

Chemical composition of barley varieties with different nutrient supplies

IV. Concentration of nitrogen, amide and amino acids in two-year experiments

Bygsorters kemiske sammensætning ved varierende næringsstoftilførsel

IV. Koncentration af kvælstof, amid og aminosyrer i toårige forsøg

Ebbe Truelsen

Summary

The concentrations of nitrogen, amide and amino acids were determined in grains from 20 barley varieties grown in pots in 1982 and 1983 and in another 21 varieties including a breeding line in 1984 and 1985.

The content of nitrogen in the barley grain increased with increasing nitrogen supplies for all varieties. With a certain nitrogen supply, however, differences in nitrogen content between the barley varieties were observed and these differences were maintained in the two years of experiments.

The concentrations of lysine and sulphur-containing amino acids in the protein decreased whereas the amide increased with increasing nitrogen supplies. Varieties with a low nitrogen content generally had a relative high lysine and low amide content in the protein. However, varietal differences in the relation between lysine and nitrogen content were found and these differences were maintained in the two years of experiments. The breeding line Ca 700202 had a fairly high content of lysine and the varieties Cerise and Gorm had a considerably higher lysine content than Torkel and Jenny despite their similar nitrogen content.

The year variations in the content of nitrogen, amide and amino acids seemed not to influence the varietal differences concerning the content of these compounds.

Key words: Barley varieties, amino acids, amide, nitrogen, nutrition, year variation.

Resumé

Koncentrationen af kvælstof, amid og aminosyrer blev undersøgt i kerner fra 20 bygsorter i 1982 og 1983 og 21 andre sorter i 1984 og 1985. Stigende kvælstofgødskning medførte et stigende indhold af kvælstof i den modne bygkerne i alle de målte sorter. For samme kvælstoftilførsel kunne der påvises forskelle i kvælstofindholdet mellem de forskellige sorter, og disse forskelle ændredes ikke i de toårige forsøg.

Proteinets indhold af lysin og svovlholdige aminosyrer faldt, mens amidindholdet steg ved stigende kvælstofgødskning. Sorter med et lavt kvælstofindhold havde i proteinet generelt et forholdsvis højt

lysinindhold og et lavt amidindhold. Imidlertid kunne der i nogle tilfælde påvises forskelle i lysin- og amidindhold mellem sorter med samme kvælstofindhold. Således fandtes i begge forsøgsår et højere indhold af lysin og lavere indhold af amid i sorterne Cerise og Gorm end i Torkel og Jenny. Højlysin linien Ca 700202 havde som forventet et betydeligt højere lysin- og lavere amidindhold end de godkendte sorter.

De årsvariationer, der blev fundet i indholdet af kvælstof, amid og aminosyrer, gav ikke anledning til målelige forskydninger i indholdet af disse stoffer sorterne imellem.

Nøgleord: Bygsorter, aminosyrer, amid, kvælstof, ernæring, årsvariation.

Introduction

The amino acid composition of the protein in the barley grain is of great importance for the use of barley for fodder due to the inability of non-ruminants to synthesize the essential amino acids (1, 5). A well balanced amino acid composition gives better utilization of the protein in the animals and thereby a higher biological value (1, 5).

Fertilization is known to have a strong influence on the amino acid composition of the grains (2, 8, 10), especially increasing supply of nitrogen gives rise to an impaired biological value of the grain protein (1). This is due to the increased synthesis of storage proteins, the prolamins, which have a very low content of lysine, the most limiting essential amino acid in the barley grain (4). The prolamins have on the other hand a fairly high content of amide and the negative relation between the concentrations of lysine and amide in the barley grain is by now well established (4, 7, 8, 10, 12).

In a previous experiment varietal differences in amino acid composition were found, even between varieties with almost the same nitrogen content (10). Furthermore, these differences appeared to be maintained irrespective of whether the barley varieties were grown in pots or in the field on different soil types. In the present investigation the purpose was to find out if varietal differences could be repeated from one year to another and whether year variations could be found in the content of nitrogen, amide and amino acids in barley varieties grown with increasing nitrogen fertilization.

