The Journal of Agricultural Sciences - Sri Lanka
Vol. 20, No 2, May 2025. Pp 239-246
http://doi.org/10.4038/jas.v20i2.11164

Analysis of Quality Indicators in the Grain of Mid-late and Late Hybrids of Maize (*Zea mays* L.) in Bulgaria

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Received: 23rd August 2024 / Accepted: 26th March 2025

ABSTRACT

Purpose: *Maize is an important food and forage crop with a high nutritional value, primarily used as feed for farm animals. The chemical composition of maize grain plays a significant role in animal productivity. The study aimed at analyzing the quality parameters such as protein, oil, starch, fibre and ash in mid-late and late hybrids of maize, specifically: i) FAO 500-599 (Kneja 560, Kneja 564, Kneja 570A, Kneja 572 and KXC1395) and ii) FAO 600-699 (Kneja 648, Kneja 649, Kneja 650A, Kneja 650 and Kneja 683).*

Research Method: *The plants were grown in the field without irrigation and NIR spectroscopy was used for analyses. The Pearson correlation coefficient was used to measure the strength and direction of the linear relationship between variables.*

Findings: *The content of the parameters studied varied depending on the vegetation group. Among the mid-late hybrids, Kneja 560 exhibited the highest protein content (10.49%), while among the late hybrids, Kneja 648 had the highest both protein (11.63%) and starch content (68.61%). Ash content was the most variable trait, with a coefficient of variation of 9.714% for mid-late hybrids and 17.183% for late hybrids. The Pearson coefficient indicated a high correlation between ash content and fiber content in hybrids from both maturity groups, with r=0.778 for mid-late hybrids and r=0.949 for late hybrids.*

Value: *The main chemical composition (excluding starch) was considered more greatly balanced in the grain of late hybrids of maize..*

Keywords: *Ash, Fiber, Grain, Maize, Oil, Protein, Starch*

INTRODUCTION

Maize (*Zea mays* L.) is the most productive crop grown in the world in terms of food, and is the third in distribution after wheat and rice (FAO 2020, http://www.fao.org/faostat/en/#home). It is a major part of the grain balance of Bulgaria. Despite the unstable weather conditions, there was no decline in the growing of maize for grain in the country (Agrarian Reports, 2022, 2023, 2024). In recent years, a positive trend towards an increase in harvested areas was found (Agrarian Report, 2022).

Maize is an important fodder, food and technical crop. Its grain has a high nutritional value (Júnior *et al.*, 2020) and is mainly used as feed for farm animals. The chemical composition of the grain is important for animal productivity. One of the goals of selection is the creation of genotypes with a balanced main chemical composition. Protein content in grains of the 14 maize inbred lines ranged from 8.34% to 11.60% (Abou-Deif *et al.*, 2012). With respect to the crosses, the values of protein content varied between 8.22% and 13.94%. There are new hybrids of maize from different maturity groups whose chemical composition has not been studied. In addition, the hybrids from the mid-late maturity group are the most used.

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The present work aimed at evaluating the qualitative parameters, i.e., content of protein, fat, starch, fibre, ash, and dry matter in the grain of mid-late (FAO 500–599) and late (FAO 600–699) hybrids of maize.

MATERIALS AND METHODS

The experiment was carried out at the experimental field of the Maize Research Institute – Kneja, Bulgaria under non-irrigated conditions. Ten (10) hybrids were tested as follows: i) mid-late hybrids (FAO 500–599): Kneja 560, Kneja 564, Kneja 570A, Kneja 572 and KXC 1395 and ii) late hybrids (FAO 600–699): Kneja 648, Kneja 649, Kneja 650A, Kneja 650 and Kneja 683. A block method was used with 4 replications, and the size of the experimental plot was 10 m^2 at a density of 53,000 plants/ha (Chen *et al.*, 2018). The soil type is typical chernozem. A standard technology of growing maize was applied. The necessary active biological temperature for ripening of mid-early hybrids is 2500°C, for mid-late 2700°C and for late up to 3200°C, respectively.

NIR spectroscopy (SupNIR-2700 Near-infrared Analyzer, China) was used to determine the main chemical composition of the grain (protein content, starch, fat, ash, fiber) (% of dry matter). For this purpose, kernel samples of 200 g were ground with a 0.5 mm sieve using a laboratory mill. The analysis was performed on mature grain. Values for individual parameters were compared with group averages (mid-late hybrids FAO 500–599 and late hybrids FAO 600–699). Minimum and maximum values and standard deviation (SD) were determined. The coefficient of variation (CV%) was used to determine the variability of the indicators studied (Dimova and Marinkov, 1999). Pearson's correlation coefficient (r) was used to determine the strength and direction of a linear relationship between indicators. Statistical processing of the experimental data was performed using the SPSS 20.0 software product for Windows.

