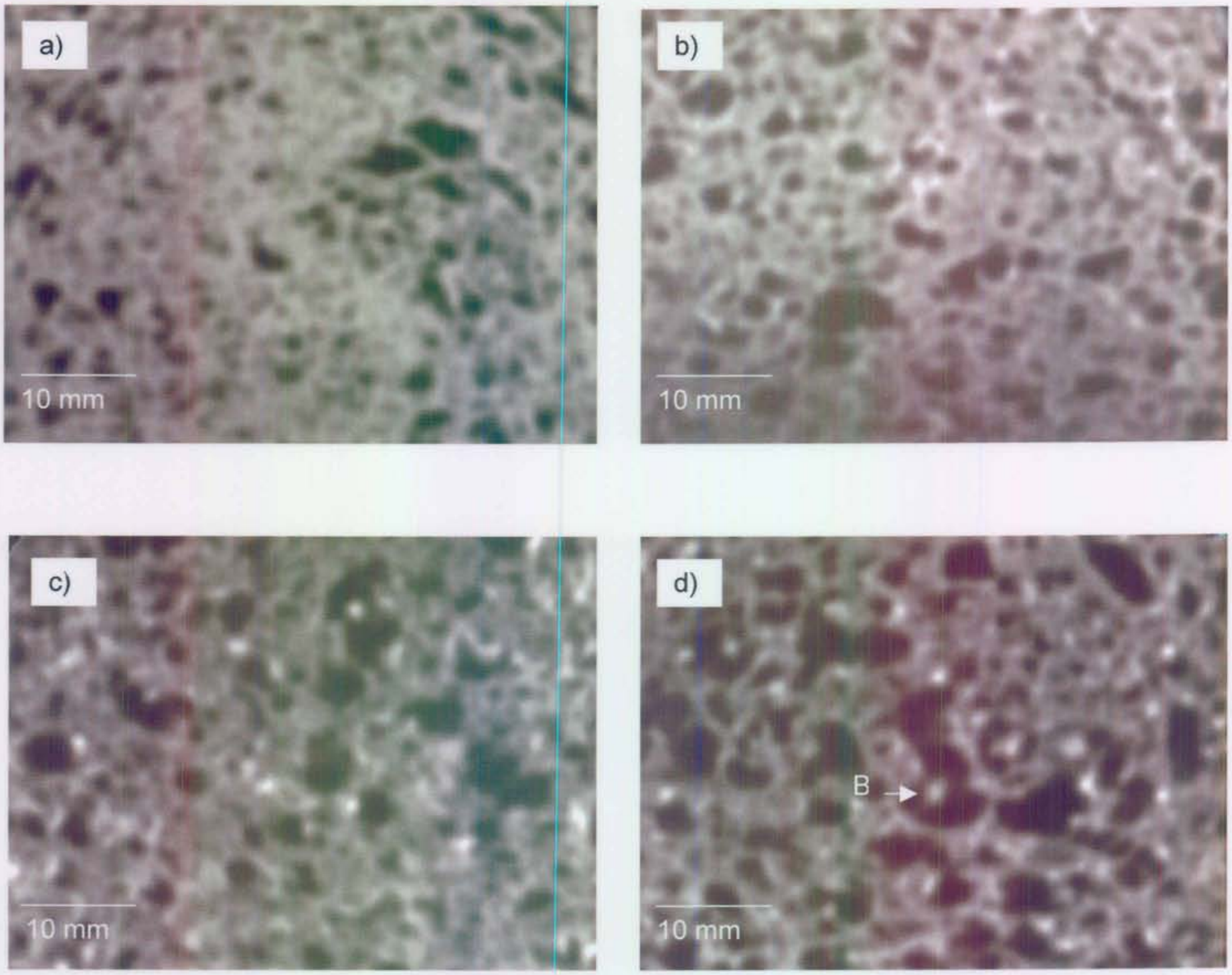



**Fig. 37:** CAT scans of loaves with Digestive bran (15%) after a) 0 min.; b) 20 min.; c) 40 min.; and d) 60 min. of proofing at 40°C. B = bran particle protruding bubble

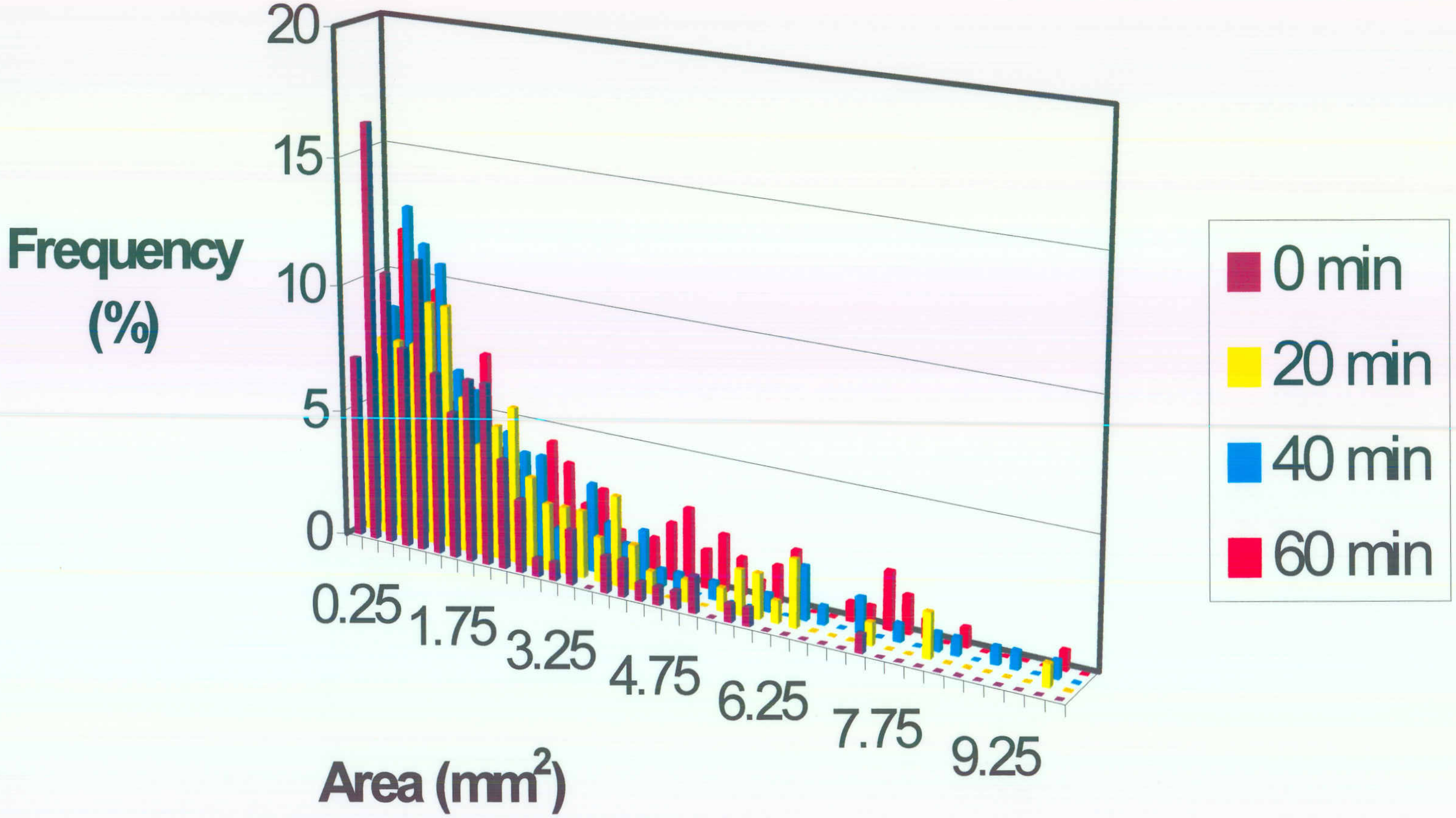



**Fig. 38: Frequency distribution of bubble area of a white bread control after 0, 20, 40 and 60 minutes of proofing at 40°C**