Materials and methods

The analysis of nitrogen, amide and amino acids were performed in the same barley grain material as was used for the determinations of tannins and β -glucans for which the growing conditions have been described (11). The barley varieties were grown in pots, supplied with 0, 1.5, 4.5 and 9 g of nitrogen per pot, respectively. The pots were arranged in a split-plot design. The methods used for the analysis of nitrogen (9) and amino acids (10) have been described previously and the amide content was determined as described by Sørensen (7).

Results

The results from the nitrogen determinations are shown in Tables 1 and 2. For all varieties the content of nitrogen in the barley grain increased with increasing nitrogen supplies and considerable differences in nitrogen content could be seen between the varieties. As a whole from the four N-supplies the highest nitrogen content was in 1982 (Table 1) found in the varieties Gula, Jarl and Emir and the lowest in Jonna and Cerise. From the same Table it can be seen that the varieties Ida, Jarl and Gula had the highest N-content in 1983 and Anna and Jonna the lowest. Generally, the varieties followed the same pattern in N-content in 1982 and 1983, and following coefficients of correlation could be calculated between 1982 and 1983: 0 N, $r = 0.71^{***}$, 1.5 N, $r = 0.83^{***}$, 4.5 N, $r = 0.46^*$, and 9 N, $r = 0.40$. In 1984 as well as in 1985 (Table 2) the highest nitrogen content was found in the varieties Galant, Taarn and Yriba

Table 1. Content of nitrogen in dry matter of barley grains with different nitrogen supplies. 1982 and 1983.
Kvælstofindhold i bygkerner i tørstof ved varierende kvælstoftilførsel. 1982 og 1983.

Year of experiment <i>Forsøgsår</i>	1982				1983			
Treatment <i>Forsøgsled</i>	0 N	1.5 N	4.5 N	9 N	0 N	1.5 N	4.5 N	9 N
Variety <i>Sort</i>	% total N				% total N			
Zita	1.35	1.56	2.17	3.28	1.27	1.62	2.51	3.15
Anna	1.24	1.51	2.16	3.30	1.12	1.42	2.36	2.91
Caja	1.29	1.59	2.27	3.38	1.26	1.63	2.58	3.05
Carina	1.23	1.54	2.33	3.53	1.21	1.64	2.51	3.11
Cerise	1.23	1.55	2.16	3.16	1.25	1.67	2.56	2.97
Emir	1.45	1.70	2.46	3.44	1.29	1.74	2.66	2.95
Europa	1.27	1.51	2.20	3.50	1.21	1.66	2.62	3.09
Gula	1.33	1.68	2.46	3.83	1.30	1.73	2.66	3.29
Havila	1.31	1.61	2.13	3.56	1.26	1.72	2.50	2.97
Ida	1.34	1.68	2.45	3.36	1.45	1.93	2.84	3.33
Jarl	1.45	1.75	2.56	3.42	1.41	1.91	2.64	3.43
Jonna	1.14	1.37	1.96	3.23	1.14	1.46	2.36	3.05
Koru	1.16	1.51	2.16	3.46	1.19	1.61	2.66	2.91
Magnum	1.28	1.59	2.34	3.20	1.29	1.59	2.36	2.96
Mandolin	1.21	1.61	2.12	4.01	1.22	1.61	2.59	3.09
Mirjam	1.27	1.67	2.41	3.33	1.33	1.80	2.48	3.04
Nery	1.32	1.61	2.45	3.49	1.29	1.71	2.59	3.22
Torkel	1.27	1.60	2.30	3.08	1.28	1.64	2.52	2.77
Triumph	1.31	1.63	2.45	3.46	1.33	1.70	2.57	3.21
Welam	1.23	1.53	2.20	3.33	1.22	1.62	2.64	2.84

and the lowest in Pamina, Susan and Albert. Comparing 1984 and 1985 the coefficients of correlation were between 0.75*** and 0.92*** for the four N-supplies.

Compared to the varietal differences the year variations were small. Between 1982 and 1983 significant differences were found for 1.5 N, 4.5 N and 9 N ($p < 0.001$) and between 1984 and 1985 for 1.5 N ($p < 0.001$) and 4.5 N ($p < 0.02$). The standard variety Zita had its highest nitrogen content in 1983 and its lowest in 1985.

