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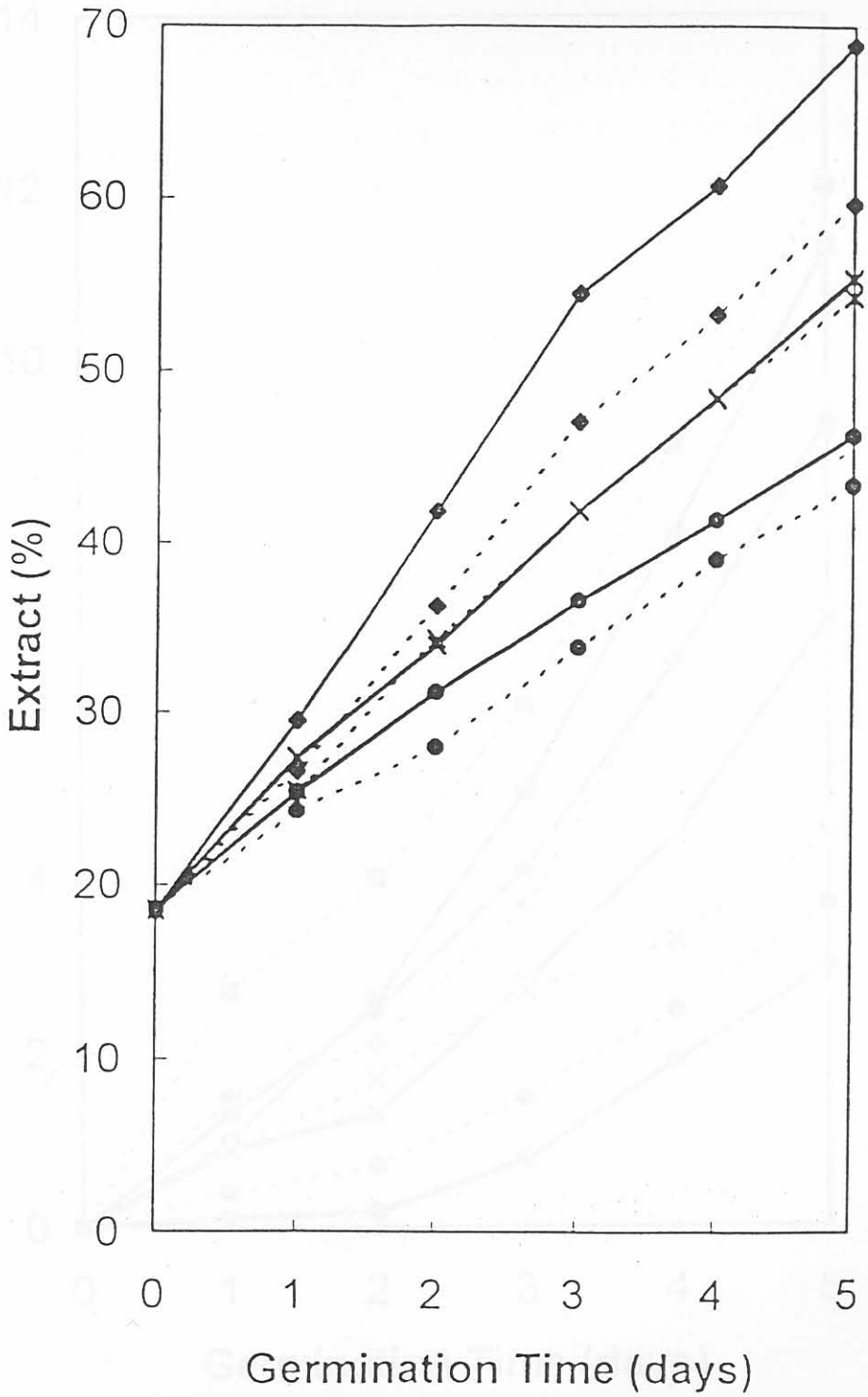

Figure 24.- Effects of germination time, watering treatment and variety on malt extract of pearl millet at 25 °C (variety SDMV 89004(–) and variety SDMV 91018 (--) at various watering treatments (•- Low watering; ×- Medium watering; ♦- High watering)

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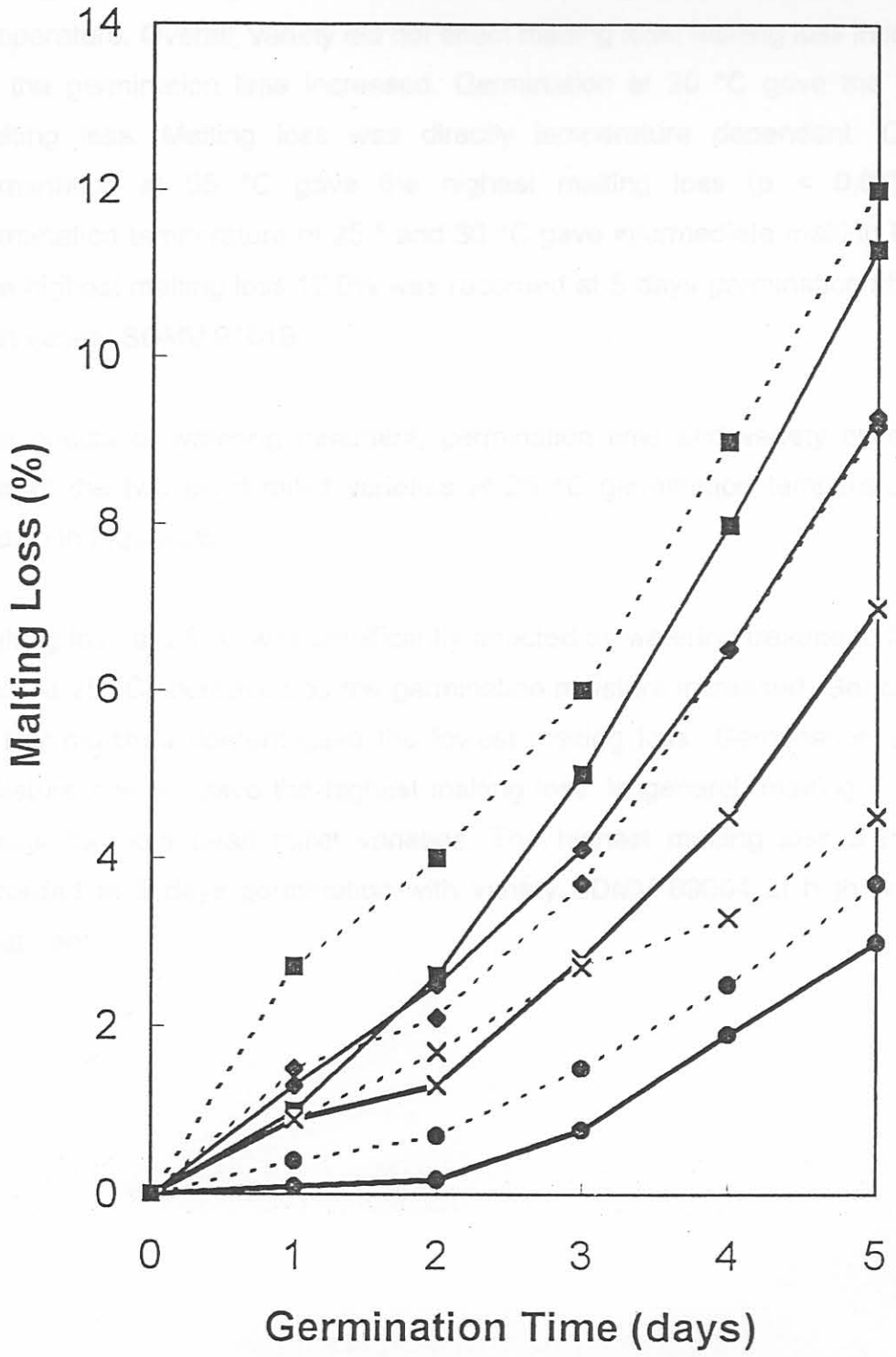

Figure 25.- Effects of germination time, temperature and variety on malting loss of pearl millet (variety SDMV 89004 (–) and variety SDMV 91018 (--); (•- 20 °C; ×- 25 °C; ♦- 30 °C; ■- 35 °C)

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Malting loss was significantly affected ($p < 0.001$) by germination time and temperature. Overall, variety did not effect malting loss. Malting loss increased as the germination time increased. Germination at 20 °C gave the lowest malting loss. Malting loss was directly temperature dependent. Overall, germination at 35 °C gave the highest malting loss ($p < 0.05$). The germination temperature of 25 ° and 30 °C gave intermediate malting losses. The highest malting loss 12.0% was recorded at 5 days germination at 35 °C with variety SDMV 91018.

