Attachment 4

SUMMARY OF PROFESSIONAL ACCOMPLISHMENTS

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TABLE OF CONTENTS

A. PERSONAL DATA

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Plant Breeding and Acclimatization Institute – National Research Institute, Radzików, 05-870 Błonie, Poland
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B. SCIENTIFIC CAREER

2002	Master of Science Gdańsk University of Technology, Faculty of Chemistry, Biotechnology, Specialization Technology of Edible Fats and Biotechnology of Lipids Master's thesis title: **„Enzymatic transesterification of olive oil with behenic acid"** Supervisor: Ph.D. Maria Tynek
2011	PhD. of agricultural sciences in the field of agronomy Plant Breeding and Acclimatization Institute – National Research Institute in Radzików Doctoral thesis title: **„Analysis of variability in dietary fibre and alkylresorcinols content in wheat grain (*Triticum aestivum* L.)"** Supervisor: Professor Danuta Boros Reviewers: Professor Jan Kaczmarek, Ph.D. Alicja Kawka

C. PROFESSIONAL EXPERIENCE

2002	Elstar Oils S.A., The Edible Oil and Fat Refinery in Czernin (now ADM), practice
2002-2004	Elstar Oils S.A., The Edible Oil and Fat Refinery in Czernin (now ADM); Specialists for quality
2002-2006	Private business activity: Investigations and Technical Analysis (PKD 7430Z)
2006-present	Plant Breeding and Acclimatization Institute – National Research Institute, Radzików, Independent Laboratory of Quality Evaluation of Plant Materials; positions: engineer (2006-2008), research assistant (2008-2012), adjunct (2012- until now)
2005/2006	Maternity and parental leave (12 months)
2011/2012	Maternity and parental leave (12 months)

D. INDICATION AND DESCRIPTION OF THE SCIENTIFIC ACHIEVEMENT SPECIFIED IN ARTICLE 16, SECTION 2 OF THE ACT OF 14 MARCH 2003 ON ACADEMIC DEGREES AND ACADEMIC TITLE AND DEGREES AND TITLE IN THE ART. (DZ. U. [JOURNAL OF LAWS] 2016, ITEM 882 CHANGED INTO DZ. U. 2016, ITEM 1311.):

1. TITLE OF THE SCIENTIFIC ACHIEVEMENT

Characteristics of the chemical composition of Polish triticale varieties (X *Triticosecale* Wittmack) including the influence of the environment and the possibility of improving their breadmaking suitability

a series of 6 thematically related publications

2. PUBLICATION CONSTITUTING THE SCIENTIFIC ACHIEVEMENT

1. **Fraś A.**, Gołębiewska K., Gołębiewski D., Boros D. 2018. Dietary fibre in cereal grains – A review. Plant Breeding and Seed Science, 77: 43-53.
(MNiSW – **11 pt.**, contribution 85%)

2. **Fraś A.**, Gołębiewska K., Gołębiewski D., Mańkowski D.R., Boros D., Szecówka P. 2016. Variability in the chemical composition of triticale grain, flour and bread. Journal of Cereal Science, 71: 66-72.
(MNiSW – **35 pt.**, IF=**2,302**, contribution 45%)

3. **Fraś A.**, Mańkowski D.R., Gołębiewski D., Gołębiewska K. 2018. Influence of genotype, environment and G×E interaction on chemical composition and alpha-amylase activity of winter triticale grain. Polish Journal of Agronomy, 35: 3-14.
(MNiSW – **10 pt.**, contribution 60%)

4. Gołębiewska K., **Fraś A.**, Gołębiewski D., Mańkowski D.R., Boros D. 2018. Content of nutrient and bioactive non-nutrient components in different oat products. Quality Assurance and Safety of Crops & Foods, 10(3): 307-313.
(MNiSW – **20 pt.**, IF=**0,558**, contribution 40%)

5. **Fraś A.**, Gołębiewski D., Gołębiewska K., Mańkowski D.R., Gzowska M., Boros D. 2018. Triticale-oat bread as a new product rich in bioactive and nutrient components. Journal of Cereal Science, 82: 146-154.
(MNiSW – **35 pt.**, IF=**2,302**, contribution 55%)

6. Mańkowski D.R., **Fraś A.**, Gołębiewska K., Gołębiewski D. 2018. Consumer acceptance of Polish bread products. Plant Breeding and Seed Science, 77: 33-42.
(MNiSW – **11 pt.**, contribution 40%)

The applicant's contribution to the above-mentioned work is described in the **Annex 5**, while copies of the works and co-authors' statements are presented in **Annexes 6** and **7**.

The total number of MNiSW points, according to the year of publication is **122**. Total IF of the presented achievement according to the year of publication is **5,162**.

All results, presented as the scientific achievement have been obtained as a part of the research project no. LIDER/019/519/L-4/NCBIR/2013, titled: „Triticale-oat bread as a new Polish food for fit and health promoting", acronym: NovelBread4Fit (2013-2017), financially supported by The Polish National Centre for Research and Development (project manager: Anna Fraś, PhD).

3. SYNTHETIC DISCUSSION OF THE SCIENTIFIC ACHIEVEMENT

INTRODUCTION

Triticale (X *Triticocsecale* Wittmack) is the first man made cereal, developed by combining the A and B genomes of wheat (*Triticum turgidum* L., *Triticum aestivum* L.) and the R genome of rye (*Secale cereale* L.) (Rakha et al., 2013; Zhu, 2018).

Nowadays Poland is the main world producer of triticale. The production of this crop in 2018 was over 5 million tones and was twice higher than production in Germany and more than three times higher than in France (Eurostat, 2018). The first Polish triticale variety, Lasko was registered in the 1982, and Polish varieties currently available on the market are consider to be the best yielding in the world, therefore they are registered in most countries and constitute the large share in total cultivation area of this crop. Currently, on the Polish National Lists of Varieties, there is 62 triticale varieties including 49 winter and 13 spring varieties (COBORU, 2018).