The results from the lysine determinations are presented in Tables 3 and 4. In per cent of the total nitrogen the lysine-N content decreased with increasing nitrogen supplies for all varieties. Also for the lysine content considerable varietal differences could be seen for all N-supplies. The highest lysine content in 1982 (Table 3) was found in the varieties Zita, Cerise and Jonna and in 1983

in Anna, Cerise and Jonna. The varieties with the lowest lysine content in 1982 were Emir, Gula, Jarl and Torkel and in 1983 Ida, Jarl and Torkel. Comparing the lysine content for 1982 and 1983 for all varieties the following coefficients of correlation were found: 0 N, $r = 0.56^{**}$; 1.5 N, $r = 0.72^{***}$; 4.5 N, $r = 0.45^*$ and 9 N, $r = 0.60^{**}$. The high-lysine line Ca 700202 (Table 4 – 1984 and 1985) had, as expected, a fairly high lysine content. Among the approved varieties Zita, Gorm and Uffe had the highest lysine content in 1984 and Golf and Uffe in 1985. The varieties Jenny, Romi and Taarn had the lowest content of lysine in 1984 and 1985. The coefficients of correlation for the lysine content comparing 1984 and 1985 were found to be between 0.76*** and 0.90***. For these calculations Ca 700202 was excluded because of its relative high lysine content. Small, yet significant year variations were found between

Table 2. Content of nitrogen in dry matter of barley grains with different nitrogen supplies. 1984 and 1985.
Kvælstofindhold i bygkerner i tørstof ved varierende kvælstoftilførsel. 1984 og 1985.

Year of experiment <i>Forsøgsår</i>	1984				1985			
Treatment <i>Forsøgsled</i>	0N	1.5N	4.5N	9N	0N	1.5N	4.5N	9N
Variety <i>Sort</i>	% total N				% total N			
Zita	1.25	1.63	2.28	3.25	1.25	1.61	2.31	3.12
Albert	1.19	1.61	2.16	2.86	1.17	1.56	2.14	2.89
Ca 700202	1.37	1.83	2.80	2.79	1.37	1.79	2.57	2.84
Claret	1.29	1.71	2.50	2.92	1.29	1.67	2.56	2.76
Galant	1.44	1.92	2.74	3.01	1.53	1.80	2.76	2.74
Golf	1.23	1.58	2.22	3.04	1.19	1.60	2.29	2.70
Gorm	1.20	1.59	2.53	3.17	1.22	1.53	2.32	3.24
Gunhild	1.28	1.59	2.38	3.05	1.29	1.52	2.21	3.06
Gunnar	1.18	1.51	2.13	3.38	1.18	1.46	2.21	3.81
Inga	1.13	1.56	2.22	3.44	1.09	1.45	2.32	3.22
Jenny	1.30	1.67	2.38	3.06	1.35	1.70	2.22	3.04
Odin	1.22	1.65	2.21	3.12	1.22	1.59	2.16	3.12
Pamina	1.22	1.58	2.20	2.94	1.16	1.49	2.15	2.81
Roland	1.30	1.81	2.43	2.87	1.29	1.66	2.37	2.85
Romi	1.18	1.49	2.21	3.28	1.16	1.48	2.12	3.27
Sune	1.31	1.71	2.30	2.74	1.25	1.65	2.30	3.31
Susan	1.30	1.71	2.21	2.48	1.25	1.64	2.24	2.44
Tyra	1.26	1.64	2.28	3.04	1.29	1.59	2.14	2.86
Taarn	1.17	1.56	2.53	3.82	1.23	1.58	2.30	3.58
Uffe	1.17	1.67	2.25	3.20	1.11	1.44	2.02	3.12
Yriba	1.40	1.81	2.52	3.24	1.37	1.72	2.36	3.46

1982 and 1983 for 1.5 N, 4.5 N and 9 N ($p < 0.001$) and between 1984 and 1985 only for 1.5 N ($p < 0.01$). The standard variety Zita had a fairly high lysine content in all experimental years.