RESULTS AND DISCUSSION

Previous studies (Pencheva and Sabeva, 2019) showed content of crude protein in maize from 9.0% to 12.93%. Olowookere *et al.* (2017) found 10.35% crude protein in grain. Pushpam *et al.* (2015) screened the genotypes for crude protein content and found it ranging from 7.01% to 12.25% with a mean protein content of 9.57%.

The results in our study showed that the content of the parameters investigated differs depending on the maturity group to which the maize hybrids belong. For the mid-late hybrid group (FAO 500–599), the protein content varied between 9.38% to 10.49%, and the fat and starch content between 3.40% and 3.78%, and between 67.66% and 68.43%, respectively (Table 01). Referred to the average values for the group (average standard), the protein content in the grain of hybrid Kneja 560 significantly exceeds that of the average standard (by 5.19% at $p < 0.05$), as well as all of the group of mid-late hybrids at a low coefficient of variation (7.34%) (Figure 01). A detailed description of the hybrid was done by Valkova and Petrovska (2018, 2021).

The comparative analysis in terms of fat content in the grain showed that none of the mid-late hybrids exceeded the average standard. Kneja 564 (detailed description was done by Yordanov, 2021) significantly exceeded Kneja 570A in fat content (by 7.41% at $p < 0.05$), and both Kneja 572 and Kneja 560 significantly exceeded KC 1395 by 7.86% and 7.61% at $p < 0.05$, respectively.

Our data are in confirmation of those of Uarrota *et al.* (2013). Relatively lower values for the content of protein and fat in the grain of maize were obtained in the studies of Koteva and Marcheva (2012). Abou-Deif *et al.* (2012) found oil content in maize inbred line grains ranged from 7.67% to 11.56%. The content of crude protein and fat in the grain depends on the hereditary predisposition of the plant and is little influenced by the growing conditions.

In terms of starch content, similarly to fat content, none of the mid-late hybrids tested by the group proved superior to the average standard. Kneja 572 significantly exceeded Kneja 564 and KC 1395 hybrids by the starch content. Our results regarding changes in starch content confirm those obtained in the studies of Egesel and Kahriman (2012). The starch content is also mainly determined by the genotype, but it can also change under the influence of external conditions (Terziev *et al.*, 2001a,b).

Kneja 570A and Kneja 572 significantly exceeded the ash content of the average standard, by 6.33% and by 10.72% at $p < 0.05$, respectively (Table 01 and Figure 01). Regarding trends within the mid-late hybrid group, the comparative analysis showed that Kneja 572 proved to exceed all hybrids in ash content in the grain. The exceeding of this indicator in Kneja 560 compared to Kneja 564 was also statistically significant.

The comparative analysis related to the fiber content showed that Kneja 572 proved to exceed the average

Table 1: Main chemical composition of grain of mid-late hybrids of maize (FAO 500–599) (% of dry matter)

Hybrids	Protein ± SE	Oil	Starch	Ash	Fiber	Dry matter
Kn 560	10.49±1.06	3.68±0.81	67.66±0.23	1.08±0.02	2.24±0.15	87.48±0.08
564	9.38±1.05	3.78±1.10	68.22±0.20	0.98±0.09	2.19±0.18	87.42±0.06
Kn 570A	10.21±1.46	3.50±0.54	69.39±0.21	1.21±0.10	2.33±0.21	87.47±0.06
Kn 572	10.01±1.16	3.69±0.62	68.53±0.29	1.26±0.10	2.41±0.23	87.29±0.05
C1395	9.77±1.32	3.40±1.14	68.33±0.27	1.16±0.13	2.18±0.20	87.35±0.04
Max	10.49±1.06	3.78±0.71	69.39±0.22	1.26±0.15	2.41±0.21	87.48±0.06
Min	9.38±1.05	3.40±1.14	67.66±0.20	0.98±0.03	2.18±0.19	87.29±0.08
Average	9.97±1.21	3.61±0.84	68.43±0.24	1.14±0.09	2.27±0.21	87.40±0.07
SD	0.424	0.155	0.628	0.111	0.098	0.081
LSD 5%	0.28	0.27	0.28	0.03	0.11	–