During last few years triticale becomes very popular crop among agronomists. Its popularity is connected with higher immunity for soil acidification, drought and wheat and rye diseases, and in a consequence higher yield potential in comparison to wheat at the same type of soil. Triticale is used mainly for animal feed, as raw material during biofuel production and in last years in spirit and brewing industry but very little for human nutrition, especially in bakery (McGoverin et al., 2011). Utilization of triticale flour in this industry sector is difficult because too high α-amylase activity and weak rheological properties of dough, what is directly connected with lower amount and worse quality of gluten in comparison to wheat. Agricultural treatments can improve a grain quality throughout increasing the protein content, a very important in the milling and baking technology (Ceglińska et al., 2005). A great breeding progress in last few years in Poland contributed to improvement of many features determining the usage value of novel triticale varieties. Nowadays, the triticale breeding is directed for improving of technological quality, resistance to diseases, and yield potential. Triticale differ from bread wheat by the presence of the R genome of rye that replaces wheat genome D. This substitution removes 1/3 of locus of proteins responsible for baking properties and introduce a secalin locus, which have unfavourably impact for flour quality. Therefore since several years a genetic researches have been made to obtain the similar content of endosperm proteins in triticale and wheat. For this purpose there are some translocations on chromosome R of triticale used, consist in inserting a chromosome D from wheat. However the obtained results were unsatisfactory in respect of agronomic properties as well baking quality mainly in case of falling number (Ceglińska et al.,2005; Martinek et al., 2008; Woś et al., 2008; Jonnala et al., 2010).

The nutritional value of triticale is similar to wheat and rye. It is characterized by a high content of protein in the grain, comparable to wheat, but with a better amino acid composition. Triticale consist higher amount of lysine, which is the basic amino acid limiting the nutritional value of protein in cereals and distinguish higher digestibility of protein and starch in comparison to rye. It is also a rich source of dietary fibre, constituting the main bioactive component of cereal grains responsible for the pro-healthy value. Triticale grain contains also other bioactive components, such as phenolic compounds including alkylresorcinols with antioxidant activity and also phytoestrogens, vitamins and microelements (Varughese et al., 1996; Iwański et al., 2009; Jonnala et al., 2010).

Considering the large area of cultivation and the growing interest of triticale from the agricultural practice point of view, it is important to know, which of the Polish triticale varieties are characterized simultaneously with a favourable chemical composition and the optimal baking value. It is also important to examine the impact of environmental conditions on grain parameters related to its nutritional and technological value. Nowadays in Poland there is not production of triticale bread due to still unsatisfactory breadmaking properties . Breads made of triticale-wheat flour blends are also uncommon. All researches were mainly directed for improving the breadmaking quality of triticale, in order to utilization the high potential of this cereal. There has been no technological method developed for baking triticale bread on a larger scale. There also weren't any investigations on improving of health promoting properties of triticale bread by supplementation of triticale flour with high-fibre preparation. Oat products, that are characterised by high pro-healthy value can be used for such substitution. There is no data in the literature regarding the use of oat products for triticale mixtures in order to increase the content of dietary fibre, in particular β-glucan. So far, oat and oat products were used for supplementation of wheat or wheat-rye bread (Gambuś et al., 2011).

Promoting the functional food in the society, including culinary novelties and diversifying the diet is an additional argument for utilization of Polish triticale varieties for consumption purposes. Changes in the diet and diets diversity contribute to the search for new raw materials in the food industry, combining high nutritional value with health-promoting properties.

THE AIM OF THE REASEARCH

A small number of studies on triticale carried out in recent years and the need for full characterization of available triticale varieties in terms of utilization for consumption purposes, as well as the need to search for new, alternative solutions to improve the quality of food, important in the prevention of diet-related diseases was the basis for the formulation of the purpose of my research.

The aim of the research was to characterise the chemical composition of selected triticale varieties including the influence of environmental conditions on the tested parameters and an indication of the possibility of using these varieties as a raw material for breadmaking. In addition, the evaluation of the possibility of enrichment the triticale flour with oat product to increase the pro-healthy value of bread.

The main objective was achieved thanks to the formulation of specific goals covering the following issues:

1. Analysis of the variability in the chemical composition between grain, flour and bread obtained from selected triticale varieties and determination of their breadmaking suitability.
2. Determination of the influence of genotype, environment and genotype-environmental interaction on the chemical composition of selected triticale varieties.
3. Searching for the oat product with the highest pro-healthy value for supplementation of triticale bread.
4. Development of a recipe for triticale-oat bread with an increased pro-healthy value.
5. Evaluation of preferences and expectations of bread consumers and producers in relations to new bakery products.

DETAILED DISCUSSION OF THE SCIENTIFIC ACHIEVEMENT

Dietary fibre is the main complex of bioactive components of cereal grains. Taking into account the high consumption of cereal products, including bread, it is important that the content of dietary fibre in the consumed products is as high as possible. The purpose of my research is to increase the pro-healthy value of triticale by enrichment of flour with high-fibre oat product, therefore the introduction to my achievement is **publication 1**, which describes the structure, characteristics and physiological effects of dietary fibre.

In accordance with the current definition, dietary fibre means carbohydrate polymers with 10 or more monomeric units, which are not hydrolysed by the endogenous enzymes in the small intestine of human. Dietary fibre is composed of the following groups of compounds: non-starch polysaccharides (including cellulose and non-cellulosic polysaccharides), non-digestible oligosaccharides, resistant starch and lignin and other compounds linked to fibre polysaccharides. In terms of water solubility, dietary fibre can be divided into two fractions: soluble and insoluble, and each of them has different physiological and health-promoting effects. First fraction constitute soluble arabinoxylans and β-glucan, as well as pectic substances, inulin, gums and mucilages. The insoluble fraction of dietary fibre consist mainly of cellulose, insoluble hemicelluloses, lignin, resistant starch, waxes, cutin and suberin.