The amide content in the protein increased with increasing nitrogen supply for all varieties. The breeding line Ca 700202 had a low content of amide, between 6.6 and 9.3 per cent of amide-N in relation to the total nitrogen content. The results from the approved varieties are expressed in Figs 1 and 2. It appears from these that for each N-supply the varieties followed the same pattern in amide content for the two experimental years. However, as it can be seen from the Figures, the results from 4.5 N were more dispersed than from the other N-supplies why weaker correlations were found for this N-supply. Following coefficients of correlation were calculated comparing

the amide content in 1982 and 1983: 0 N, $r = 0.71^{***}$; 1.5 N, $r = 0.72^{***}$; 4.5 N, $r = 0.31$ and 9 N, $r = 0.71^{***}$ and in 1984 and 1985: 0 N, $r = 0.83^{***}$; 1.5 N, $r = 0.62^{**}$; 4.5 N, $r = 0.42$ and 9 N, $r = 0.82^{***}$.

The highest amide content was found in the varieties Gula and Jarl in 1982 and in Ida and Jarl in 1983. The lowest content was in 1982 found in Cerise and in 1983 in Anna. The highest amide content was measured in the variety Jenny in 1984 and 1985 and a fairly low amide content was found in Ca 700202. Significant year variations ($P < 0.001$) were found for all N-supplies between 1982 and 1983, but only for 4.5 N and 9 N between 1984 and 1985. By means of the inserted angular bisectors it can be seen that the amide content generally were higher in 1983 than in 1982 for 0 N, 1.5 N and 4.5 N whereas 9 N behaved opposite (Fig. 1).

Table 3. Lysine-N as per cent of total nitrogen in barley grains. 1982 and 1983.
Indhold af lysin-N i procent af totalkvælstof i bygkerner. 1982 og 1983.

Year of experiment <i>Forsøgsår</i>	1982				1983			
Treatment <i>Forsøgsled</i>	0N	1.5N	4.5N	9N	0N	1.5N	4.5N	9N
Variety <i>Sort</i>	Lysine-N <i>Lysin-N</i>				Lysine-N <i>Lysin-N</i>			
Zita	5.4	4.6	4.2	3.8	5.1	4.7	3.9	3.6
Anna	5.2	4.7	3.9	3.6	5.3	4.8	3.9	3.5
Caja	4.8	4.6	4.0	3.6	5.0	4.5	3.8	3.5
Carina	5.4	4.6	3.8	3.5	5.0	4.4	3.7	3.4
Cerise	5.6	4.8	4.2	3.8	5.2	4.6	3.9	3.7
Emir	4.7	4.4	3.8	3.7	4.9	4.3	3.7	3.6
Europa	4.9	4.6	4.4	3.8	5.2	4.4	3.8	3.6
Gula	4.7	4.4	3.8	3.7	4.8	4.2	3.7	3.5
Havila	4.9	4.5	4.1	3.6	5.0	4.4	3.9	3.6
Ida	4.9	4.3	3.9	3.6	4.7	4.1	3.6	3.6
Jarl	4.9	4.4	3.8	3.6	4.7	4.2	3.7	3.5
Jonna	5.1	5.0	4.2	3.7	5.4	4.7	3.9	3.5
Koru	5.3	4.8	3.9	3.5	5.2	4.5	3.7	3.6
Magnum	5.0	4.4	4.0	3.5	4.9	4.5	3.8	3.5
Mandolin	5.0	4.5	4.0	3.5	4.9	4.3	3.6	3.3
Mirjam	5.0	4.5	4.0	3.7	4.9	4.3	3.8	3.5
Nery	5.0	4.5	3.9	3.6	4.9	4.6	3.7	3.4
Torkel	4.9	4.4	3.8	3.6	4.9	4.3	3.6	3.3
Triumph	5.0	4.7	4.1	3.8	4.8	4.4	3.8	3.6
Welam	5.1	4.9	4.1	3.5	5.1	4.5	3.6	3.4

From Fig. 2 it appears that the year variations found for 4.5 N and 9 N are due to a higher amide content in 1985 than in 1984.

Figs 3 and 5 show the relation between the content of lysine and total nitrogen for two varieties which have been chosen because of their different lysine content and their similar nitrogen content. From the Figures it appears that among varieties generally used there can be considerable differences in the lysine content. Comparing Figs 3 and 5 with Figs 4 and 6 it appears that the chosen varieties with a high lysine content had a low content of amide and vice versa.