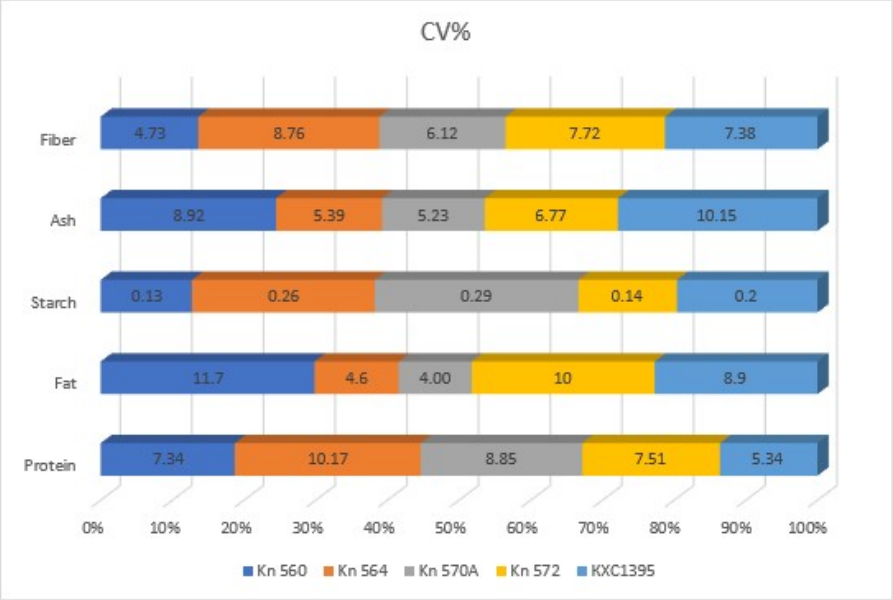

Figure 1: Coefficient of variation (CV%) of indicators of the main chemical composition of the grain of mid-late hybrids of maize (FAO 500-599).

standard, as well as Kneja 560. The hybrid Kneja 570A proved to exceed the ash content of the hybrids Kneja 564 and KC 1395. Koteva and Marcheva (2012) obtained higher values for ash and fiber content in the grain of maize. The maize hybrid Kneja 560 showed the highest content of protein and dry matter in the grain for this maturity group.

The coefficient of variation (CV%) for protein, fat and fiber content averaged for the hybrids of the group was close to 4.248, 4.300 and 4.328, respectively; and that for starch content was 0.918 (Figure 02). The value of the coefficient of variation was the highest for ash content (CV% = 9.714), indicating that it was the most variable characteristic. According to the degree of variability, the indicators are arranged as follows: ash content, starch, fiber, fat, protein, dry matter.

For the late hybrid group FAO 600-699, protein content varied between 9.82% to 11.63%, and fat and starch content between 3.79% and 4.32%, and between 65.53 and 68.61, respectively. % (Table 02). Referred to the average values for the group (average standard), the protein content of the grain of Kneja 648 proved to exceed the average standard (by 9.41% at p<0.05) and all hybrids in the group (from 9.30% to 18.4% at p<0.05), and is at a low coefficient of variation (4.44%) (Figure 03).

In terms of fat content, Kneja 648 significantly exceeded the average standard (by 8.22% at $p < 0.05$) and all hybrids in the group (from 4.0% to 14.0% at $p < 0.05$) with the exception of Kneja 650A. Regarding the other indicators, starch content of Kneja 649 and Kneja 650A significantly exceeded the average standard, and in terms of ash content, Kneja 648 significantly exceeded the average standard (by 18.89% at $p < 0.05$) and all hybrids in the group (from 9.22%