Dietary fibre is unevenly located in the individual anatomical parts of the kernel. Its content, as well as the number and proportions of its individual factions change depending on the type of grain. In addition, a large range of variation between varieties can be observed within the same species. The content of dietary fibre and its individual fractions in 187 varieties and breeding lines of different cereals were described by Boros and Fraś (2015). According to literature data, the highest amounts of fibre among all cereal species include oats and rye, while its content in triticale grain is in the range between 11.9% and 14.3%.

Analysis of the variability in the chemical composition between grain, flour and bread obtained from selected triticale varieties and determination of their breadmaking suitability

Triticale grain is only to a small extent used in human nutrition (Mergoum et al., 2009). In order to increase the use of triticale for food purposes, it is important to emphasise varieties with high health benefits and indicate their pro-healthy properties. It is also important to learn about the breadmaking suitability of varieties recommended for cultivation in Poland, as well as the intensification of breeding works aimed at introducing to the grain market varieties with clearly improved indicators of the technological value of the grain. Considering the national potential of triticale production, a lot of researches on baking properties of this cereal were made by Polish scientists. In the end of 80' Haber and Lewczuk (1988) made researches on baking bread and cookies from triticale variety Lasko. In later years, similar studies were conducted in other countries with using various methods of baking (Tohver et al., 2005; Pattison A., 2013, Pattison and Trethowan, 2013). There is little data in the literature on the comprehensive analysis of the chemical composition of triticale grain, flour and obtained bread in terms of nutritional value. Also the variability of individual components between triticale varieties as well as in subsequent stages of grain processing has not been studied.

The aim of publication 2 was to determine the differences in the content of nutrient and bioactive components in selected triticale varieties and to indicate the variability of these components between grain, flour and bread. The material for the study was eight Polish winter triticale varieties (Alekto, Atletico, Elpaso, Fredro, Pantheon, Pizarro, Preludio, Subito, Trapero) and one winter wheat variety (Tonacja) as a reference sample. The research was carried out in three stages, in grain, flour and bread.

The significant variability in terms of all analysed grain components was found between tested varieties. In the case of nutrients, low values of coefficients of variation (CV) were obtained, ranging from 3.0% for starch to 8.0% for protein. Trapero variety was the highest source of protein and lipids, among analysed triticale varieties and obtained values were 15.2% and 2.4%, respectively. The content of individual nutrients in analysed triticale varieties was consistent with the results described by other authors, although some of the varieties involved in their studies were cultivated over 25 years ago (Heger and Egum, 1991; Rakha et al., 2011; Dennett and Threthovan, 2013). Compared to the control wheat variety, all triticale samples except Alekto variety were significantly higher in minerals, while the content of protein, starch and lipids in wheat grain was within the ranges obtained for triticale. With regard to dietary fibre (DF), which was determined as the sum of non-starch polysaccharides (NSP) and lignin, it was showed that 80% of fibre is composed of the NSP, of which 85% is insoluble fraction (I-NSP) and 15% soluble fraction (S-NSP). The average content of these fractions in analysed triticale varieties was 10.2%, 8.4% and 1.9%, respectively. The NSP content in analysed varieties ranged from 9.5% for Elpaso variety to 11.2% for Atletico variety. The higher variability was observed for the content of bioactive components than for nutrients, and obtained coefficients of variation ranged from 7.0%

for NSP to 20.0% for S-NSP. The highest DF content (13.6%) was observed in Atletico and Fredro varieties, whereas the lowest (11.7%) in Preludio variety. Triticale grain contained similar DF content in comparison to the control wheat variety, but for the most of analysed varieties, the proportion of S-NSP fractions was higher, which resulted also in higher values of viscosity of water extracts (WEV). Only Fredro, Preludio and Trapero varieties did not differ significantly in this parameter in comparison to wheat. The highest value of WEV was observed for Subito variety (2.0 mPa.s). The higher content of soluble fraction is a feature that triticale inherited from rye. The main component of this fraction are soluble arabinoxylans responsible for the viscous properties of the grain.

The largest changes in the chemical composition of triticale were observed after milling grain into flour. As a result of grain milling, the average protein content in flour was about 2% lower in comparison to grain, and the values ranged from 9.8% for flour from Subito variety to 13.9% for flour from the Trapero variety. The ash content, that is important factor in flour quality, decreased by as much as 58.0%, whereas the starch content increased by 10.0%. Regarding the fact, that lipids are located mainly in the germ, which is mostly removed in milling process, their content in triticale flour decreased by almost 64.0%, and the extreme contents were observed for flours obtained from Fredro (1.2%) and Elpaso (1.6%) varieties. The same dependencies were also found for wheat flour. The flour obtained from the majority of triticale varieties was significantly higher in protein content in comparison to wheat flour. Only flour obtained from Alekto, Elpaso and Fredro varieties did not significantly differ under this ingredient. The content of mineral compounds in triticale flours was also significantly higher in comparison to wheat flour. The milling process significantly reduced the content of all bioactive components. The average dietary fibre content decreased from 12.6% to 4.6% and obtained values were in the range between 3.9% for Preludio variety and 5.4% for Pizarro. Considering the dietary fibre components, the largest difference in comparison to grain was observed in the case of I-NSP fraction with average content 2.4%. The variability of individual flour parameters among triticale varieties was in the range between 4.0% in the case of starch up to 20.0% for WEV. The analysed parameters of triticale flour were consistent with results obtained by other researchers (Fenglert and Marquart, 1988; Seguchi et al., 1999; Yaseen et al., 2007; Pattison and Trethovan, 2013).