The content of the sulphur-containing amino acids methionine and cyst(e)ine decreased with increasing nitrogen supplies. The concentrations and the decreasing rates were similar to previous findings (10). No relation between the content of

lysine and sulphur-containing amino acids could be found for any N-supply. The highest content of sulphur-bearing amino acids was found in the varieties Carina and Havila in 1982 and in Anna and Mandolin in 1983. In both years the lowest content was found in Emir and Gula. In 1984 and 1985 Jenny had the highest content and Yriba a relative low content of sulphur-containing amino acids. The content of methionine + cyst(e)ine was weaker correlated from year to year regarding the varieties than lysine and amide. Only small year variations were found for these amino acids, especially between 1984 and 1985.

Discussion and conclusion

Previous investigations have shown that the nitrogen content in barley grain could be influenced by growth conditions and soil types (9). In the pre-

Table 4. Lysine-N as per cent of total nitrogen in barley grains. 1984 and 1985.
Indhold af lysin-N i procent af totalkvælstof i bygkerner. 1984 og 1985.

Year of experiment <i>Forsøgsår</i>	1984				1985			
Treatment <i>Forsøgsled</i>	0N	1.5N	4.5N	9N	0N	1.5N	4.5N	9N
Variety <i>Sort</i>	Lysine-N <i>Lysin-N</i>				Lysine-N <i>Lysin-N</i>			
Zita	5.4	4.6	4.1	3.6	5.1	4.8	4.0	3.6
Albert	5.0	4.5	4.0	3.7	5.1	4.5	4.1	3.7
Ca 700202	6.3	6.3	5.9	5.8	6.4	6.0	5.8	5.4
Claret	4.8	4.5	3.9	3.6	4.9	4.4	3.8	3.6
Galant	4.9	4.5	4.1	3.9	4.9	4.6	4.0	4.0
Golf	4.9	4.6	4.1	3.8	5.1	4.6	4.2	3.9
Gorm	5.2	4.7	4.1	3.8	5.2	4.8	4.1	3.7
Gunhild	5.0	4.5	4.0	3.6	5.0	4.6	4.1	3.6
Gunnar	5.1	4.6	4.0	3.5	5.0	4.8	4.2	3.5
Inga	5.3	4.6	4.0	3.5	5.4	4.9	3.9	3.5
Jenny	4.7	4.1	3.7	3.4	4.6	4.1	3.7	3.4
Odin	5.2	4.6	4.1	3.7	5.2	4.6	4.1	3.7
Pamina	5.2	4.3	4.1	3.6	5.0	4.7	4.1	3.7
Roland	5.1	4.4	4.1	3.7	5.0	4.6	4.0	3.8
Romi	4.9	4.4	3.9	3.4	4.7	4.3	3.9	3.5
Sune	4.9	4.4	4.0	3.7	4.9	4.6	4.0	3.8
Susan	4.9	4.4	4.1	3.9	4.9	4.6	4.1	4.0
Tyra	4.8	4.4	3.9	3.5	4.8	4.5	4.0	3.7
Taarn	5.0	4.3	3.6	3.3	4.8	4.3	3.7	3.3
Uffe	5.4	4.5	4.1	3.8	5.1	4.9	4.2	3.7
Yriba	4.9	4.5	4.0	3.7	4.8	4.5	4.1	3.7

sent pot experiments, where only climatic conditions were changeable, the high coefficients of correlation between the two years showed that the varieties tended to maintain their mutual differences in nitrogen content even under those circumstances where year variations were found.

In some barley varieties the lysine content in the protein has been found to be higher than in other varieties and these differences seem to be maintained when the varieties are grown at different sites (10). In the present experiments the high coefficients of correlation between the two experimental years confirmed that some barley varieties have a relative high lysine content compared to other varieties. A few examples are shown in Figs 3 and 5 from where it appears that the differences in the lysine content between two varieties with almost equal nitrogen content can be as high as 10 per cent. Furthermore, compar-

ing those results with the results shown in Figs 4 and 6 the opposite directions of the curves show that the contents of lysine and amide are negative related, confirming previous investigations (4, 7, 8, 10, 12). For screening purposes of new barley lines the amide determinations together with the nitrogen determinations therefore may supplement the more complicated lysine determinations as an expression of the protein quality of the barley grain.