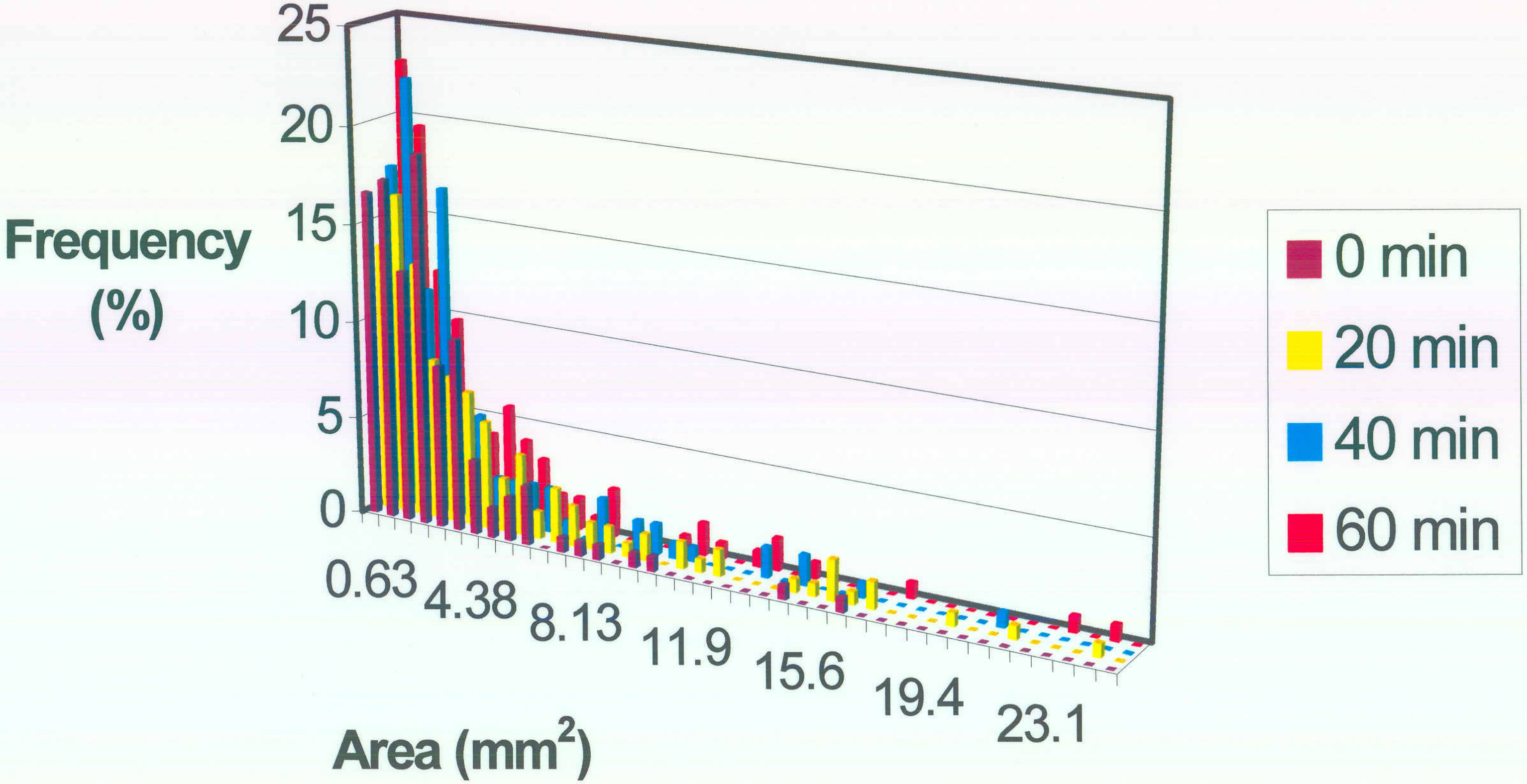



Fig. 39: Frequency distribution of bubble area of loaves with Pollard (15%) after 0, 20, 40 and 60 minutes of proofing at 40°C

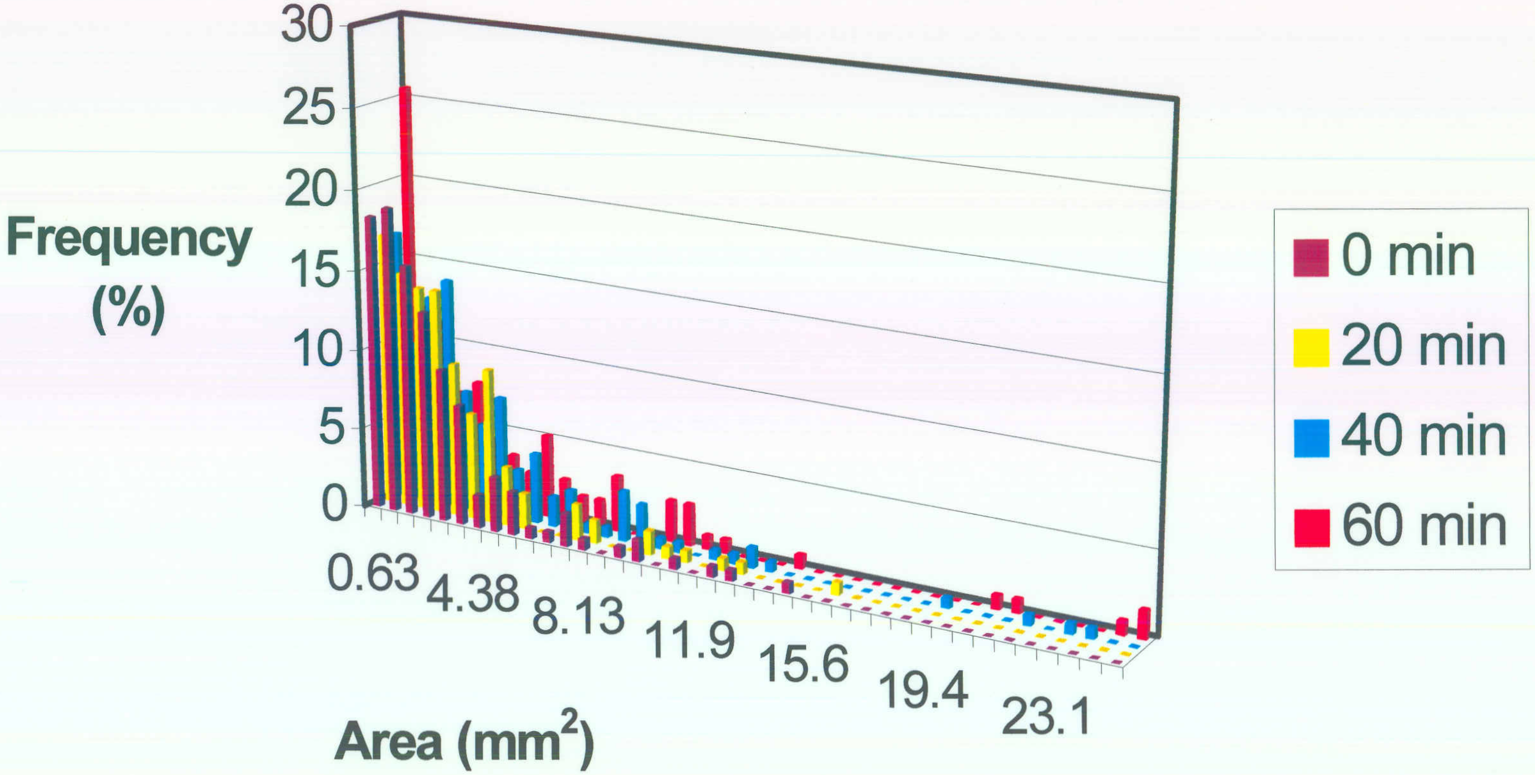



**Fig. 40: Frequency distribution of bubble area of loaves with Select bran (15%) after 0, 20, 40 and 60 minutes of proofing at 40°C**