The third stage of the research was to carry out laboratory baking and analysis of the chemical composition of obtained breads. The significant differences between flour and bread were shown for all analysed parameters, except protein. The amount of this component in breads ranged from 9.5% for Preludio and Subito varieties to 12.9% for Pizarro variety. It is worth to emphasize that despite the highest protein content in grain (15.2%) and flour (13.9%), it was impossible to bake bread from Trapero variety, which suggests that this parameter does not indicate the technological value of triticale. The addition of salt in the amount of 1.5% to triticale dough caused an increase in the ash content in breads. The 14.0% decrease in the starch content in breads was also observed, in the range between 61.0% for Elpaso variety and 69.9% for Preludio, that is connected with starch retrogradation in the high temperature (220^{o}C) and its

transformation into resistant starch and as a consequence increasing the content of DF insoluble fraction. Moreover, some starch decays during yeast fermentation, resulting in higher content of dietary fibre soluble fraction. The average DF content in breads was 5.4%, whereas in flour samples it was 4.6%. The highest value was observed in case of bread from Atletico variety, although there were no significant differences in dietary fibre content between all triticale breads, while the average WEV value was at a similar level (1.6 mPa.s). There were no significant differences in the content of dietary fibre compared to the control wheat variety, while significant differences were found for the content of lignin and WEV. Wheat bread was characterized by a higher content of lignin in comparison to triticale breads and a lower viscosity of water extracts, with the exception of breads from Elpaso and Preludio varieties.

To evaluate the triticale varieties in terms of their breadmaking suitability, it was necessary to analyse selected technological parameters of triticale flour and to measure the bread volume. The parameters obtained for all triticale varieties were significantly lower as compared to the control wheat variety. There were no significant relationship found between chemical composition, in particular with regard to the protein content and technological parameters as is usually in the case of wheat. The results have shown that triticale is a crop that requires the development of new, different than in the case of wheat standards in assessing the breadmaking suitability, and each variety should be treated individually. The triticale varieties were characterized by a wide variability among technological parameters. The highest variability was shown in case of falling number between 62 s for Atletico to 231 s for Elpaso variety and water absorption from 54.4% for Preludio to 65.3% for Elpaso variety. However, the obtained results did not correspond in any way to the bread volume. The volume of triticale breads was in the range between 313 cm^3 (Pizarro) and 438 cm^3 (Fredro), while for wheat bread it was 473 cm^3.

The main element of the achievement was the detailed characteristics of domestic triticale varieties in terms of chemical composition and to show that triticale varieties with a favourable chemical composition may be a good raw material for flour and bread production. It was also shown that it is possible to bake good quality bread from triticale flour, despite the lack of established technological standards. Varieties with an increased baking value were selected. Furthermore, it was shown that the triticale varieties were characterized by high variability of the content of individual components and the relationship in chemical composition between grain, flour and bread were similar for all analysed samples. There were no significant relationships between the chemical composition and technological parameters of triticale usually found in wheat.

Obtained results may provide valuable information for Polish breeders during the development of breeding works on triticale in the direction of using its grain for bread production.

The results obtained in this publication allowed for the selection of four triticale varieties (Alekto, Fredro, Panteon, Preludio), the best in terms of chemical composition and baking suitability, which were used in the further stages of my research.

Determination of the influence of genotype, environment and genotype-environmental interaction on the chemical composition of selected triticale varieties

The choice of use direction of cereals, depends to a large extent on the broadly understood utility and quality parameters of grain. They include both agronomic traits and chemical composition of grain, which is a very important element when using cereals for food purposes. Triticale grain is not very popular in this respect. Its use for the bread production is primarily limited by high amylose activity, connected with susceptibility to sprouting and changing environmental conditions (Dennet et al., 2013, Zhu 2018). Besides the characteristics of grain chemical composition and its nutritional and pro-healthy value, it is very important to gain knowledge about the impact of environmental conditions on individual grain components and parameters. In the literature, there are few reports on this topic and the majority of conducted research concerned typically agronomic traits, omitting the chemical composition (Oleksiak and Mańkowski 2006, Bujak et al., 2012, Kociuba et al., 2012).

The aim of publication 3 was to determine the effect of genotype, environment and G×E interaction on the content of selected chemical components of triticale grain and detailed characteristics of G×E interaction for selected parameters.

The research material consisted of four winter triticale varieties (Alekto, Fredro, Panteon, Preludio), selected on the basis of the research results obtained in **publication 2**. These varieties were characterized by the most favourable chemical composition and breadmaking suitability and were consistently used at all stages of my research. Changing weather conditions in subsequent growing seasons were adopted as the environment. The experiment included four triticale varieties cultivated in one location for three subsequent growing seasons 2013/2014, 2014/2015, 2015/2016, which were characterized in terms of temperatures and precipitation. The material was evaluated in a number of chemical components (protein, starch, minerals, lipids, dietary fibre) as well as viscosity of water extracts (WEV) and falling number (FN), parameters that are directly related to grain quality.

Based on the obtained results the significant differences were observed in the content of nutrients between the tested varieties and vegetation seasons. Protein and starch consist the key qualitative parameters of triticale grain. It was shown that the content of protein was most dependent on the variety (48.0%), then from the growing season (39.8%) and the last from the G×E interaction (11.4%). Differing dependences were obtained for the starch content, which was mainly dependent on the G×E interaction (49.5%), followed by the variety (33.0%) and the environment (10.4%). The significant influence of atmospheric conditions on the content of these parameters was confirmed by the differences between growing seasons. Varieties grown in the 2015/2016 season, abundant in rainfall, were characterized by the lowest content of these components, in the amount of 10.6% of protein and 62.0% of starch. On average, the highest protein content was found for Panteon variety (14.1%), and the lowest for Alekto (10.9%) and Preludio (11.2%) varieties. For the growing season 2015/2016 and Fredro and Preludio varieties, interactive effects close to 0 were found, which confirms their stability in terms of protein content. In the case of starch content, the highest amount of this ingredient was observed for Preludio variety

(65.1%), and the smallest for Panteon (62.2%) and Fredro (61.5%) varieties. In addition, it was shown that Fredro variety is stable in terms of starch content.