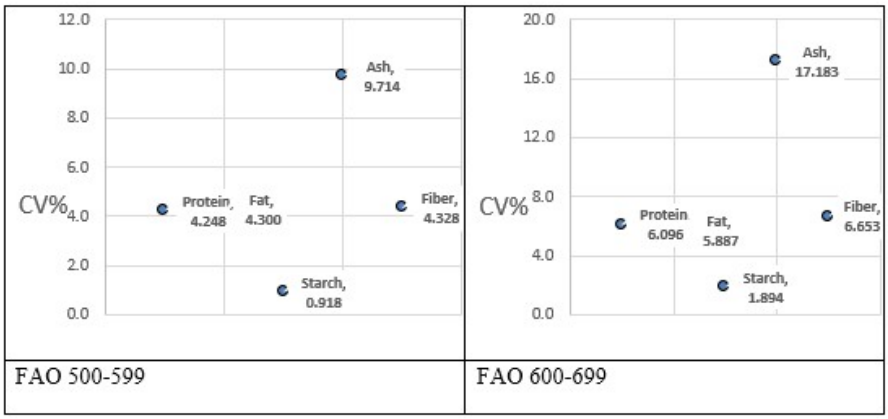

Figure 2: Coefficient of variation (CV%) of indicators of the main chemical composition of the grain of mid-late (FAO 500-599) and late (FAO 600-699) hybrids of maize (average of all hybrids

Table 2: Main chemical composition of grain of late hybrids of maize (FAO 600–699) (% of dry matter)

Hybrids	**Protein ± SE**	**Oil ± SE**	**Starch**	**Ash**	**Fiber**	**Dry matter**
Kn 648	11.63±0.84	4.32±0.83	65.53±0.21	1.41±0.03	2.43±0.11	87.29±0.06
Kn 649	10.64±1.16	3.79±0.86	68.52±0.29	1.28±0.02	2.40±0.10	87.06±0.04
Kn 650A	9.82±0.90	4.15±0.97	68.61±0.27	0.86±1.20	2.06±0.09	85.82±0.06
Kn 650	10.57±0.75	3.91±0.94	66.98±0.30	1.17±0.23	2.21±0.12	86.43±0.07
Kn 683A	10.49±0.88	3.79±0.80	67.03±0.24	1.21±0.28	2.24±0.10	86.85±0.06
Max	11.63±0.84	4.32±0.83	68.61±0.26	1.41±0.26	2.43±0.13	87.29±0.05
Min	9.82±0.90	3.79±0.86	65.53±0.24	0.86±0.22	2.06±0.10	85.82±0.04
Average	10.63±0.93	3.99±0.88	67.33±0.23	1.19±0.20	2.27±0.12	86.69±0.05
SD	0.648	0.235	1.275	0.204	0.151	0.580
LSD 5%	0.35	0.19	0.23	0.11	0.14	–

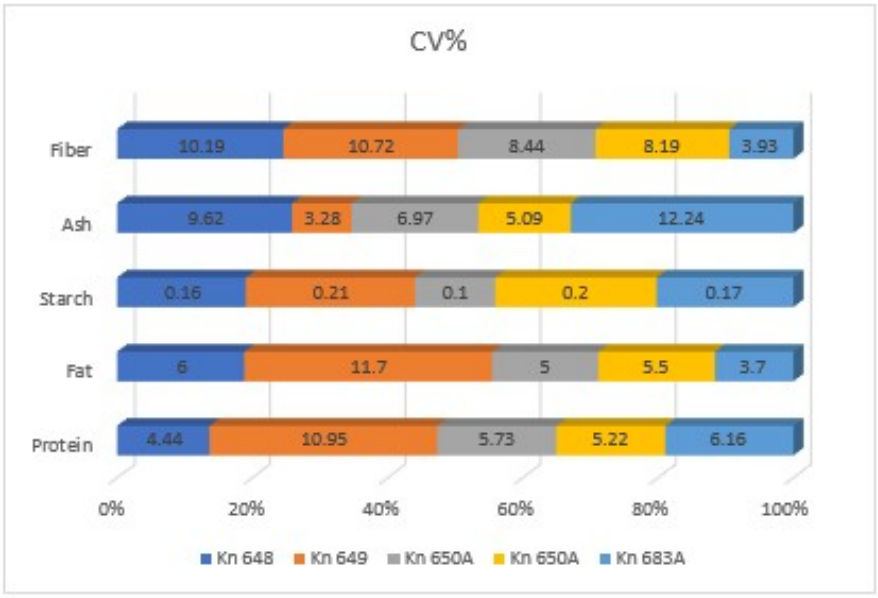

Figure 3: Coefficient of variation (CV%) of indicators of the main chemical composition of the grain of late hybrids of maize (FAO 600-699)

to 40.0% at $p < 0.05$).

A similar trend was found in terms of fiber content — Kneja 648 significantly exceeded the average standard (by 7.14% at $p < 0.05$) and all hybrids in the group (up

to 15.23% at $p < 0.05$), except for Kneja 649. Kneja 649 and Kneja 683A hybrids fell behind the average standard by 5.06% in fat content, and Kneja 650A in protein content by 7.62%, respectively. Pencheva and Sabeva (2019) found oil content ranging from 3.7% to 4.7%.