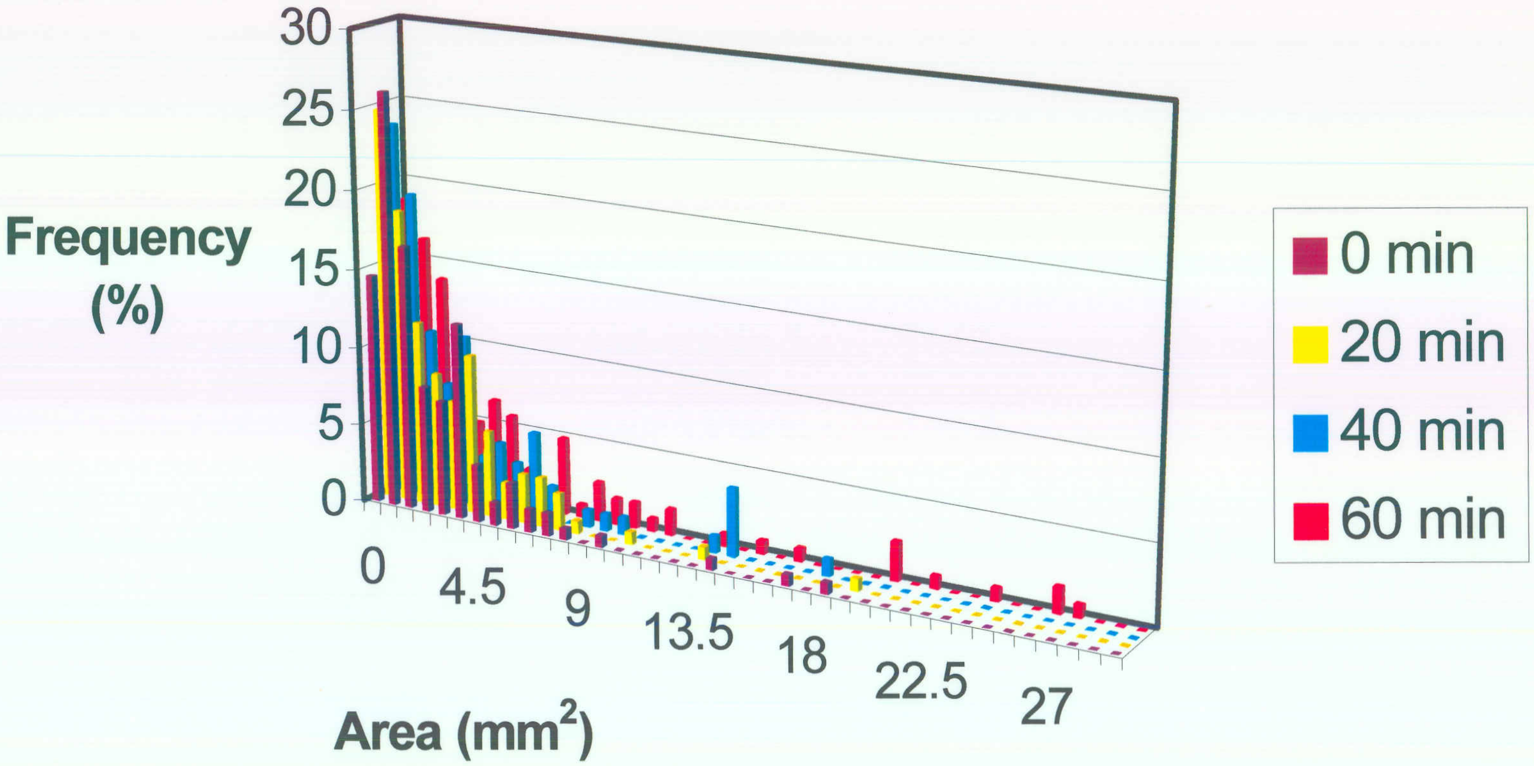



**Fig. 41: Frequency distribution of bubble area of loaves with Digestive bran (15%) after 0, 20, 40 and 60 minutes of proofing at 40°C**

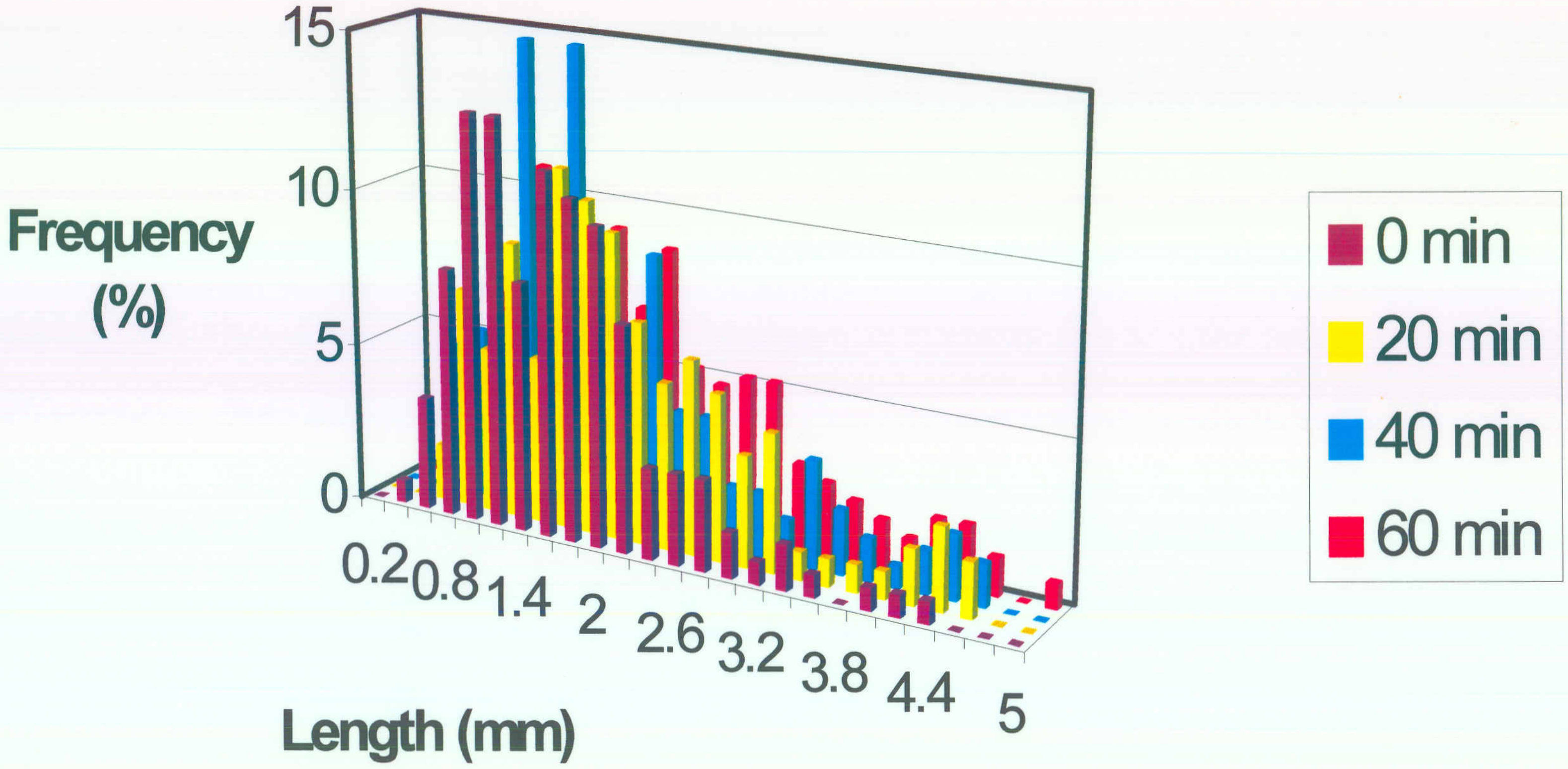



**Fig. 42: Frequency distribution of bubble length of a white bread control after 0, 20, 40 and 60 minutes of proofing at 40°C**

