# Alkylresorcinol content in the grains of winter triticale depending on production technology

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**Abstract.** Alkylresorcinols (AR) protect cereal grains against pests but they also belong to the bioactive components of the grains. The aim of the study was to determine the effect of intensive and integrated technologies on the alkylresorcinolcontent in the grains of two cultivars of winter triticale. The study indicates that the increase of the AR content in the grains was promoted by a favorable distribution of average precipitation and air temperature during the multi-year period, at the stage of grain formation as well as by intensive production technologies, and a cultivar. The grains of winter triticale cv. Pigmej cultivated under intensive technology in 2014 had the highest AR content, i.e. 358 $mg.kg^{-1}$ of grain.

**Keywords:** alkylresorcinols, cultivars, winter triticale, integrated and intensive technologies

## 1 Introduction

Triticum grains are mainly used for feed purposes. Alkylresorcinols (ARs), also called resorcinol lipids, are a group of natural phenolic compounds. They exhibit a strong antibacterial and antifungal activity and act as antioxidants in the body (Fardet 2010). It is now assumed that ARs in triticale grains as anti-nutrition compounds are not a problem in animal nutrition (Djekić et al. 2009). Triticale may, however, gain importance as consumption grain (Boros et al. 2015). AR raises interest also as a bioactive food ingredient. They are a component of grains, which occurs mainly in the bran [Ross et al. 2003]. Triticale grain is not yet applied in food, but there are works on such tritacale use (Jaśkiewicz 2014)It has been shown that the contents of phenolic compounds or ARs in cereal crops depend on a genotype (Bellato at a. 2013, Boros et al. 2015, Zigler at al. 2015), and environmental conditions (Czaban et al. 2014, Mpofu et al. 2006, Żuchowski at al. 2011). The aim of the study was to determine the effect of integrated and intensive technologies on the AR content in the grains of different cultivars of winter triticale.


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## 2 Material and methods

A two-year field study was conducted on slightly acidic soil ($pH_{KCL}$ 6,5). Winter triticale was grown in the cereal monoculture, after winter wheat. The experimental factors were integrated and intensive technologies and two cultivars: Pizarro (with a conventional straw length) and Pigmej (a short-straw form). Seeding density was 4 million seeds per ha.

The applied technologies differed in the level of mineral fertilization and chemical plant protection (Table1). Grain samples were collectedat the full maturity stage. The contents of ARs in triticale grain were determined with flow spectrophotometry with p-nitroaniline. The obtained results were statistically worked out in the software Statistica, with the method of the analysis of variance ANOVA, and the differences were estimated with Tukey's test at $\alpha = 0.05$. The coefficients of variation in AR content for the experimental factors were calculated. The relationship of the concentration of ARs on physical and chemical characteristics of grains were expressed by means of Pearson's simple correlation coefficients.

**Table 1.** Agricultural practises of triticale depending of production technology

| Specification | Production technology | |
|---|---|---|
| | Integrated | Intensive |
| Fertilization ($kg \cdot ha^{-1}$) | | |
| N (ammonium nitrate) | 50 (in spring at BBCH 24)+ 50 (at BBCH 31) | 60 (in spring at BBCH 24)+ 60 (at BBCH 31)+ 30 (at BBCH 51) |
| P(superfhosphate) | 29 | 35 |
| K(potassium salt) | 59 | 76 |
| Herbicides | At BBCH 31 (2,4 D+ dikamba) | At BBCH 25 (diflufenican, iodosulfuron-metyl-sodium, mesosulfuron- metyl) and BBCH 31 (2,4 D+ dicamba) and BBCH 34 (clopyralid) |
| Fungicides | At BBCH 45 (difenokonazol+ paclobutrazol | At BBCH 31 (flusilazol+carbendazim and BBCH 45 (difenoconazole +paclobutrazol) |
| Insecticides | - | At BBCH 47 (deltamethrin+dimethylcyclopropanecarboxylate) |
| Retardants | At BBCH 32 (trinexapaketylu) | At BBCH 32 (trinexapaketylu) |