The minerals and lipids content were mainly dependent on the growing season, 44.0% and 48.6%, respectively. In the case of minerals, the participation of G×E (39.0%) was shown in the second place, followed by cultivars (14.1%), whereas for lipids an inverse relationship was obtained, 10% for G×E interaction and 39.4% for a variety. Both components differed significantly between the analysed triticale varieties, and also between subsequent growing seasons. Among all analysed varieties, Panteon variety grown in the 2013/2014 season characterised by the highest content of mineral compounds (2.0%), while Alekto and Fredro varieties from the 2014/2015 season were distinguished by the highest amount of lipids (2.5%). The obtained content of nutrients as well as the different weather effects on their content corresponded with the results described by other authors (Erekul and Kohn 2006; Kowieska et al., 2011; Rakha et al., 2011; Dennet and Trethovan 2013; et al., 2018; Dekić et al., 2018).

Significant differences between the individual growing seasons and between varieties were also shown for the content of dietary fibre (DF) and its individual components. It was found that the content of DF, including non-starch polysaccharides (NSP) and I-NSP fraction was mainly dependent on environmental conditions, and their share in the overall variation was 51.4% (DF), 69.7% (NSP) and 82.1% (I-NSP), respectively. The share of the genotype in the formation of these components was 40.5% for DF, 24.8% for NSP and 12.7% for the I-NSP fraction, while the share of G×E interaction was the smallest, and values ranged between 3,0% for I-NSP and 4.3% for DF. The lignin content was dependent in 71.8% on the cultivar, then in 20.8% on the G×E interaction and only in 5.4% on the growing season. In the case of soluble NSP fraction (S-NSP), which is significantly related to the functional properties of the grain, the greatest influence of the variety in the overall variation of this parameter (76.4%) was observed, followed by the growing season (12.1%) and G×E interaction (9.8%). The highest content of dietary fibre (12.8%) was characterized by Fredro variety, for which the highest NSP (10.3%) was also found, including S-NSP (2.6%) and lignin (2.5 %). The lowest content of fibre (10.7%) and it's all components (NSP - 8.9%, I-NSP - 7.3%, S-NSP - 1.6%, lignin - 1.8%) was observed in Preludio variety. The results obtained for S-NSP content corresponded to the viscosity of water extracts (WEV), related to the soluble fraction of fibre, which in triticale grain are mainly soluble arabinoxylans. It was shown that WEV was mainly dependent on the growing season (49.3%) and the variety (42.3%), while the share of G×E interaction was 7.0%. The smallest value of this parameter, as in the case of S-NSP, was observed for Preludio variety (1.3 mPa.s), and the largest (1.7 mPa.s) for Alekto and Panteon varieties. Among vegetation seasons, the highest values for both features were obtained for the season 2014/2015, respectively 2.2% and 1.8 mPa.s. Similar research on the environmental impact on the content of DF and its components as well as WEV of triticale grain was conducted by other researchers (Rakha et al., 2011, Levy Haner et al., 2013), who also showed significant differences in these parameters.

The last analysed parameter was the falling number (FN), which allows to obtain information on the amylose activity of grain, very important from a technological point of view. It was shown that this parameter was mainly dependent on environmental conditions

(83.2%) among all studied features. The share of G×E interaction in the overall variability of FN was 13.5%, and the genotype only 2.3%. Triticale varieties differed significantly in terms of FN, ranging from 205 s for Alekto variety to 231 s for Panteon variety. There were also significant differences observed between successive growing seasons in the range from 129 s for 2013/2014 season to 284 s for 2015/2016 season, and obtained values were adequate to the weather conditions prevailing in particular years. Different values of FN in triticale grain and a significant effect of environmental conditions on them have been observed and described by other authors (Tohver, 2005, Erekul and Kohn, 2006).

An important element of the achievement was to indicate which components of triticale grain and to what extent depend on the individual variables, which gives the opportunity to use the analysed varieties in the most appropriate direction. The highest impact of genotype was noted for the content of S-NSP, protein and lignin, while the content of starch and minerals was the most dependent on environment. The highest impact of growing season was found for the falling number and viscosity of water extracts and the content of lipids, dietary fibre, NSP and I-NSP fraction. The conducted research also allowed to evaluate the stability of the analysed varieties in terms of the content of individual components in growing seasons. It was shown that Fredro and Preludio varieties were stable in terms of protein content, and Fredro variety also in terms of starch content.

Obtained results in connection with the results described in publication 2 provide a comprehensive description of analysed triticale varieties. Such knowledge, combined with the recommendation of these varieties for baking purposes, may be useful to triticale breeders and farmers when choosing preferred growing conditions. The results described in the study should be the basis for conducting work on a wider scale in this field, including a larger number of triticale varieties.