The effects of watering treatment, germination time and variety on malting loss of the two pearl millet varieties at 25 °C germination temperature are shown in Figure 26.

Malting loss at 25 °C was significantly affected by watering treatment. Malting loss, at 25 °C, increased as the germination moisture increased. Germination at low moisture content gave the lowest malting loss. Germination at high moisture content gave the highest malting loss. In general, malting loss was similar for both pearl millet varieties. The highest malting loss 9.2% was recorded at 5 days germination with variety SDMV 89004 at high watering treatment.

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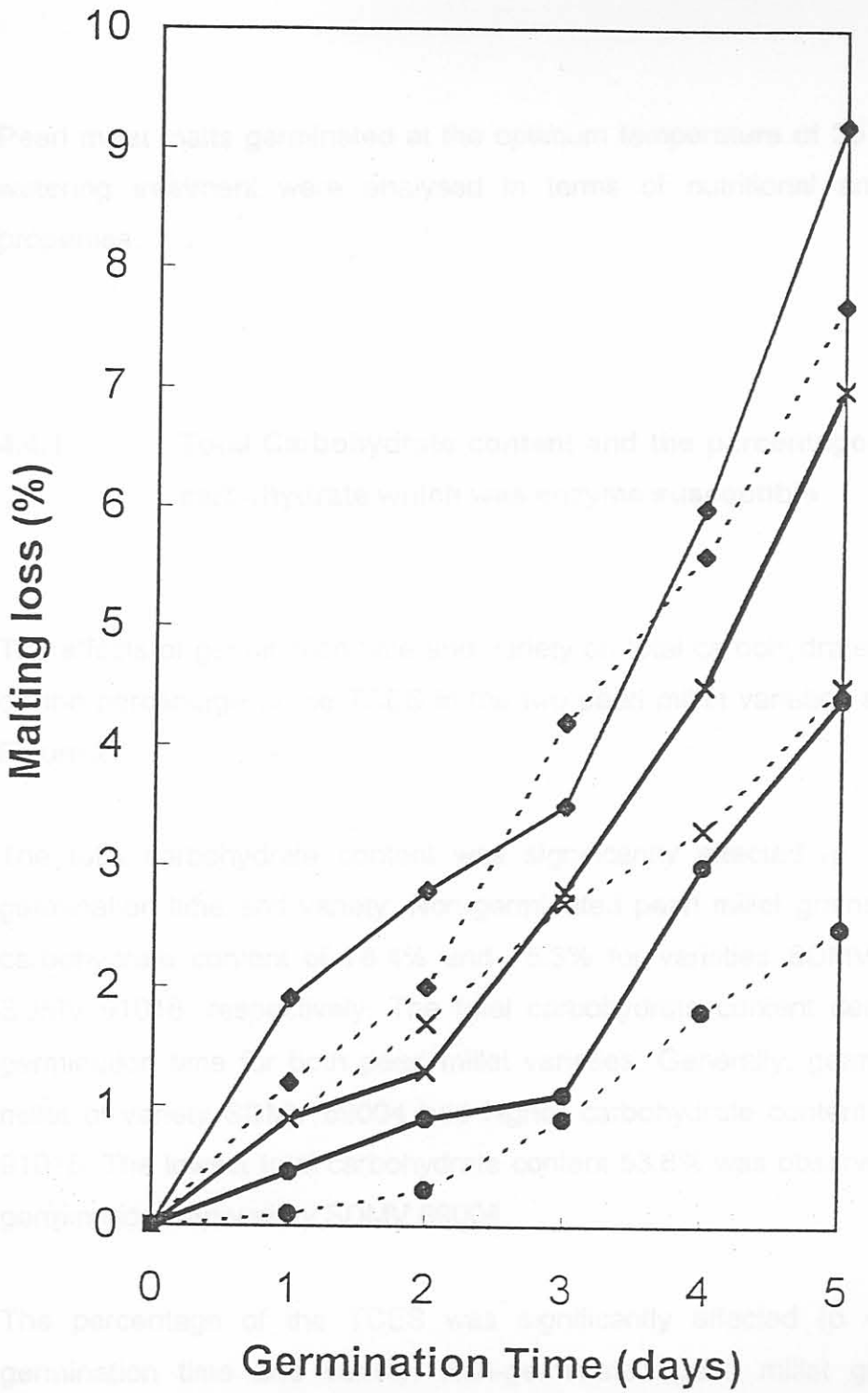

Figure 26.- Effects of germination time, watering treatment and variety on malting loss of pearl millet at 25 °C (variety SDMV 89004(–) and variety SDMV 91018 (--) at various watering treatments (•- Low watering; ×- Medium watering; ♦- High watering)

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4.4 NUTRITIONAL AND FUNCTIONAL ANALYSES OF MALTS

Pearl millet malts germinated at the optimum temperature of 25 °C, medium watering treatment were analysed in terms of nutritional and functional properties.

4.4.1 Total Carbohydrate content and the percentage of the total carbohydrate which was enzyme susceptible

The effects of germination time and variety on total carbohydrate content and on the percentage of the TCES in the two pearl millet varieties are shown in Figure 27.

The total carbohydrate content was significantly affected ($p < 0.001$) by germination time and variety. Non-germinated pearl millet grains had a total carbohydrate content of 78.4% and 75.3% for varieties SDMV 89004 and SDMV 91018, respectively. The total carbohydrate content decreased with germination time for both pearl millet varieties. Generally, germinated pearl millet of variety SDMV 89004 had higher carbohydrate content than SDMV 91018. The lowest total carbohydrate content 53.8% was observed at 5 days germination with variety SDMV 89004.

The percentage of the TCES was significantly affected ($p < 0.001$) by germination time and variety. Non-germinated pearl millet grains had a percentage of the TCES of 10.6% and 10.1% for the varieties SDMV 89004 and SDMV 91018, respectively. The percentage of the TCES increased with germination time for both pearl millet varieties. The percentage of the TCES was higher in SDMV 89004.

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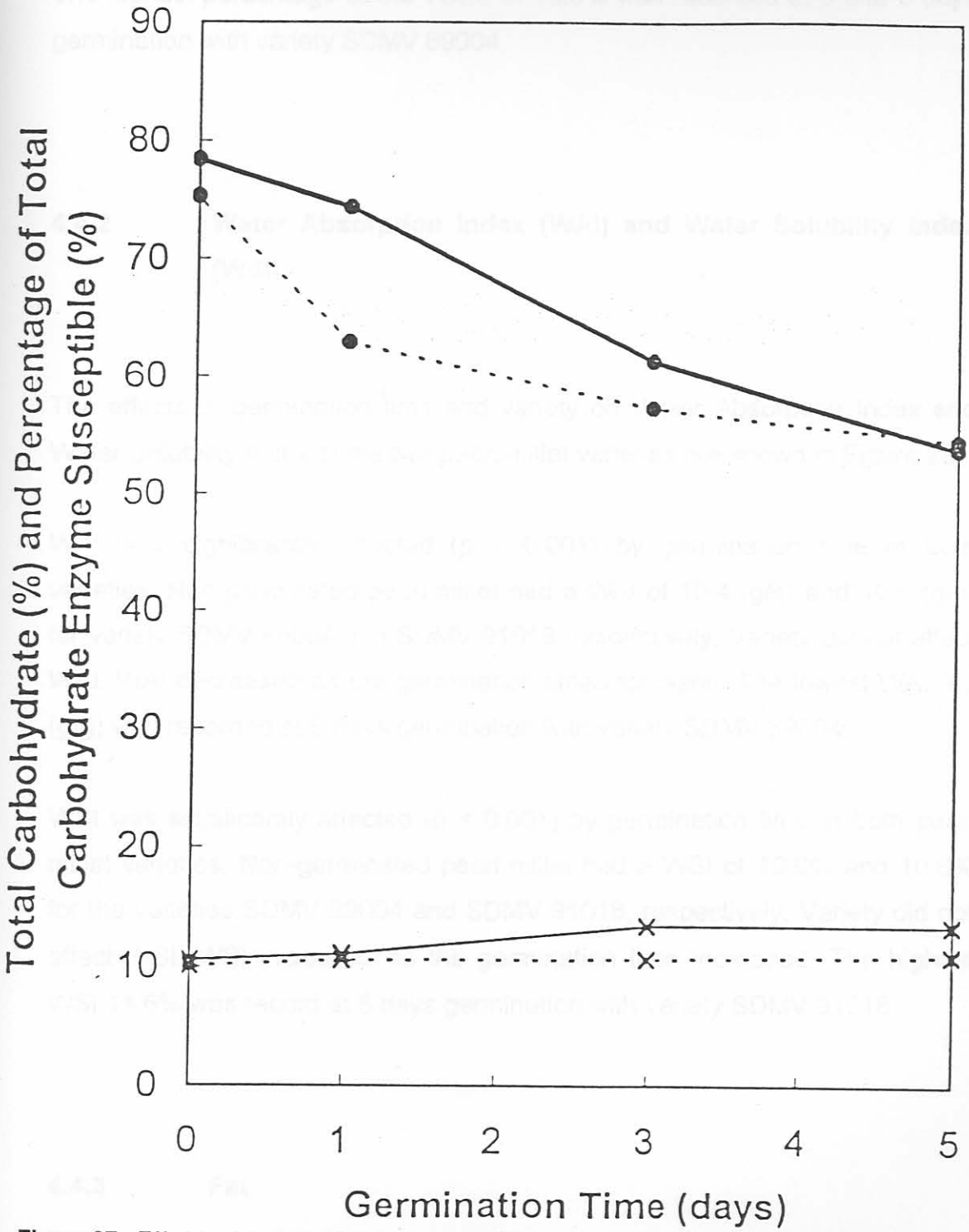