**Table 2.** Characterization of weather conditions

| Month | Year | | | | | |
|---|---|---|---|---|---|---|
| | 2011 | 2014 | 1981-2010 | 2011 | 2014 | 1981-2010 |
| | Temperature ($^{o}C$) | | | Precipitation (mm) | | |
| March | 3,0 | 6,7 | 1,6 | 11 | 31 | 30 |
| April | 10,7 | 10,7 | 7,8 | 27 | 58 | 40 |
| May | 14,6 | 14,3 | 13,5 | 60 | 172 | 57 |
| June | 19,2 | 16,5 | 16,8 | 54 | 93 | 70 |
| July | 18,7 | 20,9 | 18,5 | 250 | 68 | 84 |
| Mean/Sum | 13,2 | 13,8 | 11,6 | 402 | 422 | 281 |

## 3 Results and discussion

The analysis of variance showed a significant variability of the AR content among the cultivars and production technologies tested (Table 4). Interactions were found among the AR content in grains between years and production technologies, as well as between years and varieties. Interactions was found in content of ARs in grain between the years and production technologies and winter triticale varieties and varieties. Significant interaction was also found between production technology and a cultivar (Table 4).

The correlation coefficients showed that the content of ARs depended on the air temperature in April and May and rainfall in March, April, June and July (table 3).

Favorable weather conditions in 2014 during the development stage of BBCH 39-55 positively influenced AR content in winter triticale grains. In 2014, the mean AR content was by 13% higher than in 2011 (Table 2,4). Under intensive production technology in 2014, there was a 24% increase in the AR content in the grains compared to the integrated technology in 2011.A similar AR content was recorded for the intensive (2011) and integrated technologies (2014). Under intensive technology, at the time of the flag leaf roll (i.e. BBCH 47 development stage), a third dose of nitrogen was applied in order to enhance water use in the soil. The purpose of this treatment was to increase the protein content of the grains.

Cultivars Pigmej and Pizarro had a significantly varied AR contents in their grains (Table 4). Cv. Pigmej had a significantly higher, by 14%, content of ARs in the grains compared to Pizarro. The year of 2011 saw a shortage of precipitation in the development stages BBCH 30-59 (Table 2,3). Under these weather conditions, cv. Pizarro contained by 17% less ARs in its grains than in 2014.Also the AR content of this cultivar was by 29% lower compared to the optimal weather conditions in 2014 in cv. Pigmej. However, the AR content of this cultivar in 2011 was at the level of the AR content of Pizarro in 2014. Cv. Pigmej made a better use of favorable weather conditions in 2014, showing a significantly higher AR content, i.e. 358 $mg \cdot kg^{-1}$ of grains.

Under intensive production technology, there was a significantly higher AR content in grains than under the integrated technology (Table 4). Probably, applying plant protection products and nitrogen fertilization in the integrated technology were not as effective as in the intensive technolog**y.** Undoubtedly, weather conditions after their application might have had a significant impact on the AR content. Under the integrated production technology, the AR content of cv. Pizarro was by 25% lower, i.e. 69 $mg \cdot kg^{-1}$ of grains than of cv. Pigmej grown under the intensive technology, which scored 353 $mg \cdot kg^{-1}$ of grains. On the other hand, under the integrated technology, the AR content of cv. Pigmej was similar to that of cv. Pizarro under intensive technology. Pigmej tended to have a higher AR content than Pizarro (Table 4).

**Table 3.** The relationship between the concentration of ARs in grains and weather conditions (Pearson's correlation coefficients).

| Month | Mean air temperature | Total rainfall |
|---|---|---|
| March | -0,27 | 0,53* |
| April | -0,45* | 0,35* |
| May | 0,36* | 0,23 |
| June | -0,08 | 0,48* |
| July | 0,24 | -0,51* |

*-Significant at α=0,05

**Table 4.** Interactions in the AR content [mg kg$^{-1}$] in the grains of winter triticale among the factors of the experiment

| Year/Treatment | | Productiontechnology | | Year /Treatment | | Cultivar | | Mean |
|---|---|---|---|---|---|---|---|---|
| | | Integrated | Intensive | | | Pizarro | Pigmej | |
| Year | 2011 | 287b | 316ab | Year | 2011 | 277b | 326ab | 302b |
| | 2014 | 327ab | 356a | | 2014 | 325ab | 358a | 342a |
| Variety | Pizarro | 284b | 319ab | Mean | | 301b | 342a | 322 |
| | Pigmej | 331ab | 353a | | | | | |
| Mean | | 307b | 336a | | | | | |