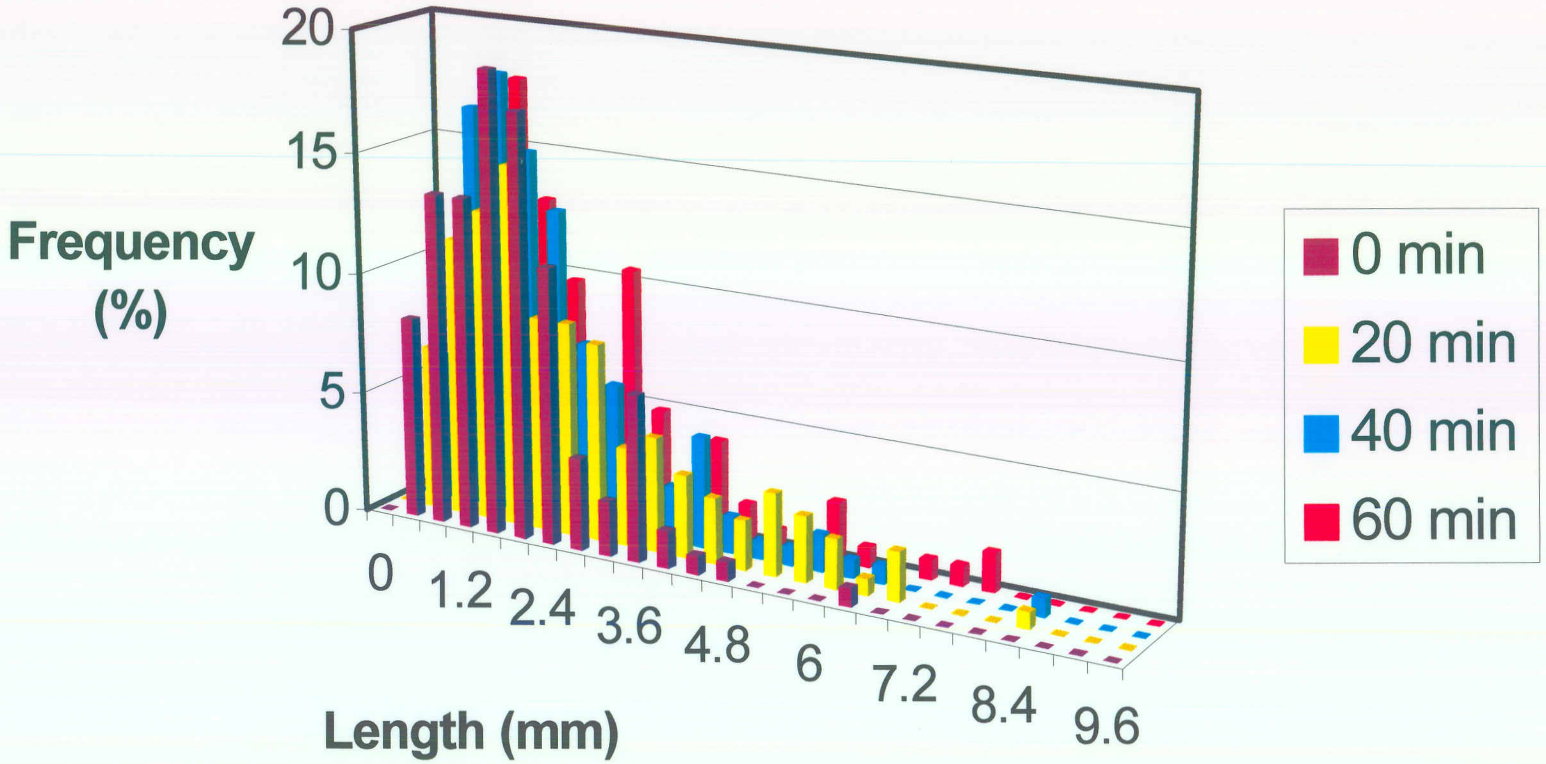



**Fig. 43: Frequency distribution of bubble length of loaves with Pollard (15%) after 0, 20, 40 and 60 minutes of proofing at 40°C**

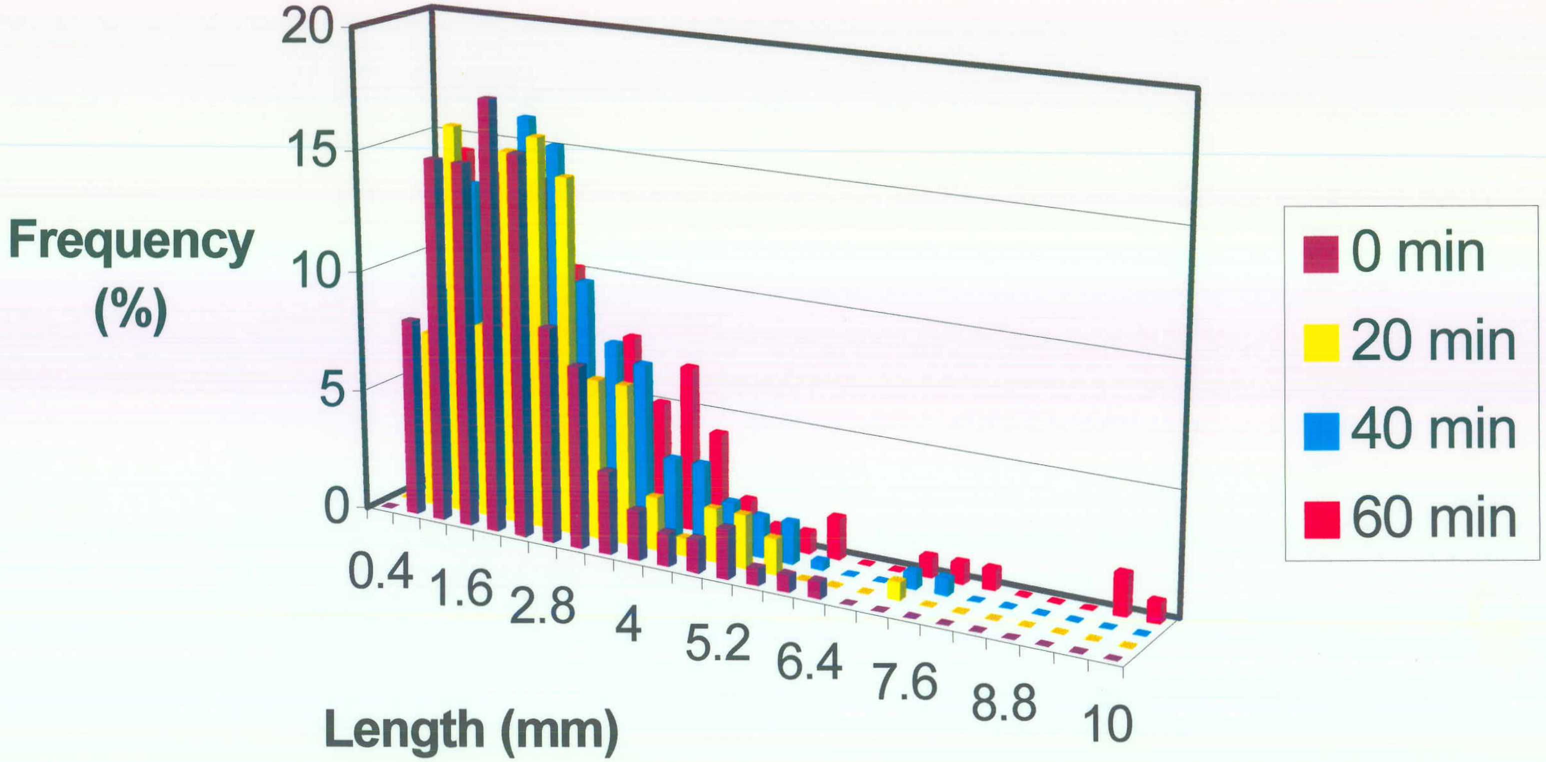



**Fig. 44: Frequency distribution of bubble length of loaves with Select bran (15%) after 0, 20, 40 and 60 minutes of proofing at 40°C**

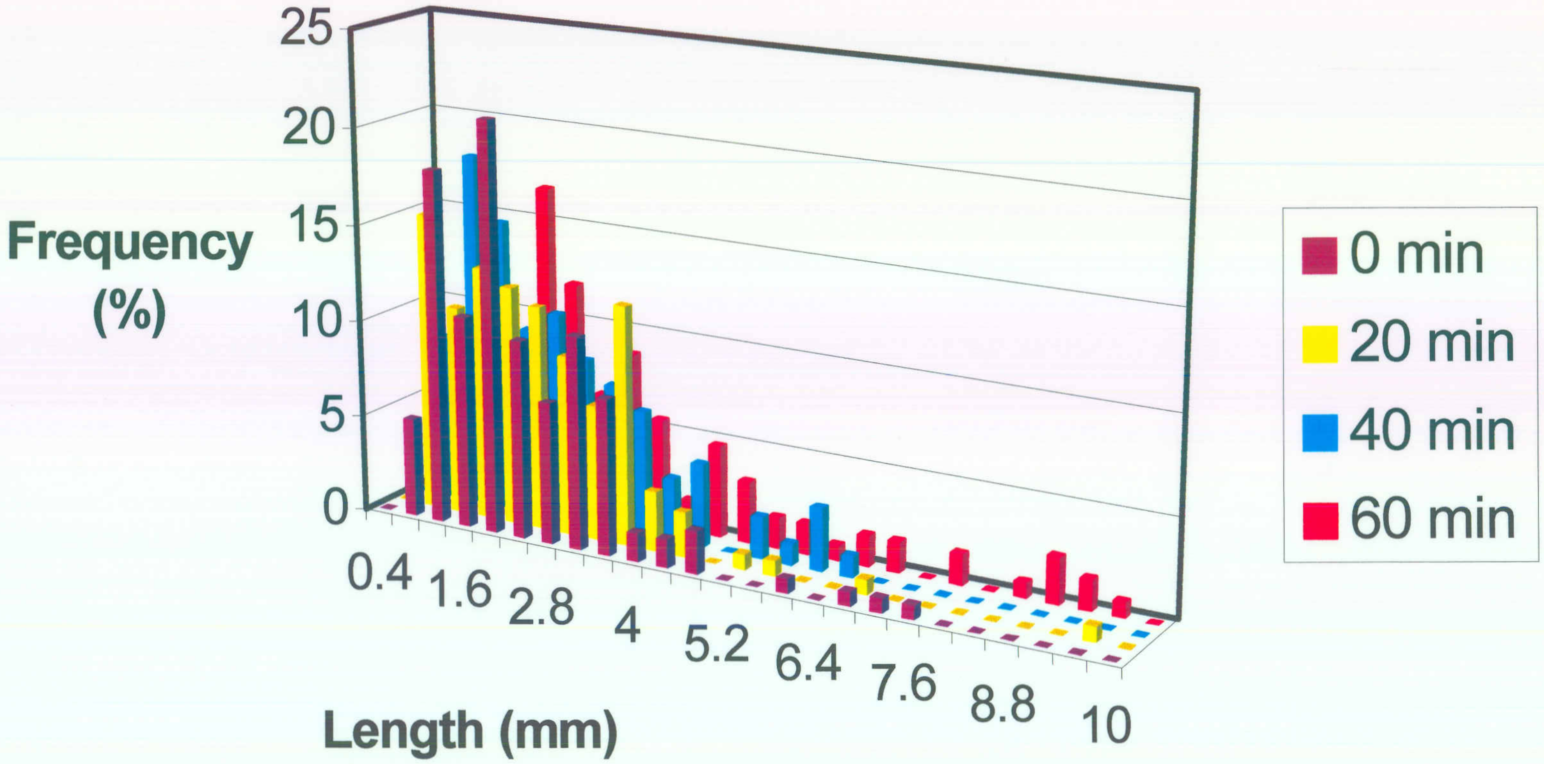



**Fig. 45: Frequency distribution of bubble length of loaves with Digestive bran (15%) after 0, 20, 40 and 60 minutes of proofing at 40°C**