Searching for the oat product with the highest pro-healthy value for supplementation of triticale bread

Oat is a cereal with a wide range of uses, as a raw material for food production, valuable fodder, in the pharmaceutical and cosmetic industries as well as for energy purposes. It is also a very valuable species in agronomic terms, because it has phytosanitary properties and due to low susceptibility to fungal diseases and weed infestation is a very good forecrop for other cereals. However oat is still an underestimated species because its cultivation from an economic point of view is less profitable in comparison to other cereal species. Oat (*Avena sativa* L.), which is a rich source of pro-healthy components occupies an important place among raw materials with functional properties used for food production. This cereal contains proteins with the highest biological value, which is characterized by high content of globulins fraction (70-80%), the most valuable in terms of nutritional value and low content of prolamins and glutelines (20-25%) (Kawka, 2010). In comparison to other cereals oat grain also contains lower by about 10% starch content (55%), and is the richest source of lipids (4-10%) (Hoover et al., 2003; Berski et al., 2011). Essential fatty acids (EFAs) play an important role among the oat lipids and are involved in biochemical transformations and regulation of physiological functions.

Oats is an important source of dietary fibre and contains from 12.2% in hulled grain to 38.4% in husked grain (Boros and Fraś, 2015). The main part of oat fibre is its soluble fraction, responsible for functional properties, and its main component is β-glucan, that has been described in the **publication 1**. The β-glucan content in oat grain is in the range between 2.2% and 6.6% (Genc et al., 2001; Gajdasowa et al., 2007). Other components that affect the unique character of oat grain include antioxidant compounds such as vitamin E and polyphenolic compounds: phenolic acids, flavonoids or aventhramides and B vitamins (Peterson, 2001, Bratt et al., 2003).

Considering the nutritional and health benefits properties of oats I decided to enrich the bread obtained from selected triticale varieties, described in **publication 2** with oat products, to improve its pro-healthy value.

The aim of publication 4 was to evaluate the content of nutritional and bioactive components in selected oat products available on the market. Analysed products were compared to each other and also to oat grains to indicate the most valuable among them.

The research material were 6 oat products: concentrated oat fibre (COF), oat bran with high fibre content (HFOB), regular oat bran (ROB), quick rolled oats (QRO), regular rolled oats (RRO) and oat flour (OFL). Additionally, one more flour sample was tested (ROFL), which is a by-product in the production of concentrated oat fibre (COF). Because the raw material for food production is dehulled oat grain, two reference varieties, Bingo and Krezus, were included for comparison purposes.

Presented research confirmed that oats and oat products are a rich source of nutrients and bioactive components. The oat fibre concentrate characterized by the most favourable chemical composition. This product contained the highest content of protein (22.9%), minerals (4.4%), lipids (10.2%) and the lowest content of starch (26.5%). COF was also the richest source of dietary fibre (27.7%), with a soluble fraction of 15.9%, of which as much as 15% was β-glucan. The amount of fibre in this product exceeded its content almost 3 times in the remaining samples. Additionally, COF was the richest source of polyphenols (1.8 mg eq. of gallic acid/g). It is worth to emphasize that according to the manufacturer (Microstructure Ltd.) COF production is based on physical methods, without the use of any chemicals, and the raw material comprised of selected oat varieties. Moreover, the manufacturer declares that this product contains a reduced amount of lipids and carbohydrates.

The second product, most valuable in terms of nutritional and health-promoting value was high fibre oat bran (HFOB), which following COF was the richest source of protein (17.3%), minerals (2.4%) and dietary fibre (11.8%) with 5.3% of β-glucan. With the exception of the residual oat flour (ROFL), the rest of oat products were characterized by a comparable content of individual components. The content of DF was in the range between 9.0% for regular rolled oats and 9.5% for regular oat bran, and β-glucan content was from 4.1% to 4.6%. Different properties were observed for residual oat flour (ROFL), that was a by-product and the process of COF production has an impact on its chemical composition. ROFL characterised by high starch (63.8%) and lipids (7.4%) content and simultaneously the lowest content of protein (13.9%), minerals (1.6%), total dietary fibre (6.1%) and β-glucan (2.3%). Many other researchers have analysed oat products, but

usually involved one type of product. The values obtained in this publication were consistent with the results presented in the literature (Marlett, 1993; Luhallo et al., 1998, Huttner et al., 2010, Beccerica et al., 2011, Choi et al., 2012; Hu et al. 2014). The coefficients of variation for individual components were high and ranged from 7.7% for lignin to 40.0% for minerals. High variability is probably related to the different technology of production for each product and the quality of raw materials used. In the case of evaluation of reference oat varieties, it was shown that the content of protein, minerals and starch in grain was comparable to all products, with the exception of COF and for the protein also HFOB. Additionally, oat grain, as an unprocessed product, was a rich source of lipids, dietary fibre and polyphenols.

An important element of the achievement is demonstration of a large variation in the content of nutrients and bioactive components in oat products available on the market and indication of the product with the largest amount of these ingredients, which can be used to enrichment of triticale bread. It was also shown that all analysed products are characterized by pro-healthy properties and are a rich source of dietary fibre. Synthetic summary of the quality of many popular oat products can be a compendium of knowledge for producers of this cereal, as well as consumers of healthy food. There are very few publications in the literature focused on the broad characteristics of a large number of products in one article. Considering the poor nutrition habits and growing number of diet-related diseases in the society, all described oat products should be widely recommended for daily consumption. The increase in oats consumption may contribute to increasing the interest in cultivating this valuable species in every respect in the perspective of the coming years.

The results of the research described in this publication allowed me to choose the concentrated oat fibre as the best oat product, which was used to supplementation of triticale bread in the next stage of research.

Development of a recipe for triticale-oat bread with an increased pro-healthy value

In recent years, non-bread cereals due to their favourable chemical composition are increasingly used in the production of high-quality food.