Figure 27.- Effects of germination time and variety on the total carbohydrate content and the percentage of the total carbohydrate which was enzyme susceptible of pearl millet (variety SDMV 89004(–) and variety SDMV 91018 (--); total carbohydrate (•-); the total carbohydrate which was enzyme susceptible (×-))

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The highest percentage of the TCES of 13.5% was recorded at 3 and 5 days germination with variety SDMV 89004.

4.4.2 Water Absorption Index (WAI) and Water Solubility Index (WSI)

The effects of germination time and variety on Water Absorption Index and Water Solubility Index of the two pearl millet varieties are shown in Figure 28.

WAI was significantly affected ($p < 0.001$) by germination time in both varieties. Non-germinated pearl millet had a WAI of 10.4 (g/g) and 10.6 (g/g) for variety SDMV 89004 and SDMV 91018, respectively. Variety did not affect WAI. WAI decreased as the germination time increased. The lowest WAI 9.0 (g/g) was recorded at 5 days germination with variety SDMV 89004.

WSI was significantly affected ($p < 0.001$) by germination time in both pearl millet varieties. Non-germinated pearl millet had a WSI of 10.0% and 10.6% for the varieties SDMV 89004 and SDMV 91018, respectively. Variety did not affect WSI. WSI increased as the germination time increased. The highest WSI 11.6% was record at 5 days germination with variety SDMV 91018.

4.4.3 Fat

The effects of germination time and variety on the fat content of the two pearl millet varieties are shown in the Figure 29.

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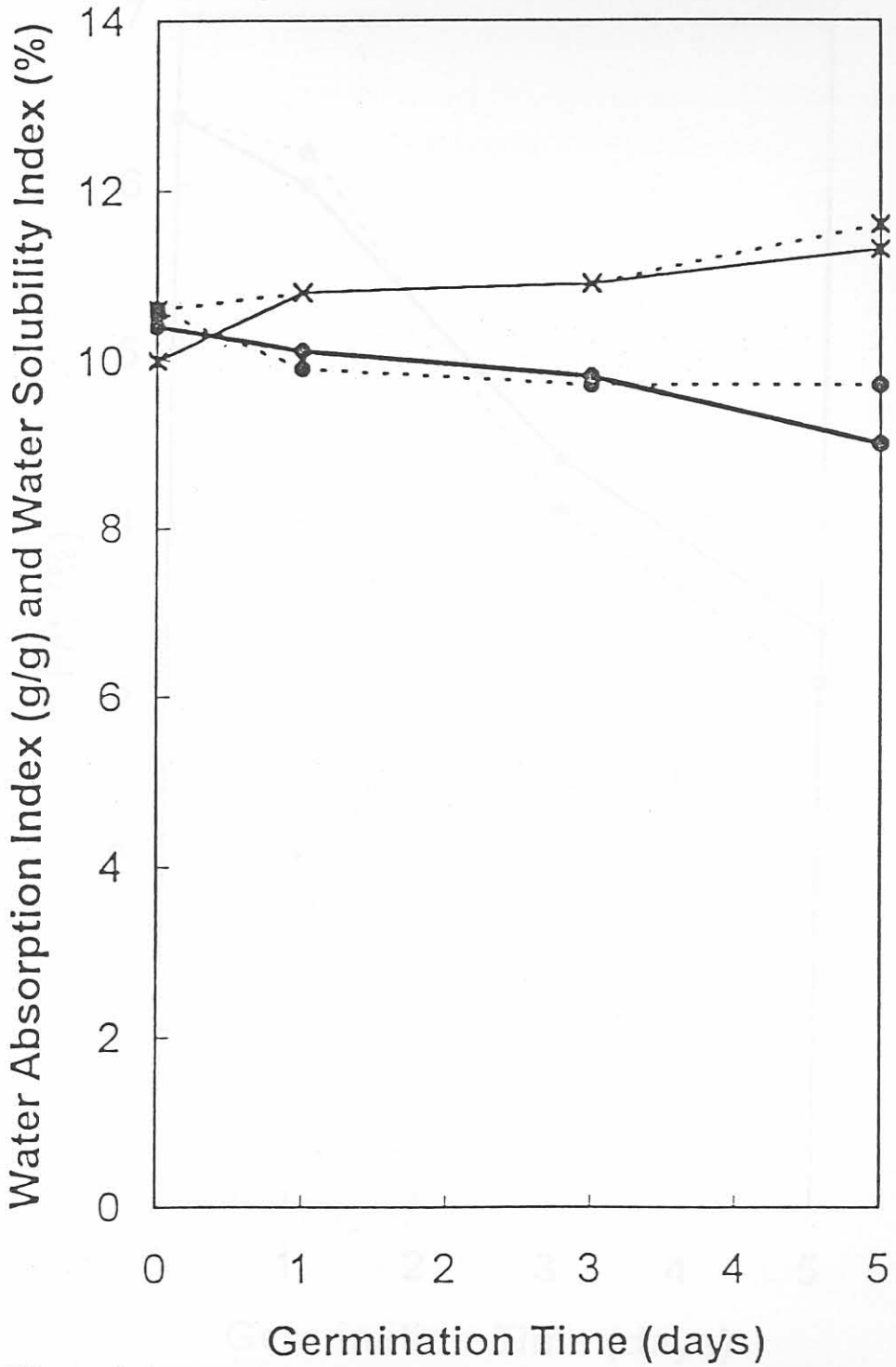

Figure 28.- Effects of germination time and variety on WAI and WSI of two pearl millet (variety SDMV 89004(–) and variety SDMV 91018 (--); water absorption index (•-); water solubility index (×-))