The hybrid Kneja 648 showed the highest content of protein (11.63%), fat (4.32%), ash (1.41%), fiber (2.43%) and dry matter (87.29%) in the grain for this maturity group. Referred to the average values for the group, it turns out that the grain of maize hybrid Kneja 648 in all tested indicators, except for starch, exceeds the average values as follows: in protein content by 9.41%, in fat content by 8.22%, fiber by 7.14%, and ash by 18.89%.

The data from Figure 03 show that the coefficient of variation for the indicators of the chemical composition of the grain of hybrid Kneja 649 has the highest values, as follows: CV% = 11.70 for fat content (vs. CV% = 3.70 for Kneja 683A); CV% = 10.95 for protein content (vs. CV% = 4.44 for Kneja 648); and CV% = 10.72 for fiber content (vs. CV% = 3.93 for Kneja 683A).

Similarly, as with the FAO 500–599 group, ash content was the most variable characteristic (CV% = 17.183). Similar results regarding the variability of ash content in the grain were obtained in other crops such as pea (CV% = 7.81) (Vasileva and Kosev, 2021).

In general, the indicators of grain quality were more variable in late hybrids, and according to the values of the coefficient of variation, they are arranged as follows: ash, fiber, protein, fat, starch, dry matter (Figure 02).

On average for the hybrids, the main chemical composition (excluding starch content) in the grain was found more balanced in the late group (FAO 600–699) of maize. The exceeding was greatest in terms of fat content (by 10.58%), followed by protein content (by 6.60%) and ash content (by 4.22%). We assume that this was due to the formation of a higher number of leaves and a larger ear leaf area than the hybrids of the late maturity group (data not shown). It is known that one of the important factors for the formation of the leaf area is the genotype, especially relevant for hybrids of this maturity group. Total leaf area was found to be highly correlated with growing season length (Ilchovska *et al.*, 2019). The number of leaves and the area of the ear leaf determine the photosynthetic potential of the plant. The greater leafiness of the late hybrids allows the formation of a larger photosynthetic area, which, due to the longer vegetation period, has a longer functional activity. This contributes to the accumulation of more assimilates to feed the grain.

Figure 04 presents the main chemical composition of grain of maize hybrids from the two maturity groups (FAO 500–599 and FAO 600–699) by indicators (average values of all hybrids of the respective group). Fiber content was the same for both groups (2.27%), so it is not presented. The data confirm the better grain composition of the late hybrids.

Correlation dependences between individual parameters showed the interrelationship between them. The following correlation dependences were found: for the group of mid-late hybrids (FAO 500-599) (Table 03): weak positive correlation between fat and fiber content (r=0.128); moderate positive correlation between protein and dry matter content (r=0.380), between protein and ash content (r=0.418) and between starch and fiber content (r=0.488). A strong positive correlation was found between starch and ash content (r=0.565).

A moderate negative correlation was found between fat and starch content (r= -0.426) and fat and ash content (r=- 0.491), as well as between ash and dry matter content (r= - 0.482) and between fiber content and dry matter (r= - 0.336).

For the late hybrid group (FAO 500-599) (Table 04): weak positive correlation between fat and fiber content (r=0.028); moderate positive correlation between protein and fat content (r=0.380). In this group, protein content was highly correlated with dry matter content (r=0.865), fiber content (r=0.867) and ash content (r=0.921).

A moderate negative correlation was found between fat and starch content (r= -0.450) and between starch and fiber content (r=- 0.483), and a significant negative correlation between starch and ash content (r=- 0.683) and between the content of starch and dry matter (r=- 0.578). Pearson's coefficient showed that ash content correlated highly with fiber content for hybrids of both maturity groups, viz. r=0.778 for FAO 500-599 and r=0.949 for FAO 600-699, respectively.