Supplementation of flour with ingredients with functional properties, including dietary fibre is often used for increasing the health-promoting value of bread. According to some literature data, the addition of more fibre to wheat flour has a negative impact on rheological properties of the dough and bread parameters (Sabanis et al., 2009, Rosell et al., 2010, Rubel et al., 2015). However, the works of Polish authors indicate, that when the source of fibre was oat flour, the addition of 15% did not cause a decrease in the quality of wheat bread (Gambuś et al., 2006, Wójcik et al., 2017). This type of research using triticale flour has not been conducted so far. The triticale was used only for wheat flour supplementation, and the work carried out focused mainly on the choice of baking method and obtained bread parameters (Pena and Amaya, 1992; Naeem et al., 2002; Ceglińska et al., 2003; Tohver et al., 2005). There were also no studies on the health-promoting properties of triticale, from a nutritional point of view.

The reason for choosing the high-fibre oat component for triticale supplementation was its chemical composition of oat, especially with regard to dietary fibre. Oat fibre is a rich

source of β-glucan, whereas in triticale dietary fibre consist mainly of arabinoxylans. The combination of these two species ensures to obtain bread with a specific chemical composition and high healthy value.

The aim of publication 5 was to develop a recipe for triticale-oat bread with pro-healthy properties, by replacement as much as possible of triticale flour by high fibre oat concentrate, without decreasing the technological quality of bread.

The material comprised four Polish winter triticale varieties (Alekto, Fredro, Panteon, Preludio), which were chosen based on the results described in **publications 2 and 3**. Triticale flour was supplemented with oat fibre concentrate (COF), characterized in **publication 4** in the amount of 2.5%, 5% and 10%. Triticale-oat breads were baked from the prepared mixtures. Additionally, for comparison purposes two popular commercial breads, purchased at the bakery were included: wheat bread (CB1) and wheat-rye bread (CB2).

As a result of the research, it was shown that the nutrients content in bread changed in proportion to the amount of COF added. Because oat fibre concentrate was a rich source of protein, the increase by 2 percentage points in content of this ingredient between control bread and supplemented with 10% COF was observed for all triticale breads. The richest sources of protein were breads obtained from Panteon variety, in the range from 13.9% for control bread to 15.9% for bread with 10% of COF. The lowest protein content (from 7.8% to 10%) was observed for breads obtained from Alekto variety. On the basis of amino acids analysis in the breads supplemented with 5% COF, the significant increase in the content of exogenous amino acids after supplementation was observed, including lysine, which is the first amino acid limiting nutritional value of protein in cereals. These results showed that triticale-oat breads are source of protein of high biological value. A slight increase in minerals content was observed in obtained bread, while the lipid content increased almost twice, and values ranged from 1.2% in control breads from Alekto and Fredro varieties to 2.6% for Preludio with 10% COF. Concentrated oat fibre as a poor source of starch caused a decrease in the content of this component by about 5% in bread. Considering the nutritional value, the breads obtained from Panteon and Fredro varieties characterized by the best quality among all samples. They were distinguished by the highest content of protein and lipids and the lowest amount of starch.

An important element of the research was the evaluation of changes in the content of bioactive components that occurred after the combination of triticale flour with COF. The addition of oat fibre concentrate caused a significant increase in the content of dietary fibre, from 6.9% for Preludio control bread to even 11.5% in the case of bread obtained from Panteon variety with 10% COF. Breads obtained from this variety were the richest source of fibre among all samples. It is also worth to indicate the changes in the content of individual fibre components, in which the basic component constitute non-starch polysaccharides (NSP). In triticale, over 80% of NSP is insoluble fraction (I-NSP), whereas in COF the dominant part of fibre is the soluble fraction. Therefore, the addition of oat concentrate to triticale flour caused a significant increase in the content of this fraction for all varieties, in the range between 1.4% for bread obtained from Preludio to 3.5% for bread obtained from Panteon with 10% COF. The main component of the soluble fraction in COF is β-glucan, in an amount of almost 15%. Therefore, as expected,

supplementation of triticale flour caused a several-fold increase in the content of this compound in the bread. The average β-glucan content in control bread was 0.3%, while in supplemented with 10% COF it was even 1.8% in case of Alekto, Fredro and Panteon varieties. As a result, triticale bread with a high β-glucan content was obtained. The consequence of increasing content of soluble fibre fraction after the COF addition was an almost two-fold increase in the viscosity of water extracts (WEV). This parameter is directly related to the content of soluble fraction, whose viscous properties are responsible for the feeling of satiety after a meal. The smallest value of WEV (from 1.5 mPa.s to 3.3 mPa.s) and simultaneously S-NSP (from 1.4% to 2.7%) were observed in breads obtained from Preludio variety, while the highest viscosity (from 2.7 mPa.s to 6.9 mPa.s) was found in breads from Alekto variety. Along with the addition of fibre concentrate, the majority of the obtained breads showed an increase in the polyphenols content (TPC) and antioxidant activity (ABTS), although these differences were not always statistically significant. The highest values for both parameters were obtained for Panteon variety and the lowest for Preludio variety. The obtained triticale-oat bread in comparison to popular commercial products was characterized by a comparable content of protein, minerals and starch, and smaller lipids than wheat bread (CB1). In contrast, wheat-rye bread (CB2) contained significantly more nutrients, whereas triticale-oat bread contained significantly more dietary fibre in comparison to breads bought in the store (CB1, CB2).

Analysis of selected technological parameters, closely related to the quality of the obtained products was a necessary element of my research, allowing for full characterization of the analysed triticale varieties. It is known from the literature, that the baking value of wheat flour depends on the amount and quality of protein. The triticale properties in this respect are unsatisfactory due to the low amount and poor gluten quality. Addition of COF to triticale flour caused the dilution of gluten proteins and thus the deterioration of rheological parameters of dough, bread texture and the loaves volume. It was shown that the increasing COF content in triticale flour did not significantly affect the value of falling number, whereas a significant increase in water absorption of flour was observed. This parameter was very diverse, and extreme values were observed for flours obtained from Preludio (from 50.9% to 57%) and Panteon (from 66.5% to 72.3%) varieties.