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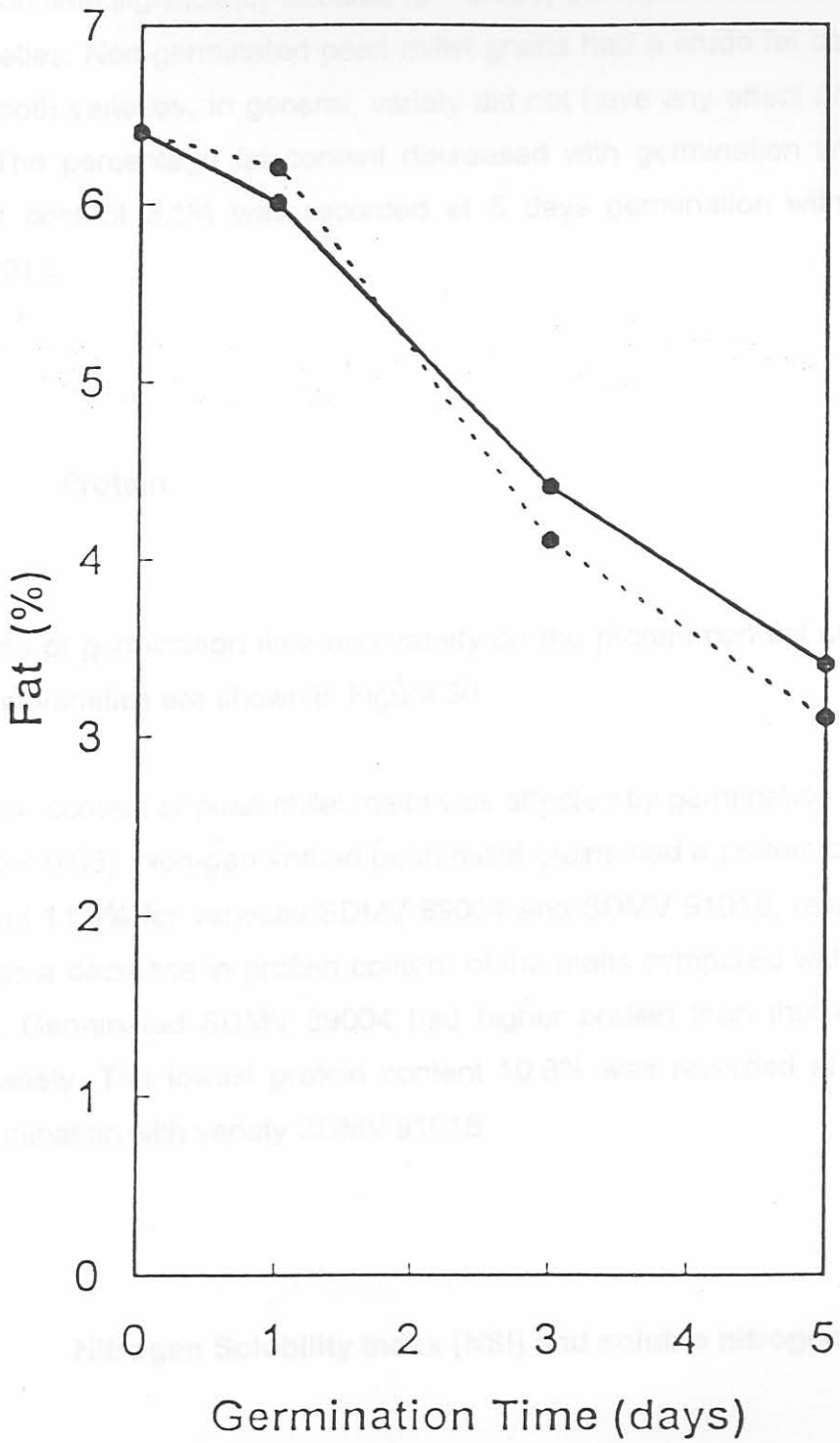

Figure 29.- Effects of germination time and variety on the fat content of pearl millet (variety SDMV 89004(–) and variety SDMV 91018 (--))

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Germination time significantly affected ($p < 0.001$) the fat content of both pearl millet varieties. Non-germinated pearl millet grains had a crude fat content of 6.4% for both varieties. In general, variety did not have any effect on the fat content. The percentage fat content decreased with germination time. The lowest fat content 3.1% was recorded at 5 days germination with variety SDMV 91018.

4.4.4 Protein

The effects of germination time and variety on the protein content of the two pearl millet varieties are shown in Figure 30.

The protein content of pearl millet malts was affected by germination time and variety ($p < 0.05$). Non-germinated pearl millet grains had a protein content of 11.7% and 11.3% for varieties SDMV 89004 and SDMV 91018, respectively. There was a decrease in protein content of the malts compared with control samples. Germinated SDMV 89004 had higher protein than that of SDMV 91018 variety. The lowest protein content 10.8% was recorded at 3 and 5 days germination with variety SDMV 91018.

4.4.5 Nitrogen Solubility Index (NSI) and soluble nitrogen

The effects of germination time and variety on the NSI and soluble nitrogen of the two pearl millet are shown in Figures 31 and 32, respectively.

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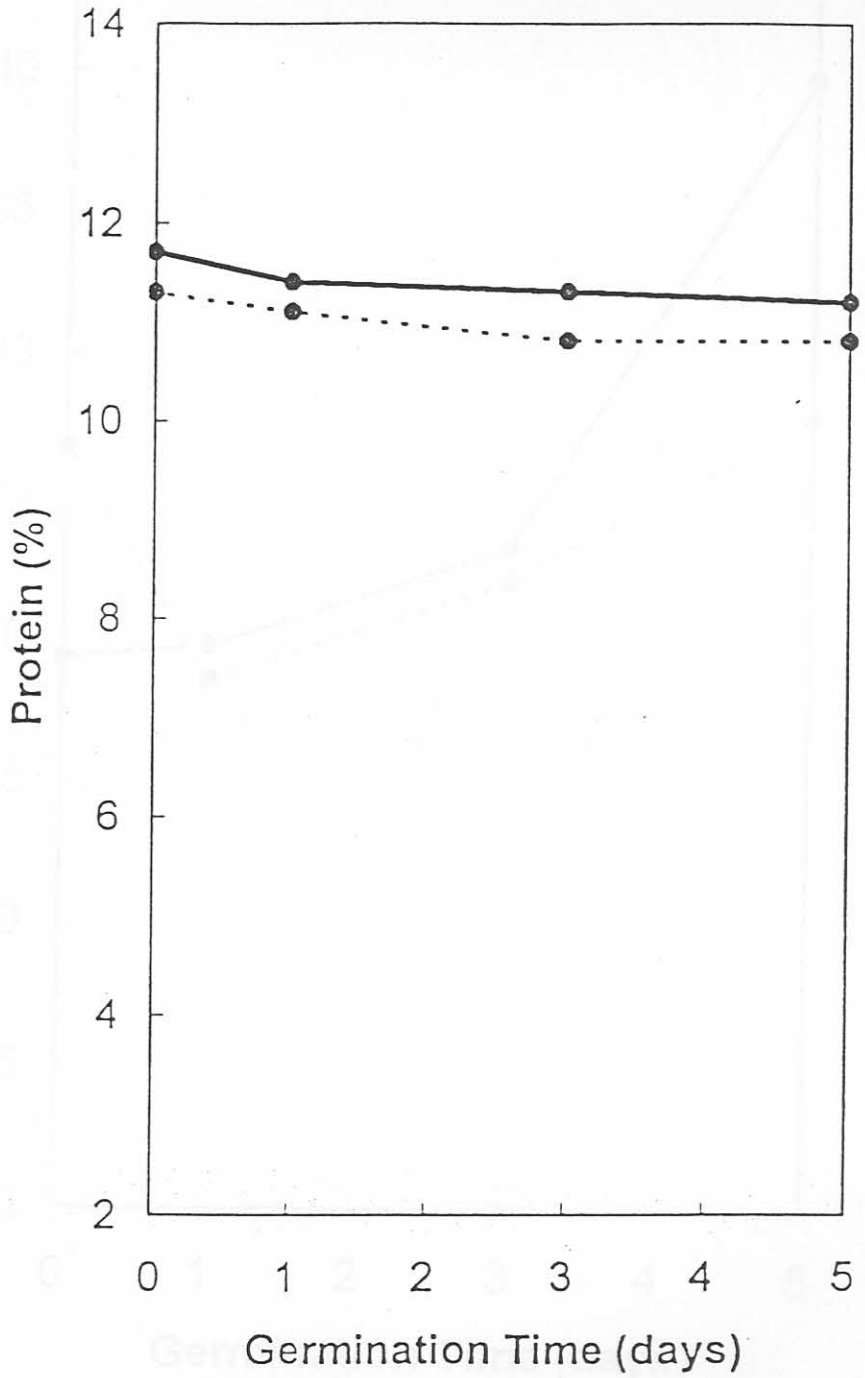

Figure 30.- Effects of germination time and variety on the protein content of pearl millet (variety SDMV 89004(–) and variety SDMV 91018 (--))