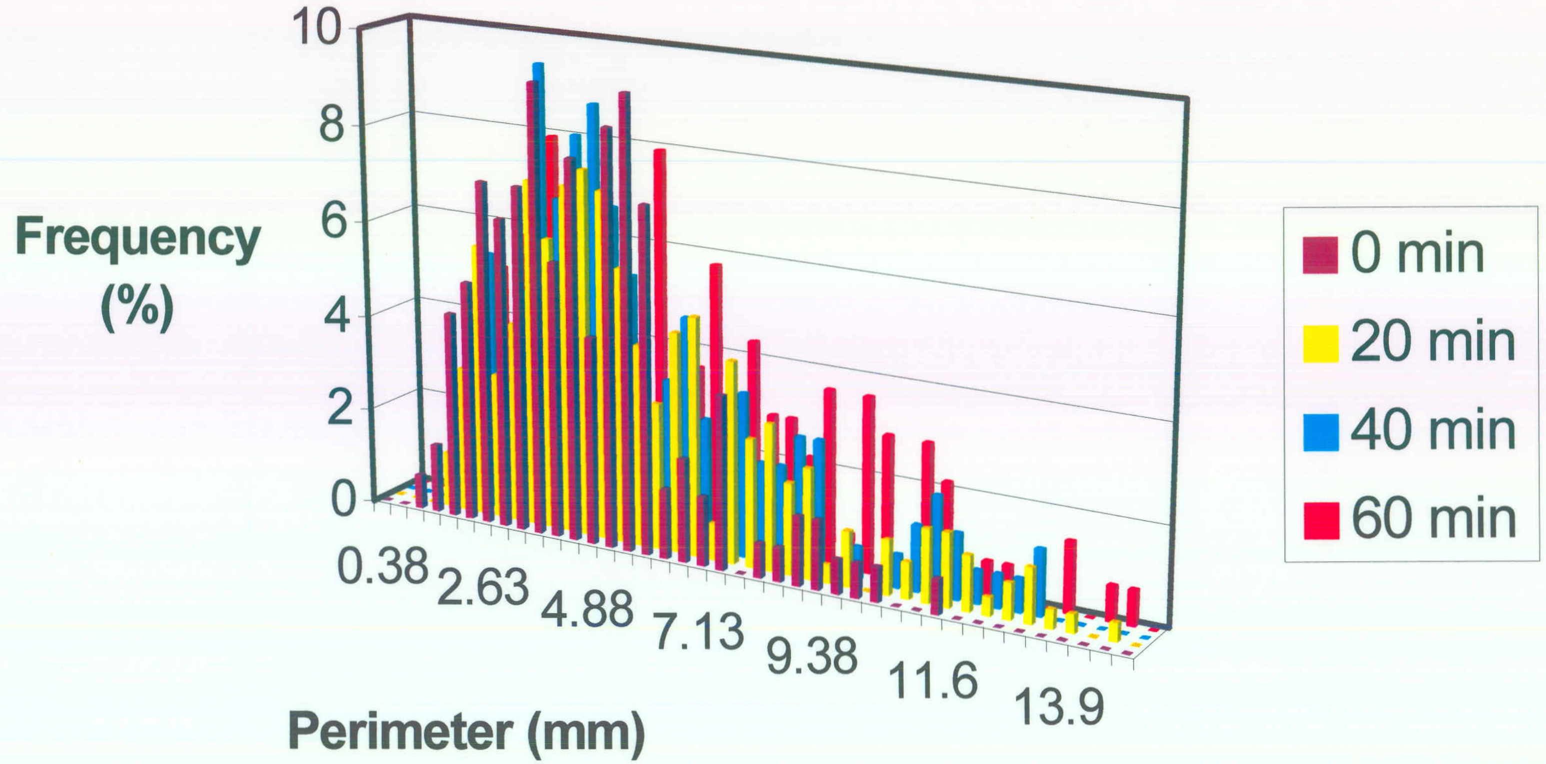



**Fig. 46: Frequency distribution of bubble perimeter of a white bread control after 0, 20, 40 and 60 minutes of proofing at 40°C**

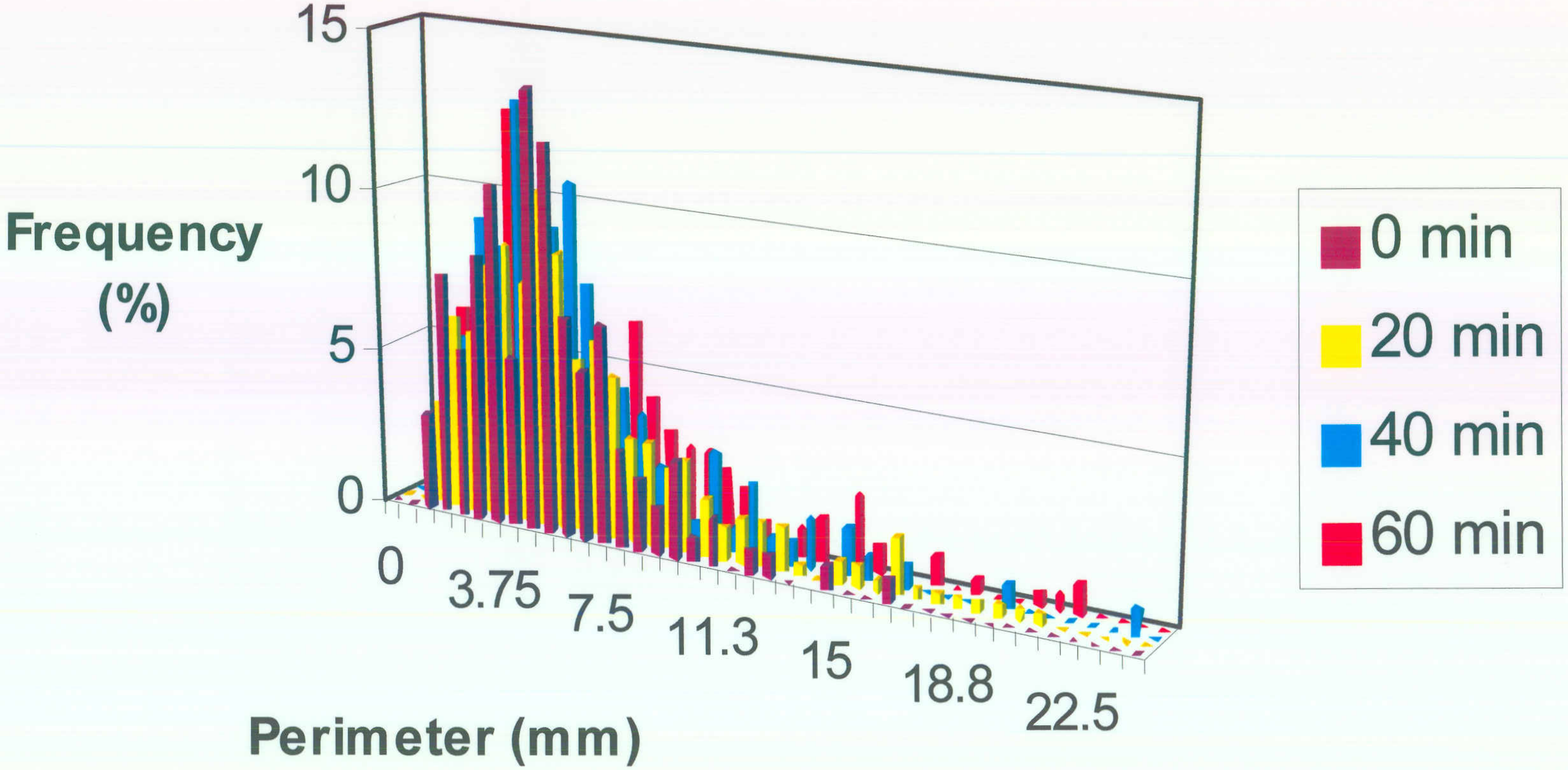



**Fig. 47: Frequency distribution of bubble perimeter of loaves with Pollard (15%) after 0, 20, 40 and 60 minutes of proofing at 40°C**