CONCLUSIONS

An evaluation of the main chemical composition (protein, fat, starch, fiber, ash and dry matter) in the grain of maize hybrids from two vegetation groups, viz. mid-late (FAO 500-599) (Kneja 560, Kneja 564, Kneja 570A, Kneja 572 and KXC 1395) and late

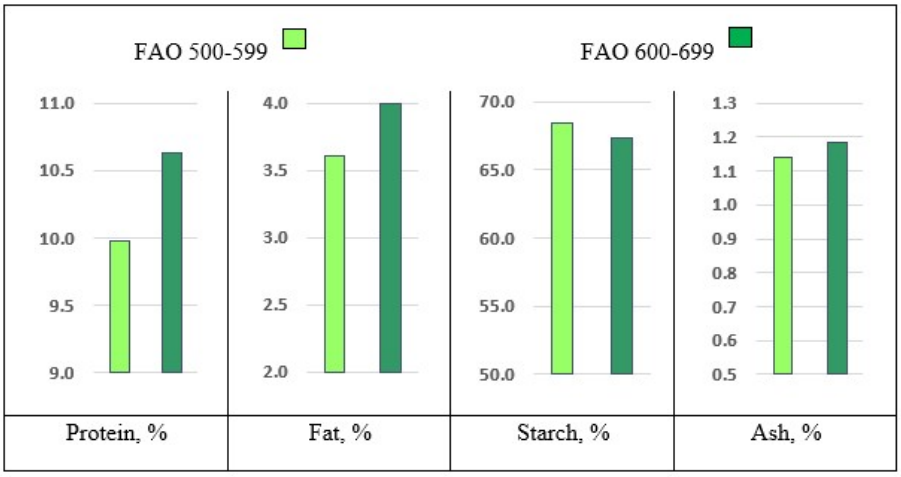

Figure 4: Protein, fat, starch and ash content (% of dry matter) in the grain of mid-late (FAO 500-599) and late hybrids of maize (FAO 600-699) (average values of all hybrids of the respective group)

Table 3: Correlational dependences between parameters of the main chemical composition of grains of mid-late (FAO 500–599) hybrids of maize

	Fat	**Starch**	**Ash**	**Fiber**	**Dry matter**
Protein	-0.171	-0.021	0.431	0.418	0.380
Fat		-0.426	-0.491	0.128	0.060
Starch			0.565	0.488	-0.022
Ash				0.778	-0.482
Fiber					-0.336

Table 4: Correlation dependences between parameters of the main chemical composition of grain from late (FAO 500-599) hybrids of maize

	Fat	Starch	Ash	Fiber	Dry matter
Protein	0.3796	-0.835	0.921	0.867	0.865
Fat		-0.450	-0.003	0.028	-0.048
Starch			-0.683	-0.483	-0.578
Ash				0.949	0.974
Fiber					0.964

The dependencies found could be used to evaluate the quality composition of maize hybrids of different maturity groups.

(FAO 600-699) (Kneja 648, Kneja 649, Kneja 650A, Kneja 650 and Kneja 683) showed that the content of the investigated parameters differed depending on the maturity group, to which the hybrids belonged. For the mid-late group (FAO 500-599), Kneja 560 showed the highest protein content in the grain and significantly exceeded the average standard by 7.37%. For the late group (FAO 600-699) Kneja 648 significantly exceeded the average standard as follows: in protein content by 9.41%, in fat content by 8.22%, in ash content by 18.89% and in fiber content by 7.14%, respectively.

The main chemical composition in the grain (except starch content) on average for hybrids was found more balanced in the late hybrids of maize (FAO 600-699). For the group of mid-late hybrids (FAO 500-599), the following correlations between the parameters of the main chemical composition of the grain were found: a weak positive correlation between the content of fat and fiber (r=0.128); moderate positive correlation between protein and dry matter content (r=0.380), between protein and ash content (r=0.418) and between starch and fiber content (r=0.488). A strong positive correlation was found between starch and ash content (r=0.565). A moderate negative correlation was found between fat and starch content (r= -0.426) and fat and ash content (r=- 0.491), as well as between ash and dry matter content (r= - 0.482) and between fiber content and dry matter (r= - 0.336).

For the late hybrid group (FAO 600-699) the correlations were as follows: weak positive correlation between fat and fiber content (r=0.028); moderate positive correlation between protein and fat content (r=0.380). In this group, protein content was highly correlated with dry matter content (r=0.865), fiber content (r=0.867) and ash content (r=0.921). A moderate negative correlation was found between fat and starch content (r= -0.450) and between starch and fiber content (r=- 0.483), and a significant negative correlation between starch and ash content (r=- 0.683) and between the content of starch and dry matter (r=- 0.578).

The ash content in grain was the most variable characteristic for both vegetation maturity groups (CV% 9.714 and CV% 17.183, for hybrids group FAO 500-599 and hybrids group FAO 600-699, respectively).

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