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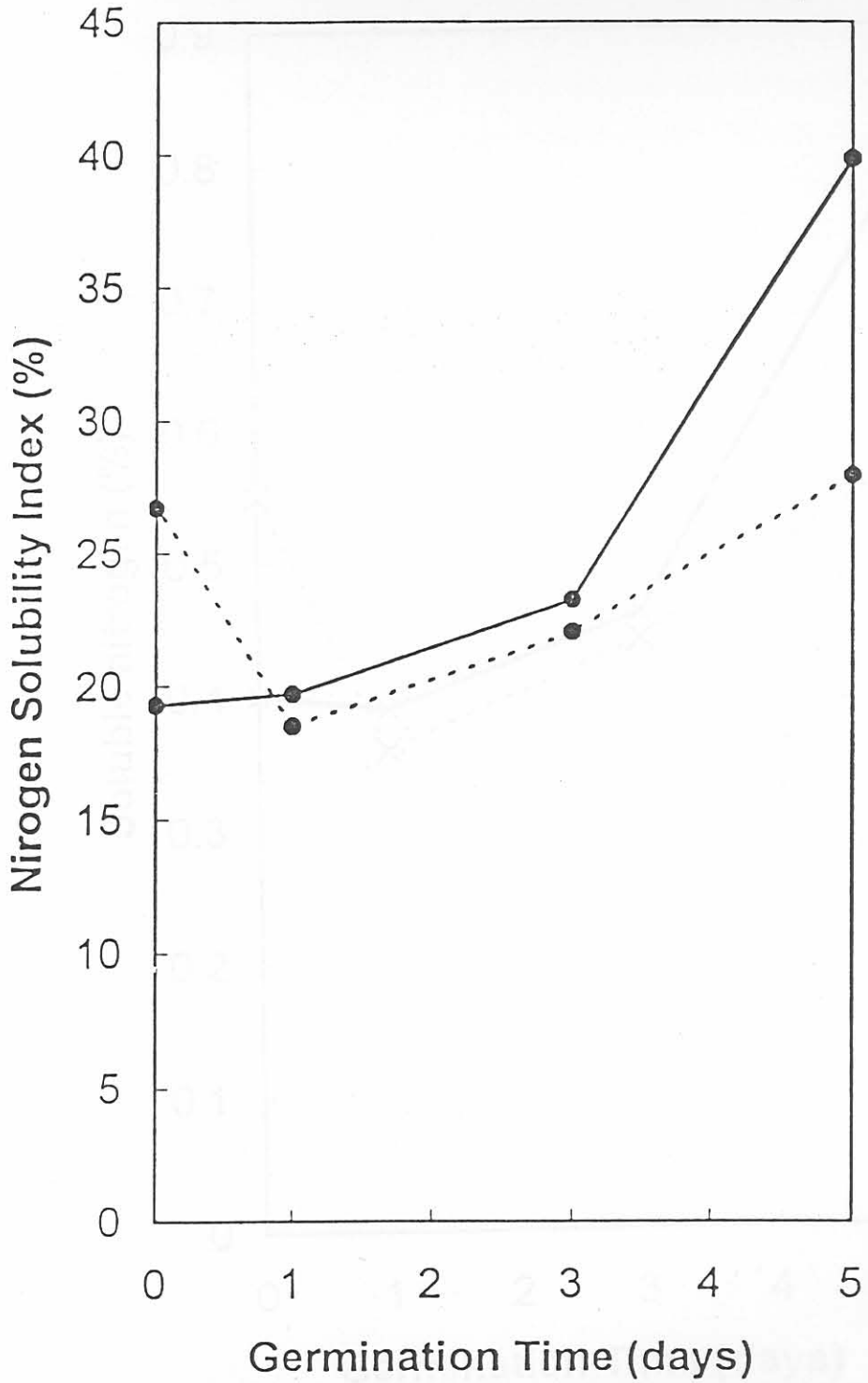

Figure 31.- Effects of germination time and variety on the Nitrogen Solubility Index of pearl millet (variety SDMV 89004(–) and variety SDMV 91018 (--))

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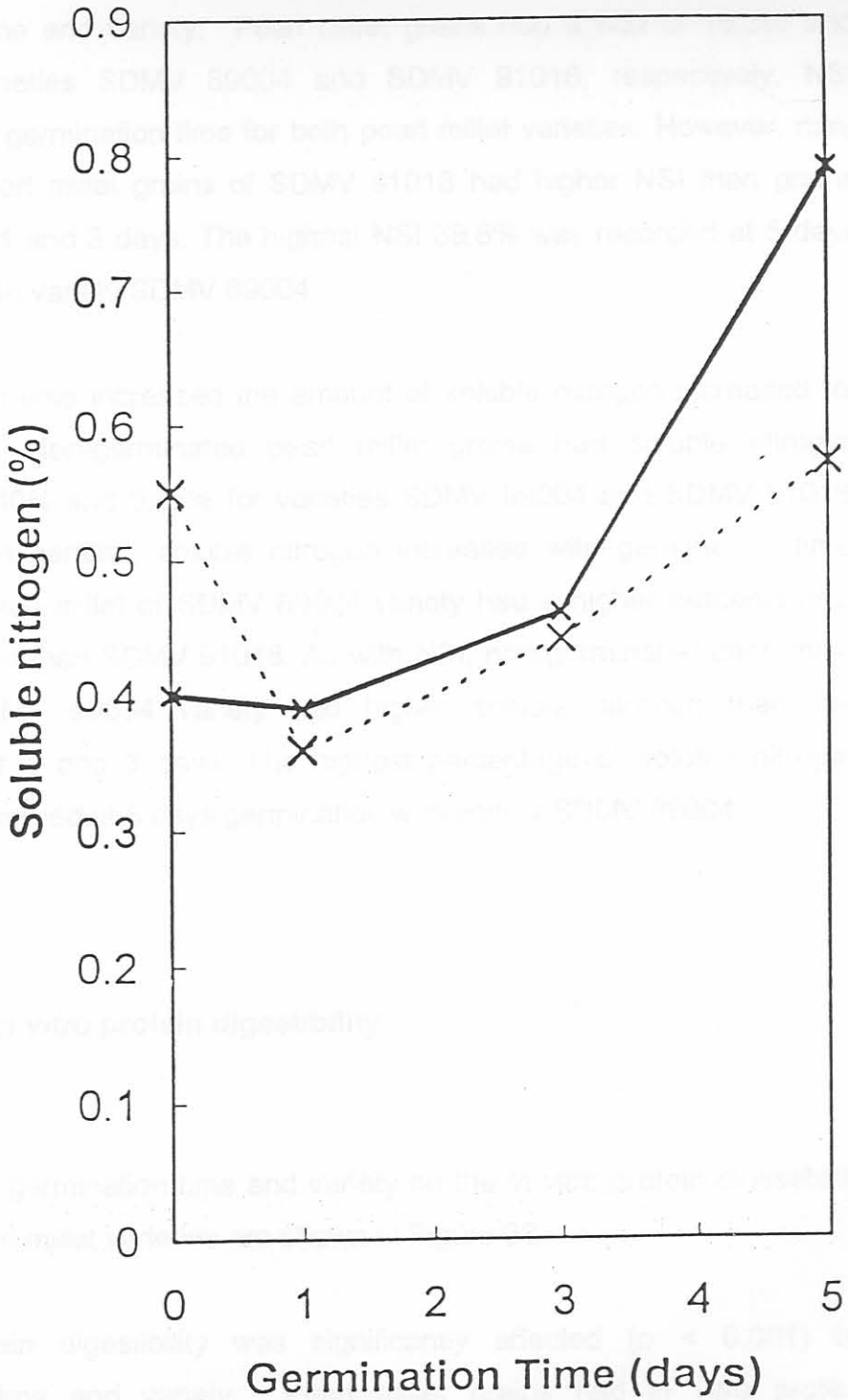

Figure 32.- Effects of germination time and variety on the percentage of soluble nitrogen of pearl millet (variety SDMV 89004(–) and variety SDMV 91018 (--))

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NSI and soluble nitrogen were significantly affected ($p < 0.001$) by germination time and variety. Pearl millet grains had a NSI of 19.3% and 26.7% for varieties SDMV 89004 and SDMV 91018, respectively. NSI increased with germination time for both pearl millet varieties. However, non-germinated pearl millet grains of SDMV 91018 had higher NSI than grains germinated at 1 and 3 days. The highest NSI 39.8% was recorded at 5 days germination with variety SDMV 89004.

As germination time increased the amount of soluble nitrogen increased for both varieties. Non-germinated pearl millet grains had soluble nitrogen contents of 0.40% and 0.55% for varieties SDMV 89004 and SDMV 91018, respectively. In general, soluble nitrogen increased with germination time. Germinated pearl millet of SDMV 89004 variety had a higher percentage of soluble nitrogen than SDMV 91018. As with NSI, non-germinated pearl millet grains of SDMV 89004 variety had higher soluble nitrogen than that germinated for 1 and 3 days. The highest percentage of soluble nitrogen 0.79% was recorded at 5 days germination with variety SDMV 89004.

4.4.6 *In vitro* protein digestibility

The effects of germination time and variety on the *in vitro* protein digestibility of the two pearl millet varieties are shown in Figure 33.

In vitro protein digestibility was significantly affected ($p < 0.001$) by germination time and variety. Pearl millet grains had *in vitro* protein digestibilities of 68.8% and 58.5% for varieties SDMV 89004 and SDMV 91018, respectively. *In vitro* protein digestibility increased with germination time. Variety SDMV 89004 had higher *in vitro* protein digestibility than SDMV 91018. The highest percentage of *in vitro* protein digestibility 95.5% was recorded at 5 days germination with variety SDMV 89004.