The proanthocyanidin-free variety Galant (11) which is a mutant from Triumph (6) had a rather high nitrogen content but not an accordingly low content of lysine (Tables 2 and 4). However, the variety Triumph had a content of nitrogen and lysine near average (Tables 1 and 3). This shows that the mutation also has changed the protein composition in the grain.

When barley grain is mixed with feeding stuffs

Amide-N as per cent of total N. 1983.
Amid-N i procent af TN. 1983.

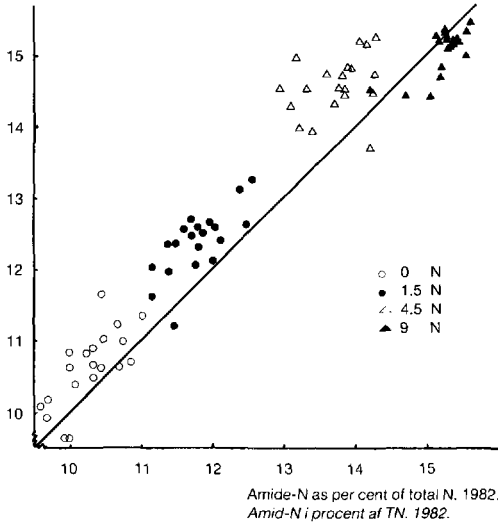


Fig. 1. Amide content in grains from 20 barley varieties grown in 1982 and 1983 with increasing nitrogen supplies.

Amidindhold i kerner fra 20 bygsorter dyrket i 1982 og 1983 ved stigende kvælstoftilførsel.

Amide-N as per cent of total N. 1985.
Amid-N i procent af TN. 1985.

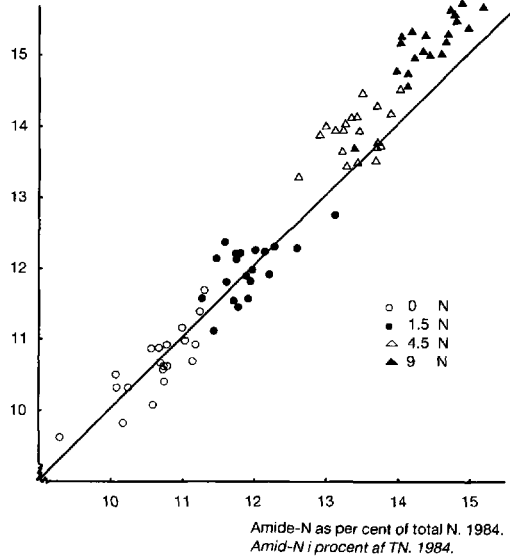


Fig. 2. Amide content in grains from 20 barley varieties grown in 1984 and 1985 with increasing nitrogen supplies.

Amidindhold i kerner fra 20 bygsorter dyrket i 1984 og 1985 ved stigende kvælstoftilførsel.

Lysine-N as per cent of total N.
Lysin-N i procent af TN.

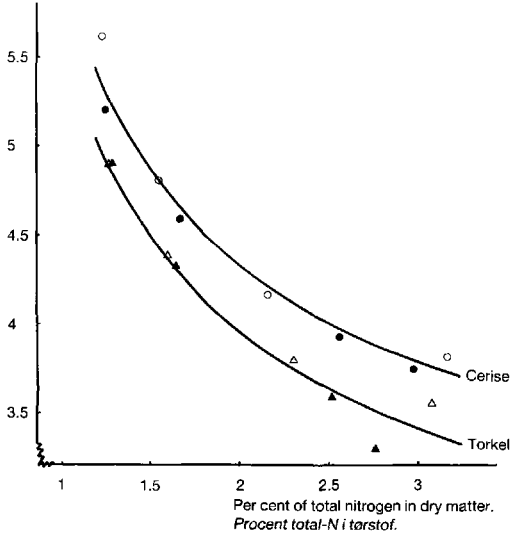


Fig. 3. The relation between lysine-N and total nitrogen in grains from the barley varieties Cerise and Torkel.

Sammenhængen mellem lysin-N og totalkvælstof i kerner fra bygsorterne Cerise og Torkel.

○ Cerise 1982. ● Cerise 1983. △ Torkel 1982. ▲ Torkel 1983.

Amide-N as per cent of total N.
Amid-N i procent af TN.