Notes: Different letters denote statistically significant differences (α=0,05)

**Table 5.** Variation coefficient of ARs content in winter triticale grains depending on varieties and production technology (%)

| Productiontechnology | | Cultivar | | Mean |
|---|---|---|---|---|
| Intensive | Integrated | Pigmej | Pizzaro | |
| 11,8 | 15,4 | 9,6 | 15,8 | 18,6 |

**Table 6.** The relationship between the concentration of ARs in grains, TKW and parametres of chemical composition.

| Type of grain component | Total protein | -0,38 |
|---|---|---|
| | Crude fiber | 0,53* |
| | Oil | -0,47* |
| | Carbohydrates | 0,46* |
| | Ash | 0,51* |
| TKW | | 0,57* |

*-Significant at α=0,05

Descriptive characteristics show that the AR content of cv. Pigmej has a relatively low coefficient of variation (V = 9.6%) (Table 5). This indicates a higher stability of this feature in these cultivars compared to cv. Pizarro, where the coefficient of variation was 2-fold higher (V = 15.8%). In the studies of Boros et al. [2015], cvs. Pigmej and Pizarro contained 475 and 418 mg of AR per 1 kg of grains, respectively. In our study, these cultivars had a lower content of this compound, namely cv. Pigmej 342 mg, while cv. Pizarro 301 mg per 1 kg of grains.

Intensive technology tended to have by 30% lower variance of AR content than integrated technology. In the studies of Kulawinek and Kozubek [2007] and Ross

[2003], the highest AR content was recorded in the grains of rye, triticale and wheat, small amounts in the grains of barley, whereas these compounds were not present in oats

The correlation analysis has shown that the AR content the winter triticale cultivars was positively correlated with the 100 grain weight, whereas there was no clear correlation between the grain content and AR content (Table 6). The studies of Fernandez-Orozco et al. [2010], Mpofu et al. [2006], Żuchowski et al. [2011] found no significant correlation between the phenolic acid and protein contents. In the studies of Mpofu et al. [2006] and Żuchowski et al. [2011], wheat grains originating from Winnipeg, grown under organic farming, had a lower protein content and higher phenolic acid content than those from theconventional one.Studies conducted on winter wheat cultivars [Czaban et al. 2015], concerning the content of individual acids of phenolic compounds under the conventional technology, wheat grain was richer in the dominant phenolic acids (ferulic and synaptic) compared with the cultivars from the theintegrated and medium-intensive technologies.The said acids, similarly to ARs, are located in the outer layer of the grain. In contrast to Fernandez-Orozco et al. [2010], Mpofu et al. [2006], Żuchowski et al. [2011], and Czaban et al. [2015] found a positive correlation between the protein and ferulic acid contents. At the same time, the grains of cultivars grown under the conventional sytems were suppler and had higher protein content.

We found a positive correlation among the content of fiber, carbohydrates in grains. However, together with the increase of fat content in winter triticale, the AR content decreased. Among cereal species, oats are the richest source of fats, containing 5 times more of these compounds than other species (3.5-8%) [Pisulewska et al. 2011]. At the same time, ARs were not found in this species [Kulawinek and Kozubek, 2007, Ross 2003]. The close correlation of the AR content with ash percentage in cereal grains has also been reported by Ross et al. [2003].

Minerals, similarly to ARs, are mainly found in the outer layer of the grain, therefore wholegrain products constitute a rich source of fiber. These days, they are of great interest as an important ingredient in bioactive food and a potential biomarker for the consumption of whole-grain products.

## 4 Conclusions

The research shows that the increase in the AR content of grains is positively shaped by a favorable rainfall distribution, air temperature at the mean level of many years during the grain formation period, intensive production technology and a cultivar. The winter triticale grains of cv. Pigmej grown under intensive technology had the highest AR content, i.e. 358 $mg \cdot kg^{-1}$ of grains in the harvest year 2014.

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