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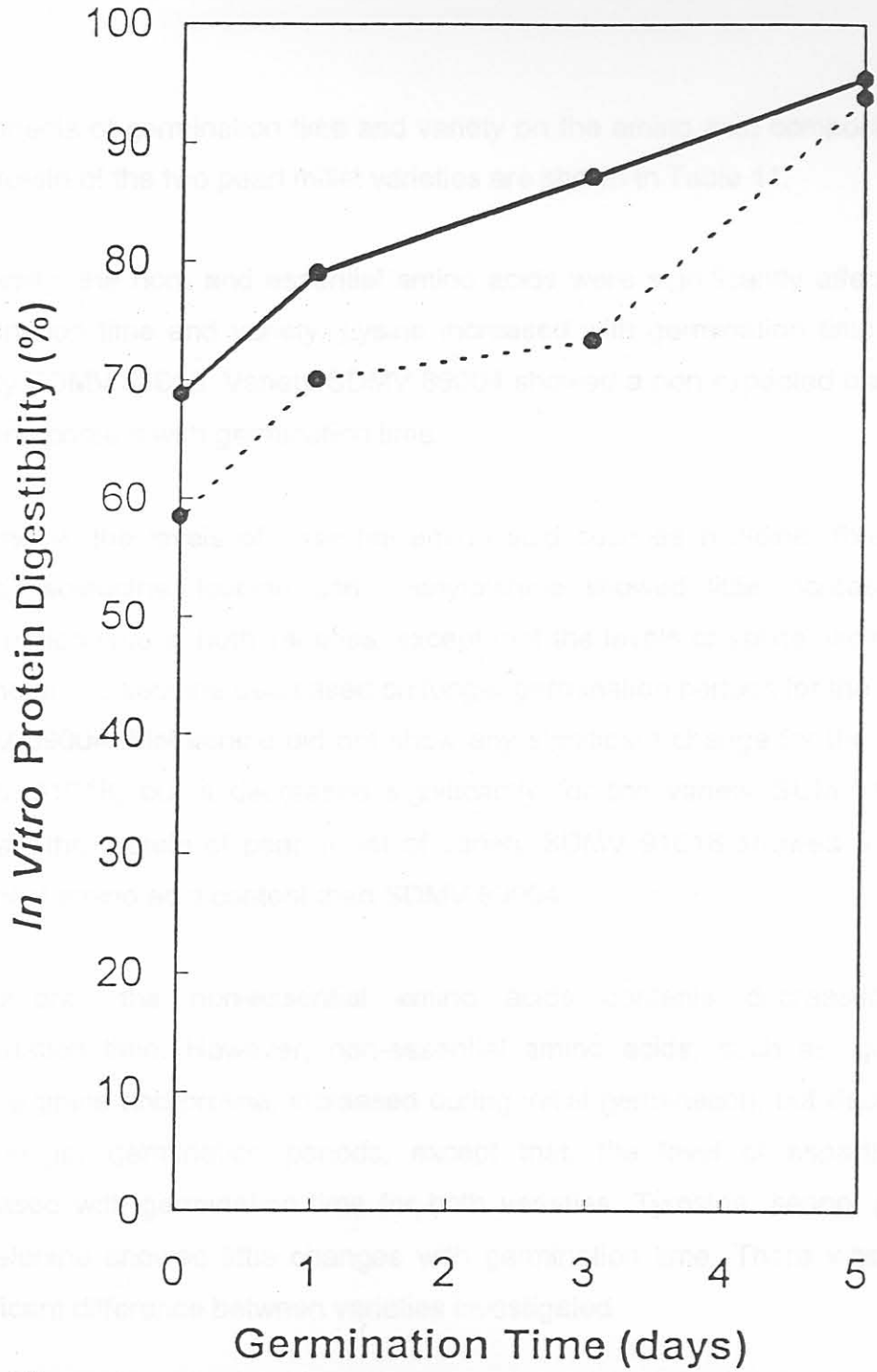

Figure 33.- Effects of germination time and variety on the *in vitro* protein digestibility of pearl millet (variety SDMV 89004(–) and variety SDMV 91018 (--))

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4.4.7 Amino acid composition

The effects of germination time and variety on the amino acid composition of the protein of the two pearl millet varieties are shown in Table 11.

Generally, the non- and essential amino acids were significantly affected by germination time and variety. Lysine increased with germination time in the variety SDMV 91018. Variety SDMV 89004 showed a non expected decrease in lysine content with germination time.

In general, the levels of essential amino acid such as histidine, threonine, valine, isoleucine, leucine and phenylalanine showed little increase with germination time in both varieties, except that the levels of valine, isoleucine, leucine and isoleucine decreased on longer germination periods for the variety SDMV 89004. Methionine did not show any significant change for the variety SDMV 91018, but it decreased significantly for the variety SDMV 89004. Overall, the protein of pearl millet of variety SDMV 91018 showed a higher essential amino acid content than SDMV 89004.

In general, the non-essential amino acids contents decreased with germination time. However, non-essential amino acids, such as, glutamic acid, arginine and proline, increased during initial germination, but decreased with longer germination periods, except that, the level of aspartic acid increased with germination time for both varieties. Tyrosine, serine, glycine and alanine showed little changes with germination time. There was not a significant difference between varieties investigated.

The levels of essential amino acids in the proteins of non-germinated pearl millet in both varieties were generally lower than the FAO Scoring Pattern. However, pearl millet grains non-germinated and germinated for 1 day met the FAO Scoring Pattern for leucine. The lysine content of the protein of

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TABLE 11.- Amino acid composition of the protein of the two pearl millet varieties (g/100 g protein)

Amino Acid	Control ()[a]	Germination Time (Days) 1	3	5	FAO Scoring Pattern [b]
Essential amino acids					
Valine	(4.8-7.0)				5.0
SDMV 89004	3.6	3.7	3.5	2.9	
SDMV 91018	3.2	3.2	3.8	3.6	
Methionine	(1.5-2.9)				3.5
SDMV 89004	1.9	1.6	1.6	1.1	
SDMV 91018	1.5	1.5	1.6	1.5	
Isoleucine	(3.6-5.9)				4.0
SDMV 89004	2.2	2.2	2.0	1.5	
SDMV 91018	1.7	1.7	2.6	2.4	
Leucine	(8.0-25.1)				7.0
SDMV 89004	8.2	8.5	7.4	5.7	
SDMV 91018	7.7	7.5	8.6	8.1	
Phenylalanine	(4.4-5.6)				6.0
SDMV 89004	4.3	4.8	4.6	3.9	
SDMV 91018	4.3	4.3	4.6	4.5	
Lysine	(1.7-6.5)				5.5
SDMV 89004	3.3	3.2	2.9	2.9	
SDMV 91018	2.7	2.7	4.0	4.1	
Histidine	(1.8-2.6)				4.0
SDMV 89004	1.9	2.1	2.0	1.9	
SDMV 91018	1.9	2.0	2.2	2.2	
Threonine	(1.2-4.8)				4.0
SDMV 89004	4.2	4.7	4.3	4.0	
SDMV 91018	4.1	4.2	4.3	4.3	
Non-essential amino acids					
Aspartic acid	(4.9-10.3)				
SDMV 89004	8.2	8.9	9.9	10.3	
SDMV 91018	8.1	7.7	10.4	12.7	
Glutamic acid	(12.3-25.4)				
SDMV 89004	19.3	22.8	19.9	16.1	
SDMV 91018	19.8	20.1	18.2	17.0	
Serine	(3.7-5.6)				
SDMV 89004	6.6	7.1	6.6	6.0	
SDMV 91018	6.6	6.6	6.4	6.5	
Glycine	(2.8-5.8)				
SDMV 89004	4.3	4.1	3.5	3.6	
SDMV 91018	3.8	3.8	3.8	3.8	
Arginine	(3.2-8.1)				
SDMV 89004	6.0	6.0	5.3	4.9	
SDMV 91018	5.3	5.3	5.5	5.2	
Alanine	(7.5-10.5)				
SDMV 89004	8.7	9.1	8.7	8.0	
SDMV 91018	8.6	8.9	8.2	8.2	
Proline	(5.9-14.2)				
SDMV 89004	6.4	7.1	7.0	6.1	
SDMV 91018	6.4	6.4	6.4	6.3	
Tyrosine	(1.7-4.8)				
SDMV 89004	3.0	2.9	2.8	2.7	
SDMV 91018	2.5	2.5	3.5	3.4	

[a]Data in brackets are of pearl millet amino acids range from a review by Serna-Saldivar & Rooney (1995). [b]Food and Agriculture Organisation of the United Nations, according to Serna-Saldivar, McDonough & Rooney (1990) and Hoseney (1994).