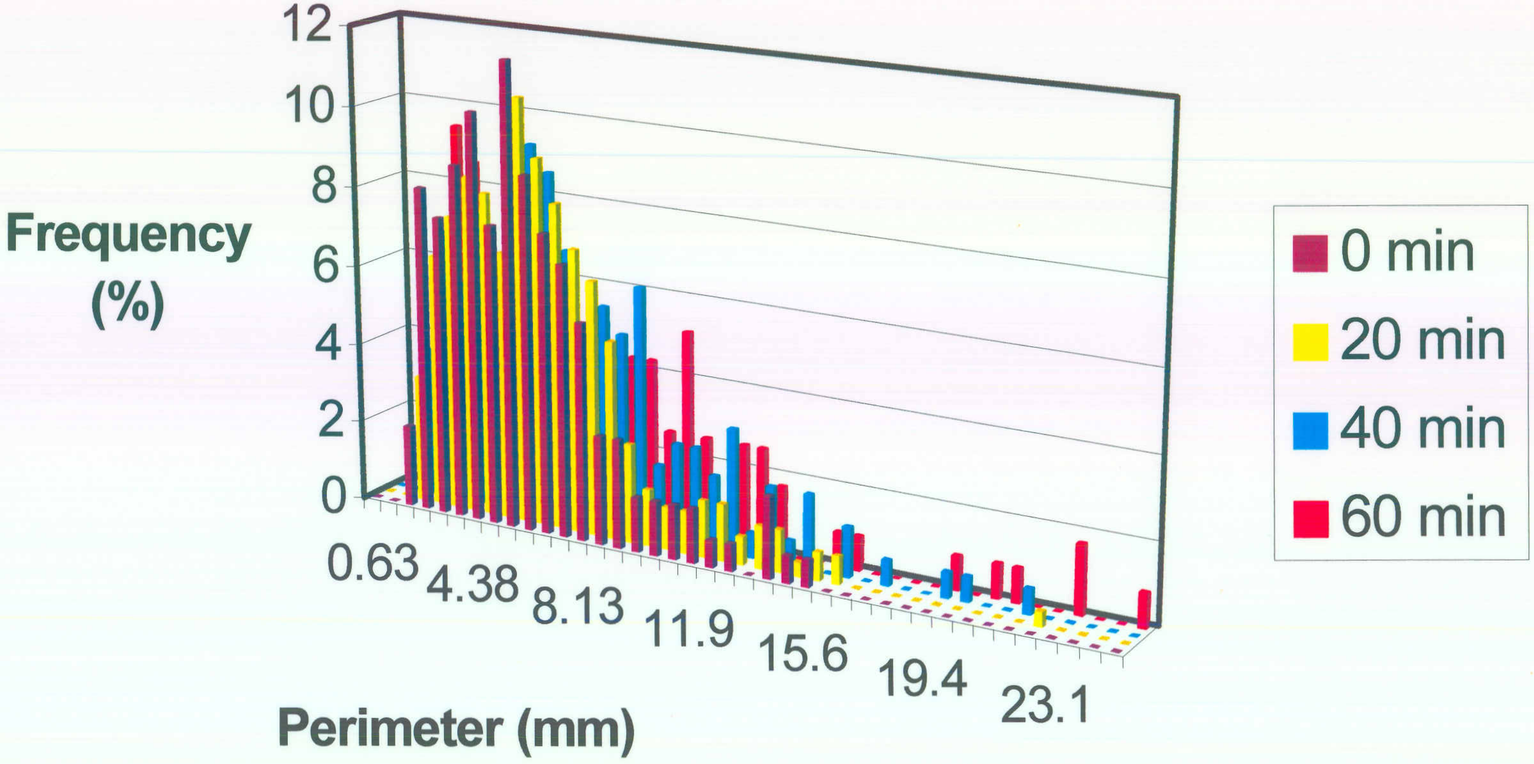



**Fig. 48: Frequency distribution of bubble perimeter of loaves with Select bran (15%) after 0, 20, 40 and 60 minutes of proofing at 40°C**

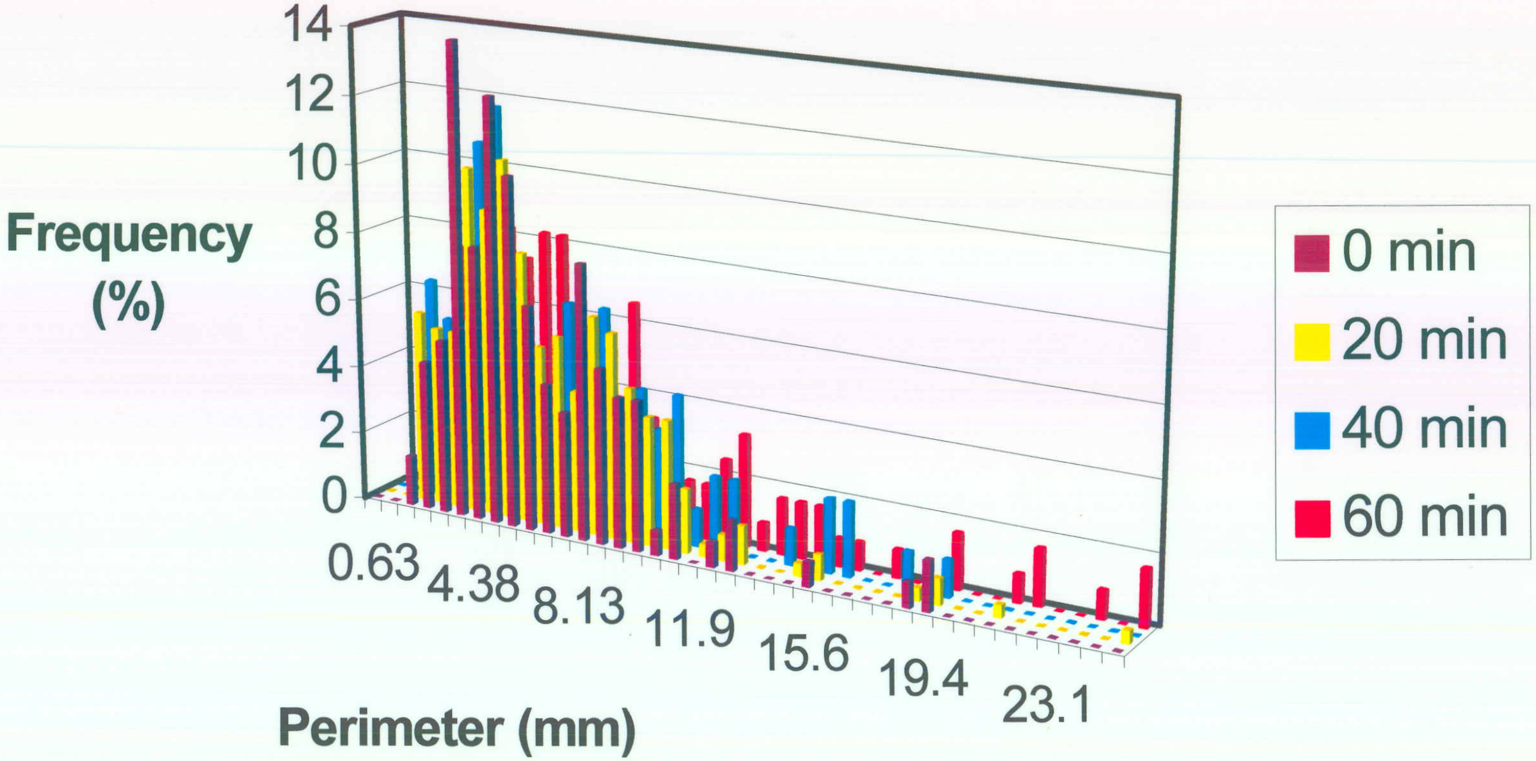



**Fig. 49: Frequency distribution of bubble perimeter of loaves with Digestive bran (15%) after 0, 20, 40 and 60 minutes of proofing at 40°C**