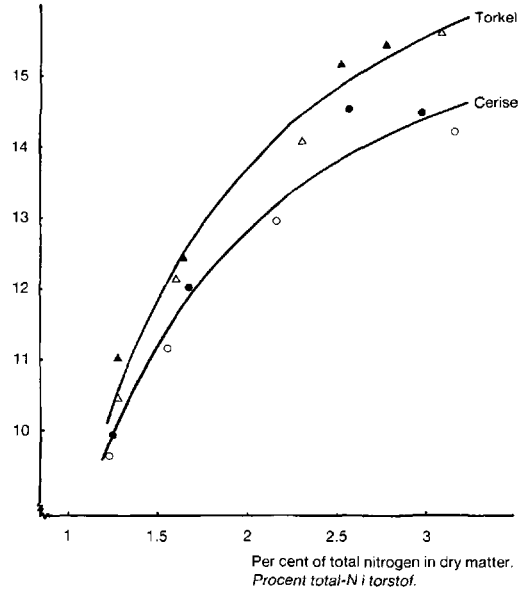


Fig. 4. The relation between amide-N and total nitrogen in grains from the barley varieties Cerise and Torkel.

Sammenhængen mellem amid-N og totalkvælstof i kerner fra bygsorterne Cerise og Torkel.

○ Cerise 1982. ● Cerise 1983. △ Torkel 1982. ▲ Torkel 1983.

Lysine-N as per cent of total N.
Lysin-N i procent af TN.

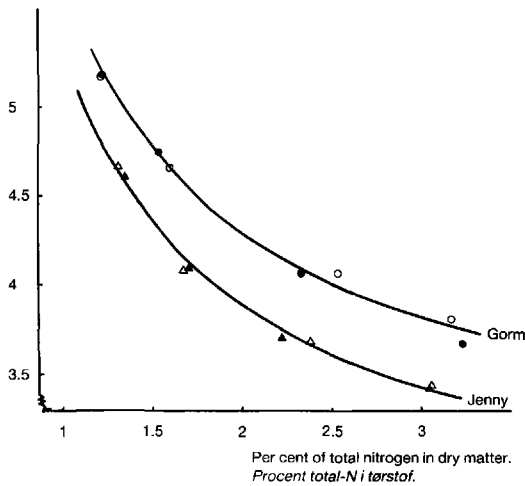


Fig. 5. The relation between lysine-N and total nitrogen in grains from the barley varieties Gorm and Jenny. *Sammenhængen mellem lysin-N og totalkvælstof i kerner fra bygsorterne Gorm og Jenny.*

○ Gorm 1984. ● Gorm 1985. △ Jenny 1984. ▲ Jenny 1985.

with relative high lysine concentrations, the content of other essential amino acids as methionine + cyst(e)ine could limit the monogastric animals utilization of the protein in the mixture (3). From the present investigations it appears that only small varietal differences in the content of sulphur-containing amino acids are found.

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Amide-N as per cent of total N.
Amid-N i procent af TN.

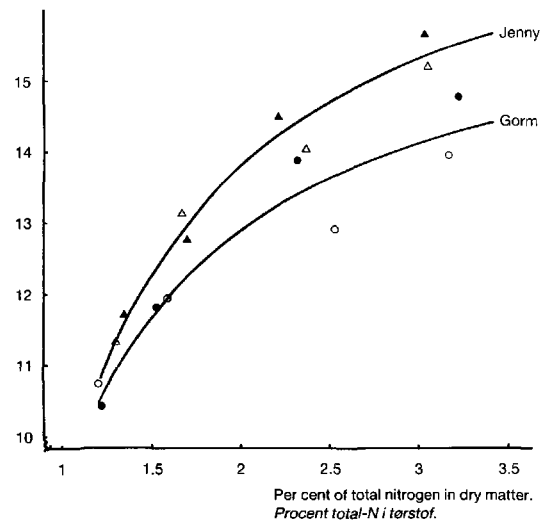


Fig. 6. The relation between amide-N and total nitrogen in grains from the barley varieties Gorm and Jenny. *Sammenhængen mellem amid-N og totalkvælstof i kerner fra bygsorterne Gorm og Jenny.*

○ Gorm 1984. ● Gorm 1985. △ Jenny 1984. ▲ Jenny 1985.

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