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germinated pearl millet of SDMV 91018 variety accounted for about 75.0 % of the FAO Scoring Pattern.

4.4.8 Phytic acid

The effects of germination time and variety on the phytic acid content of the two pearl millet are shown in Figure 34.

Phytic acid was significantly affected ($p < 0.001$) by germination time and variety. Non-germinated pearl millet grains had a phytic acid content of 0.24% and 0.27% for the varieties SDMV 89004 and SDMV 91018, respectively. Phytic acid decreased greatly with germination time in both pearl millet varieties investigated. Germinated pearl millet of SDMV 89004 variety had a lower percentage of phytic acid than SDMV 91018 throughout germination. The lowest percentage of phytic acid 0.024% was recorded at 5 days germination with variety SDMV 89004.

4.4.9 Pasting properties

The effects of germination time and variety on the pasting properties of the flours of the two pearl millet varieties are shown in Figures 35 and 36 for the variety SDMV 89004 and SDMV 91018, respectively.

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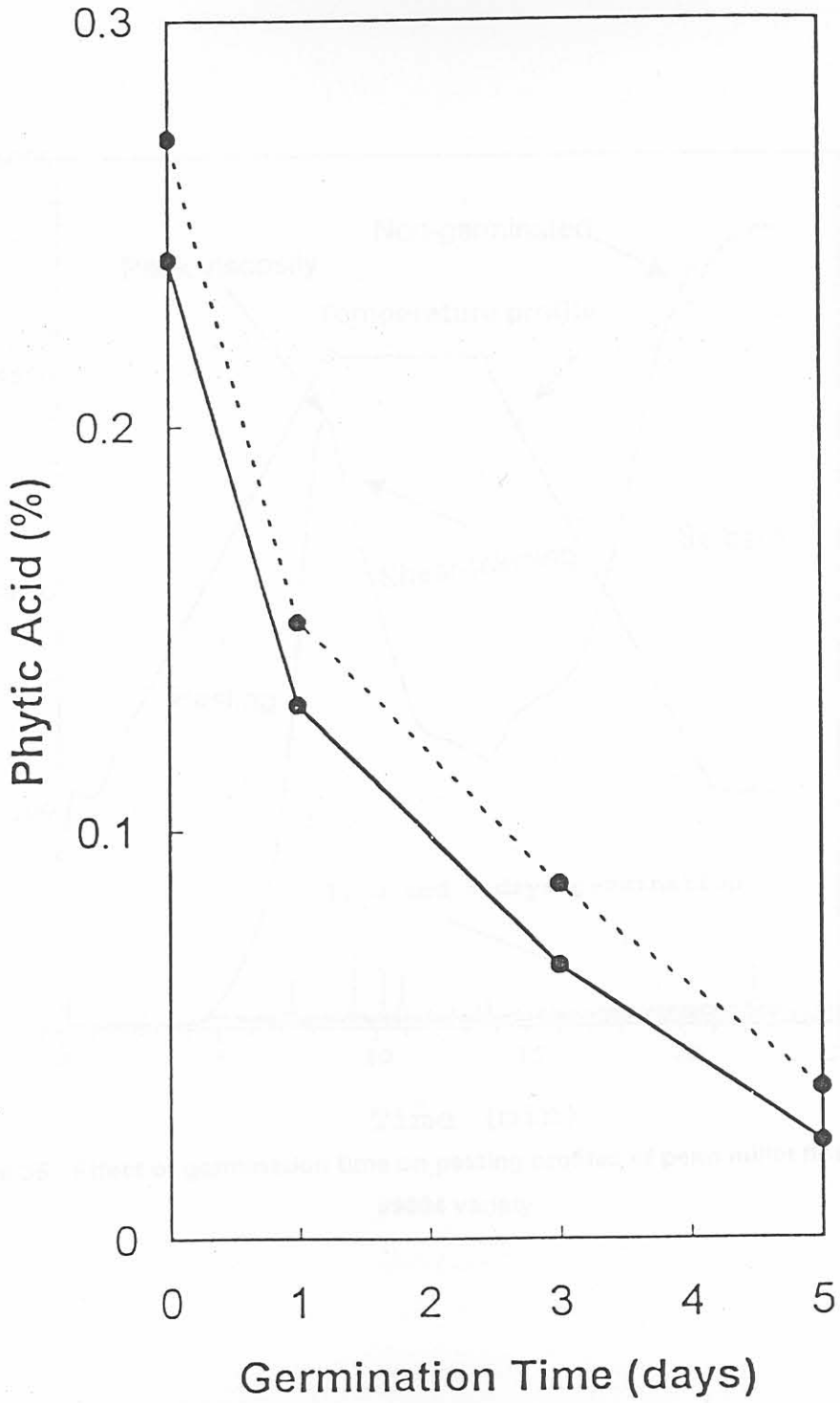

Figure 34.- Effects of germination time and variety on the phytic acid content of pearl millet (variety SDMV 89004(–) and variety SDMV 91018 (--))

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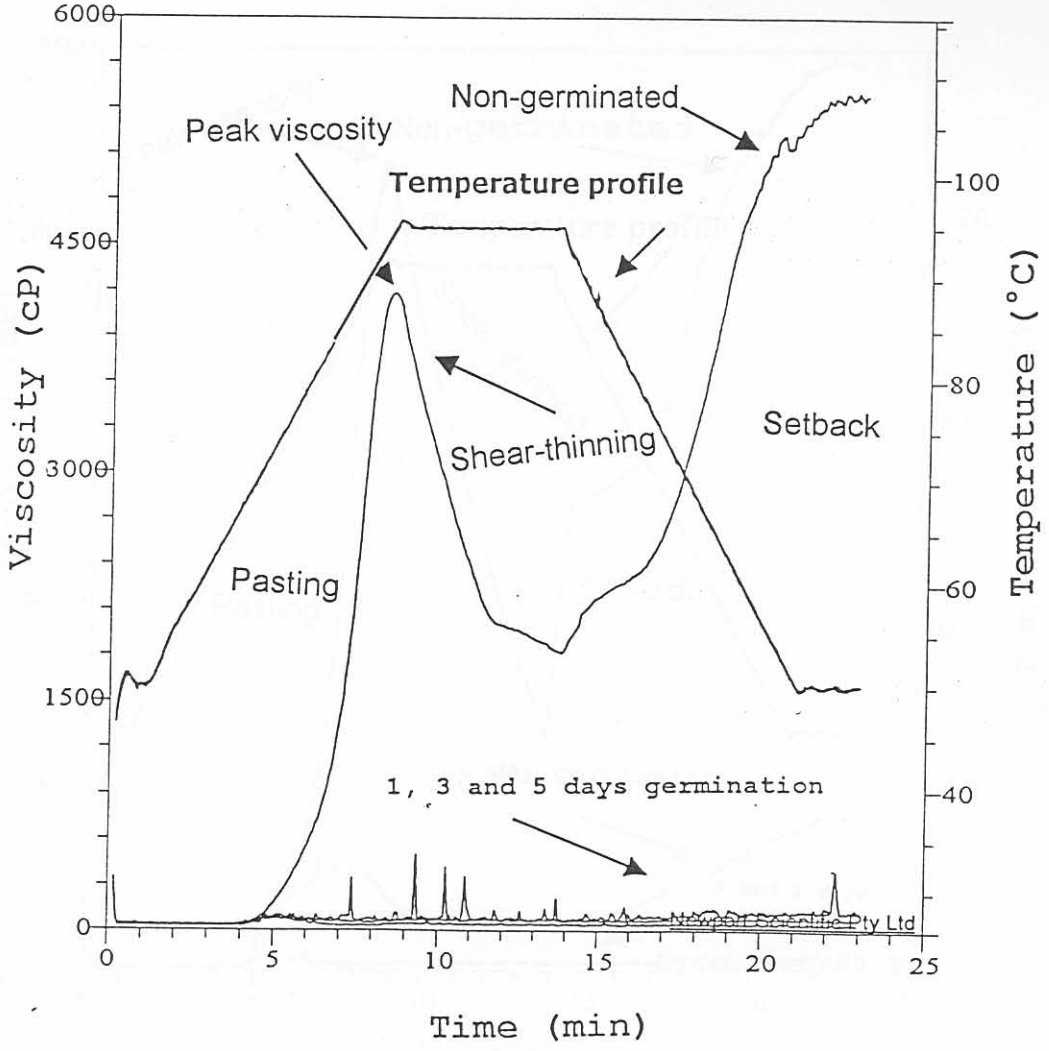

Figure 35.- Effect of germination time on pasting profiles of pearl millet flour of SDMV 89004 variety

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Peak viscosity of pearl millet flour was significantly affected ($p < 0.001$) by germination time and variety. Peak viscosity of germinated pearl millet flour decreased dramatically with germination time for both varieties investigated. Peak viscosity of the malted pearl millet flours were very much lower than that of flour of grain in both varieties. Peak viscosity of pearl millet germinated for periods longer than 1 day was very low and the viscosities almost as low as water.