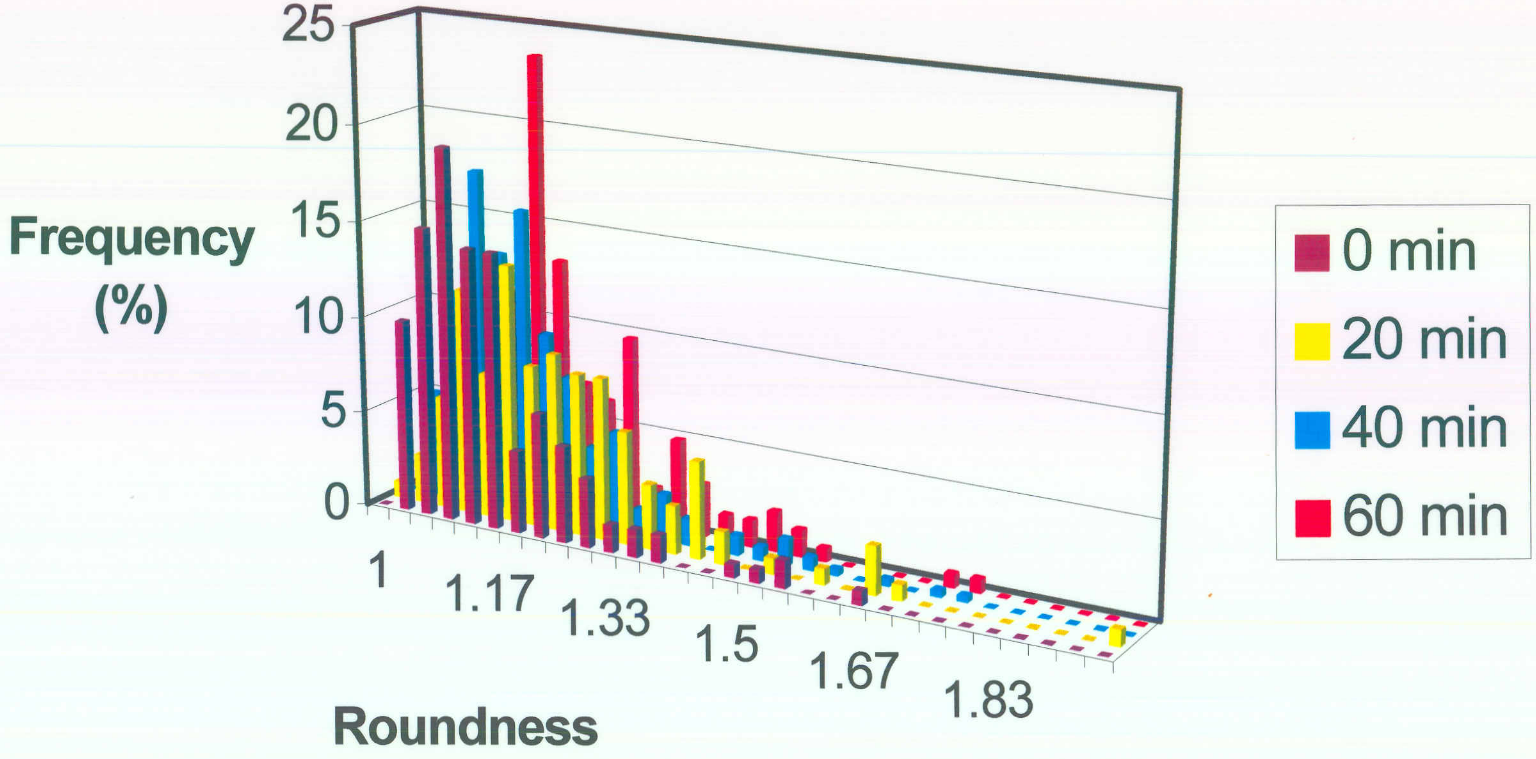



**Fig. 50: Frequency distribution of bubble roundness of a white bread control after 0, 20, 40 and 60 minutes of proofing at 40°C. Perfectly round = 1**

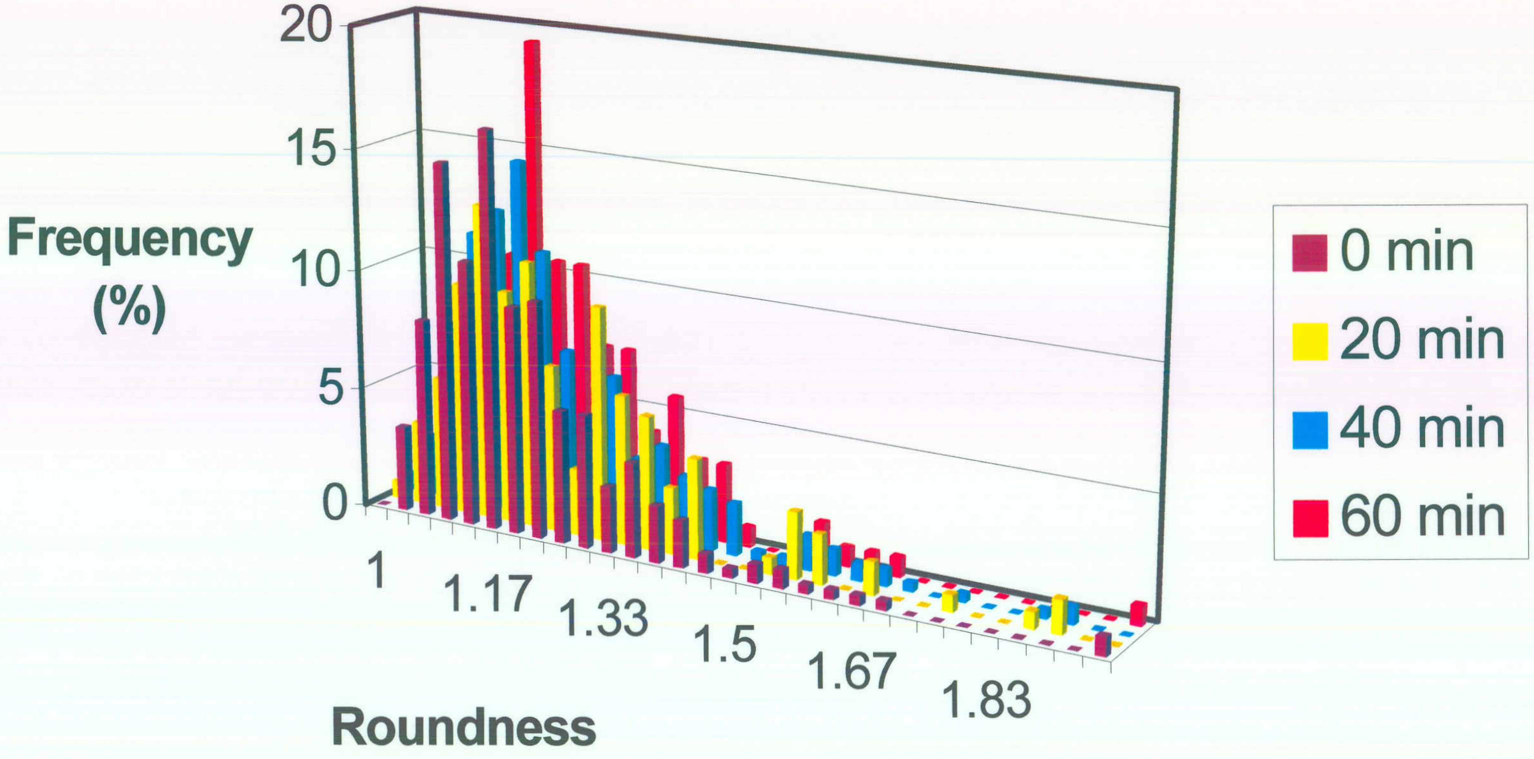



**Fig. 51: Frequency distribution of bubble roundness of loaves with Pollard (15%) after 0, 20, 40 and 60 minutes of proofing at 40°C. Perfectly round = 1**