The effects of germination time and variety on peak viscosity, hot peak viscosity, cool peak viscosity and setback of the two pearl millet varieties are shown in Table 12. Grains and malts of the variety SDMV 91018 had significantly higher ($p < 0.001$) peak viscosity compared to SDMV 89004 (Table 12).

The peak viscosity, hot peak viscosity (ability of starch to withstand heating and shear stress), cool paste viscosity (final viscosity) and setback, a rapid increase in viscosity due to cooling of starch (cool paste viscosity – hot peak viscosity), decreased as the germination time increased. The lowest peak viscosity, hot peak viscosity, cool paste viscosity, setback and peak time 84, 36, 48, 12 (cP), and 4.9 min, respectively, were recorded at 5 days germination, with variety SDMV 89004. In general, both grain and malt of variety SDMV 89004 had lower hot peak viscosity, cool paste viscosity and set back as well as peak time compared to SDMV 91018.

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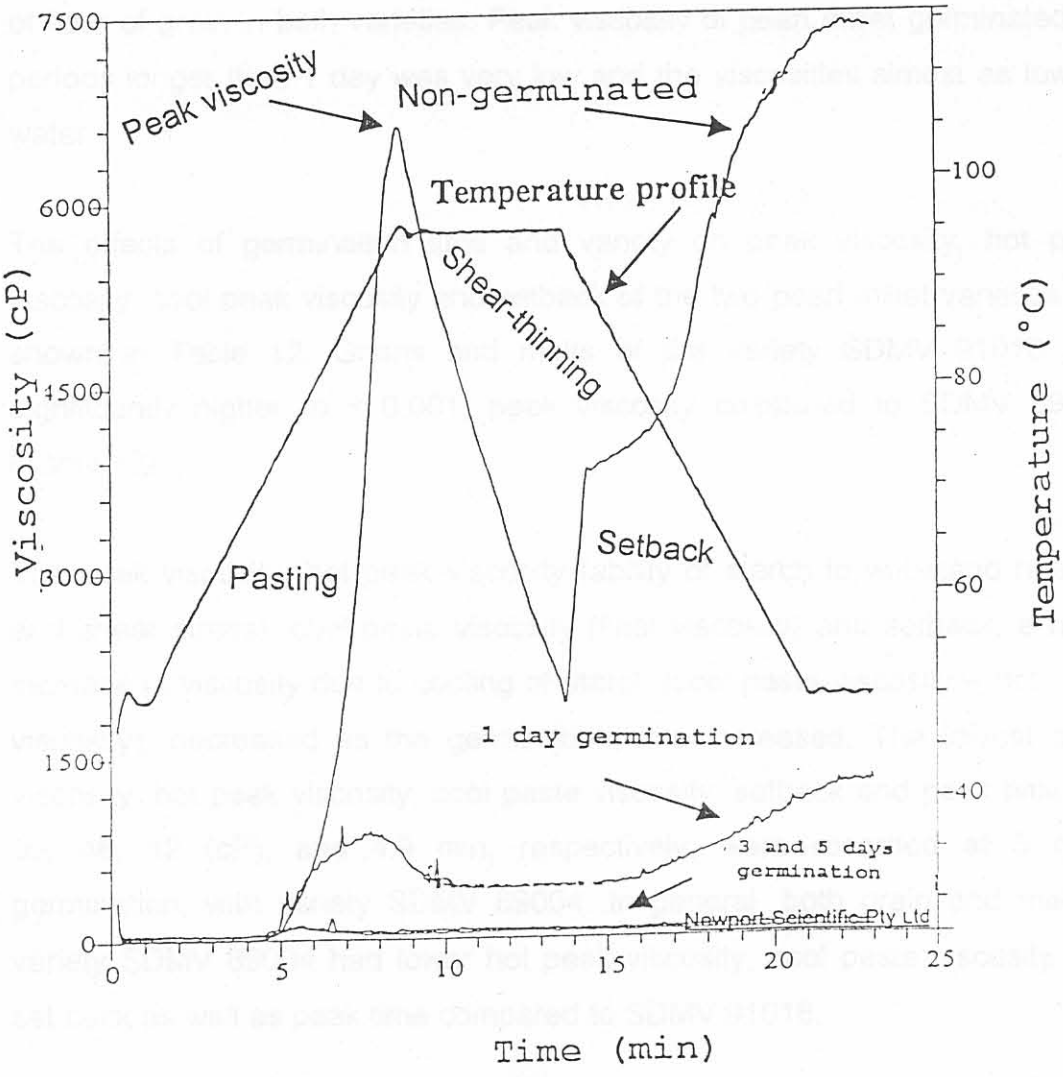

Figure 36.- Effect of germination time on pasting profiles of pearl millet flour of SDMV 91018 variety

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TABLE 12.- Pasting properties of non- and germinated pearl millet varieties

Samples/ Germination Time	Peak Viscosity (cP)	Hot Peak Viscosity (cP)	Cool Paste Viscosity (cP)	Set Back (cP)	Peak Time (min)
SDMV 89004					
	4188[a]	1416[a]	5076[a]	3660[a]	8.6[a]
1 day	552[b]	84[b]	192[b]	108[b]	7.6[b]
3 days	108[c]	48[c]	72[c]	24[c]	5.1[c]
5 days	84[d]	36[d]	48[d]	12[c]	4.9[c]
SDMV 91018					
	6084[a]	1704[a]	7320[a]	5616[a]	8.6[a]
1 day	948[b]	480[b]	1320[b]	840[b]	7.0[b]
3 days	168[c]	72[c]	108[c]	36[c]	6.3[c]
5 days	108[d]	36[d]	60[d]	24[c]	5.5[d]

Means values with different letters in each block are significantly different from each other ($p < 0.001$).

Hot peak viscosity – The ability of starch to withstand heating and shear stress.

Cool paste viscosity – Final viscosity.

Set back = cool paste viscosity – hot peak viscosity.

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4.4.10 Sensory evaluation of the mousy odour in pearl millet varieties

The Table 13 shows the results of the mousy odour evaluation by 12 trained panelists of the Department of Food Science of the University of Pretoria.

TABLE 13.- Sensory evaluation of mousy odour in non- and germinated pearl millet varieties

Panelists	Variety SDMV 89004				Variety SDMV 91018			
	Germination Time (days)							
	0	1	3	5	0	1	3	5
1	9	5	3	2	8	4	2	2
2	8	4	4	1	8	6	2	2
3	8	4	2	1	9	4	2	1
4	9	4	2	1	9	5	2	1
5	9	5	3	2	8	4	3	2
6	9	5	4	2	8	5	3	1
7	9	4	3	1	7	5	2	1
8	8	4	2	1	8	4	2	2
9	9	5	3	1	8	5	2	2
10	9	5	2	1	9	5	2	2
11	9	5	1	1	8	4	1	2
12	9	4	3	1	9	5	2	1
Mean	8.8^{a}	4.6^{b}	2.7^{c}	1.3^{d}	7.5^{a}	4.7^{b}	2.1^{c}	1.6^{d}

The level of intensity in the scale is 1– least intense and 9 – most intense mousy odour.
Mean values with different letters in each variety are significantly different from each other ($p < 0.001$).

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The mousy odour of pearl millet grains was significantly affected ($p < 0.001$) by germination time and variety. Non-germinated pearl millet grains had a rate of intensity of mousy odour of 8.8 and 7.5, on the scale of 1 least intense and 9 most intense mousy odour, for variety SDMV 89004 and SDMV 91018, respectively. Mousy odour decreased with germination time in both pearl millet varieties. Non-germinated pearl millet grains of SDMV 89004 variety had a significantly more intense mousy odour than SDMV 91018. However, in variety SDMV 91018 the reduction of the mousy odour due to malting was less than in SDMV 89004. The lowest level of intensity of mousy odour 1.3 was recorded at 5 days germination with variety SDMV 89004.