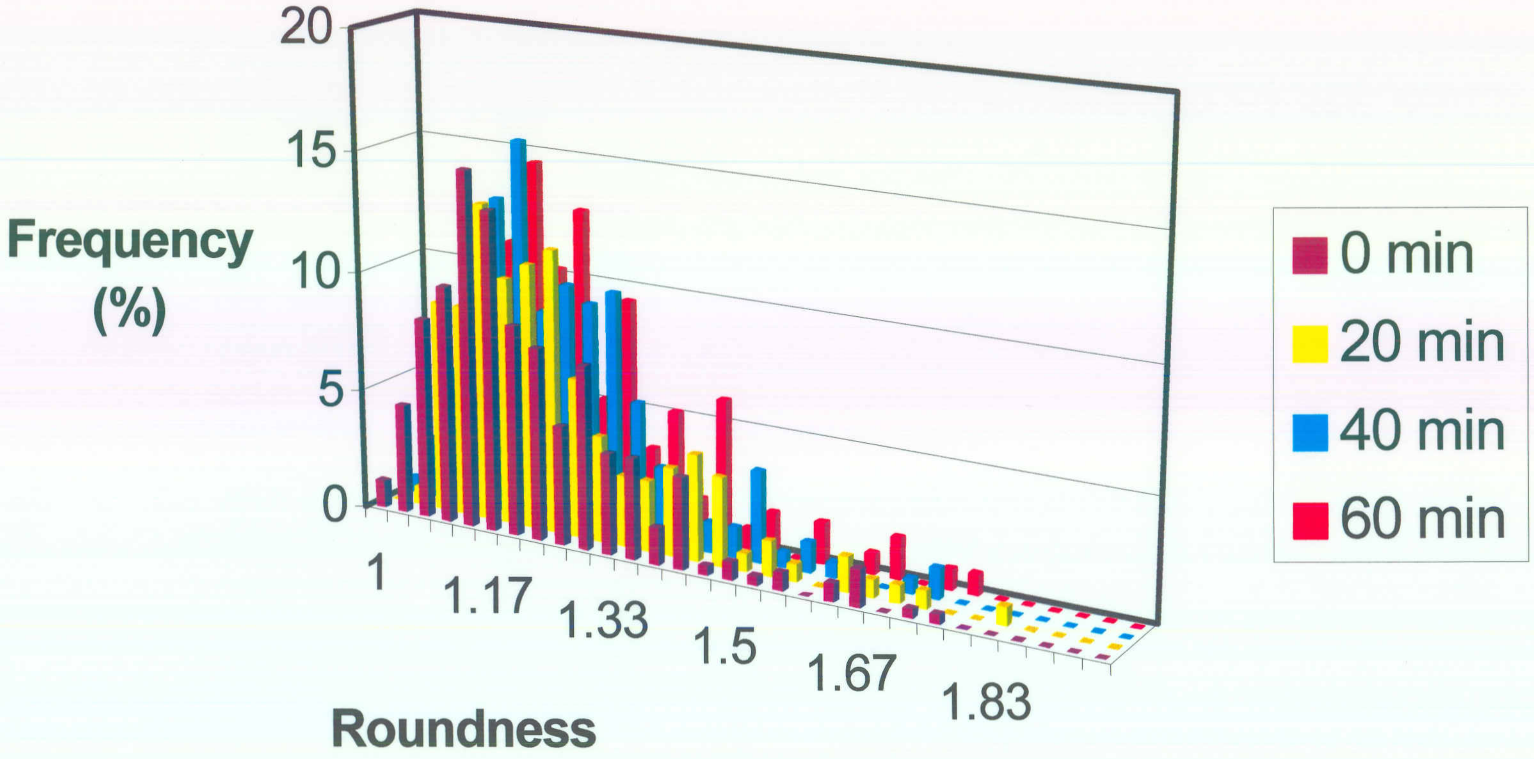



**Fig. 52: Frequency distribution of bubble roundness of loaves with Select bran (15%) after 0, 20, 40 and 60 minutes of proofing at 40°C. Perfectly round = 1**

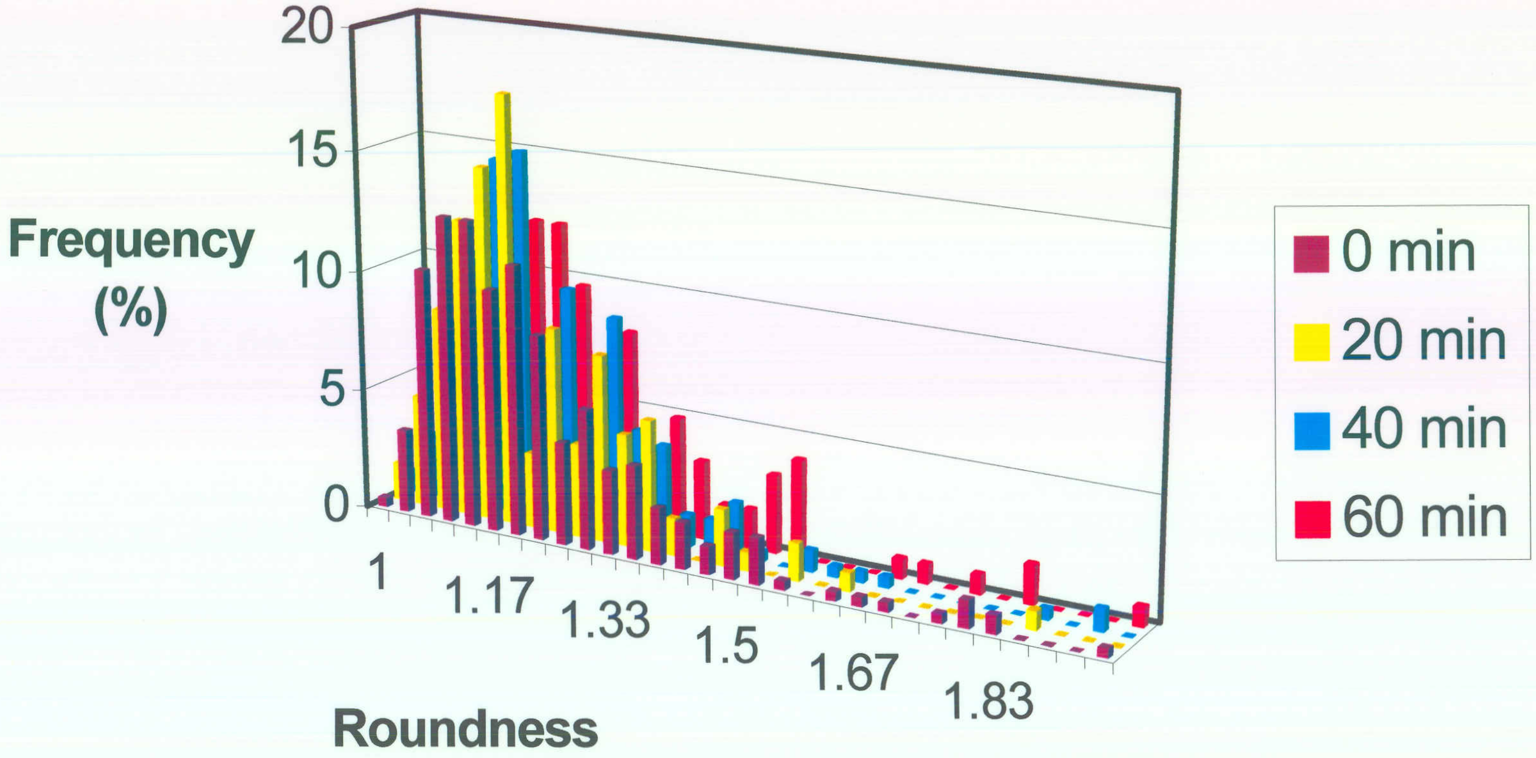



**Fig. 53:** **Frequency distribution of bubble roundness of loaves with Digestive bran (15%) after 0, 20, 40 and 60 minutes of proofing at 40°C. Perfectly round = 1**

From these figures it is evident that bubble size (measured as bubble area, length and perimeter) increased during proofing. Bubble size in the white bread was the smallest and the largest in the bread with Digestive bran. The white bread also had bubbles which were uniform and round, which was in sharp contrast with the irregularly shaped bubbles in the bread with Select and Digestive bran. Bubble shape and size in the bread with Pollard were more like that of the white bread. It could also be seen that bubble roundness decreased with proofing time in all cases (Fig. 50 to 53). Bran particles protruding through bubbles could be observed in the breads made with Select and Digestive bran (Fig. 36d and 37d)

## 4.9 SENSORY EVALUATION

Some sensory qualities of bread baked with different bran types are given in Table 25.

**Table 25: Sensory qualities of bread baked with different bran types (12% level of addition)**

| Attribute | Bran type | Mean score[a,b] |
|---|---|---|
| Texture | Pollard | 6.2 a |
| | Heat-treated Pollard | 4.8 b |
| | Heat-treated Digestive | 2.4 c |
| | Select | 2.2 c |
| | Digestive | 2.0 c |
| | Heat-treated Select | 1.8 c |
| Moistness | Heat-treated Pollard | 3.2 a |
| | Pollard | 2.6 a |
| | Select | 2.6 a |
| | Heat-treated Digestive | 2.2 a |
| | Digestive | 1.8 a |
| | Heat-treated Select | 1.6 a |

**Table 25 (cont.)**

| Attribute | Bran type | Mean score |
|---|---|---|
| Graininess | Pollard | 5.2 a |
| | Heat-treated Pollard | 5.2 a |
| | Heat-treated Digestive | 3.6 ab |
| | Select | 2.4 bc |
| | Heat-treated Select | 2.0 bc |
| | Digestive | 1.3 c |
| Chewiness | Pollard | 6.0 a |
| | Heat-treated Pollard | 5.8 a |
| | Select | 4.0 b |
| | Heat-treated Digestive | 3.4 bc |
| | Heat-treated Select | 2.2 cd |
| | Digestive | 1.5 d |
| Taste | Pollard | 5.8 a |
| | Heat-treated pollard | 5.4 ab |
| | Select | 3.6 bc |
| | Heat-treated Digestive | 3.2 cd |
| | Heat-treated Select | 3.0 cd |
| | Digestive | 1.5 d |
| Overall acceptability | Pollard | 6.4 a |
| | Heat-treated Pollard | 5.6 a |
| | Select | 3.4 b |
| | Heat-treated Digestive | 3.4 b |
| | Heat-treated Select | 2.2 bc |
| | Digestive | 1.5 c |

[a]1 = Do not differ at all from “ideal brown bread”; 7 = Differ very much from “ideal brown bread”

[b]Values with different letters in the same cell are significantly different ($P<0.05$)

From this table it is evident that bread baked with Digestive bran and heat-treated Select bran were the closest to the panelists' idea of an "ideal brown bread". The bread baked with Pollard was found to differ most from an "ideal brown bread" and was not acceptable.