Because all triticale-oat breads were characterized by a high pro-healthy value, an important element of the research was the selection of the maximum COF concentration, allowing to obtain bread with acceptable technological parameters. The increase in COF concentration caused deterioration of the bread parameters. For all analysed varieties, breads with 2.5% and 5% addition of concentrate had comparable quality. The loaves were medium-baked with a light brown colour of the crust, while the crumb was characterized as light, flexible and non-sticky. Significantly worse parameters were obtained for bread supplemented with 10% COF. Obtained loaves were poorly baked, with a flat shape and a pale crust, and the crumb was defined as heavy, inflexible and sticky. Moreover, for most varieties these breads were characterized by the smallest volume. Similar dependencies associated with the reduction of technological parameters after wheat flour supplementation with preparations rich in dietary fibre have been described in the literature by other researchers (Chen et al., 1988, Czubaszek and Karolini-Skaradzińska, 2005, Rubel et al., 2015). Taking into account the poorest rheological parameters of the dough

and low quality of bread obtained with the addition of 10% COF, it was shown that 5% is the maximum possible addition of concentrate, allowing to obtain good quality bread .

As a result of the research, it was shown that enrichment of flour obtained from selected triticale varieties with the oat fibre concentrate allows to obtain bread with high content of nutrients and bioactive components.

The main achievement of this work was to show that the breads obtained from analysed triticale varieties and enriched with an oat product are a rich source of dietary fibre (contain more than 6 g per 100 g). Furthermore, all breads supplemented with 5% and 10% COF meet the conditions of the health claim regarding β-glucan.

The studies showed that supplementation of triticale flour with oat fibre concentrate in the amount of 5% allows to obtain a new type of bread characterized by optimal quality and very good bioactive value. The high healthy value and the original composition of the new product result primarily from the combination of oat β-glucan and triticale fibre.

The Panteon variety was distinguished in terms of chemical composition, as well as technological parameters among all analysed triticale samples. This variety was registered in 2015 by the Plant Breeding Strzelce Ltd. Co. and undoubtedly should be promoted for breadmaking purposes. The indication of the possibility of increasing the pro-healthy value of triticale may contribute to a further increase in utilization of triticale for baking purposes.

Investigation of preferences and expectations of consumers and bread producers in relation to new bakery products

Polish bread market is highly diverse in terms of the number of products and their quality, despite the steady decline in bread intake has been observed both in Poland and worldwide (Kendall et al., 2010; Pal et al., 2011). Moreover, technological progress, diverse consumer preferences and promotion of healthy lifestyle have resulted in a demand of higher-quality food products, including breads (Kopeć and Bać, 2013). Thus, understanding of consumer behaviour and preference should help bread manufacturers offers satisfy the needs of customers, particularly during launching new products (Jeżewska-Zychowicz, 2014).

The supplement of my achievement was publication 6, that was aimed at investigation preferences and expectations of Polish consumers concerning bread products as well as their comparison with manufacturers opinions. It analyses consumers attitudes to available types of breads and determines their demands for products that bring health benefits

Surveys were conducted in collaboration with BIOSTAT consortium (Rybnik, Poland). The data were collected using CATI (computer-assisted telephone interviewing) method. The study sample consisted of a representative group of 1080 Polish consumers (statistical error <3%), aged 17 to 65, across Poland who were selected via stratified sampling per demographic structure of voivodeships. An independent set of 24 questions, including 17 survey (study-related) items and 7 questions referring to the respondents particulars was used in the survey. On a parallel basis, a comparison survey among bread manufacturers was carried out in a group of 68 small and medium-sized bakeries across Poland that were

selected via stratified sampling: 4 to 5 bakeries per voivodeship. A set of 12 questions, corresponding to the questions addressed to bread consumers as well as relating to the bread production management in particular bakeries, was used in the survey. The responses were divided into five topic-related categories, including purchase and consumption of bread products, assortment, quality and prices of breads as well as the impact of diet on health.

The conducted surveys confirmed that bread is an important element of our daily diet, which was declared by 85% of consumers, and 13.1% declared consumption a few times weekly. Considering amounts of consumed bread products, 46.5% of respondents reported daily consumption of 4 to 8 slices of bread or 2 to 3 rolls. 16.7% of respondents declared consumption of more and 36.9% of less bread products. Both the frequency and amount of bread consumed were to such factors as: sex, age, pace of residence, education level, work place. Regarding available bread products, the respondents mainly chose bread (82.6%) and, to a lesser extent, rolls (14%), whereas among the types of breads available on the market, the most popular products were: wheat and rye/wheat bread, then products with cereal and other grains, wholemeal and rye bread. The survey conducted among the manufacturers showed that they try to satisfy consumers expectations by fitting production to demand. Wheat and rye/wheat breads are produced by 97%, wholemeal bread by 88%, products with cereal and other grains by 84% and rye bread by 75% of responding bakeries.

Based on the research described in this publication, it was shown that among consumers, the 83.2% were satisfied with the available bread assortment. Considering new brands on the market, as many as 61.9% of respondents tried new, unusual brands of bread. The survey showed that new products are more readily purchased by educated individuals, women and respondents who declare higher income. Unfortunately, very often products with a better composition are still more expensive than others. Other authors have also confirmed this relationship in their publications (Niewczas, 2013). Moreover, concluded in their study that more attention was paid to the quality of foods (including bread products) in households with higher monthly incomes, so new or better-quality products could be found more frequently there.

Consumers are increasingly paying attention to the composition of purchased products. In the survey, approximately 59% of consumers reported selecting bread in an aware manner by reading labels. Selection of bread products was mainly driven by taste and flavour, then by their composition and addition contents, appearance, nutritional value, price and manufacturer. Such dependencies have been confirmed by results of other studies in other countries (Kacen and Lee, 2002; Inman et al., 2009). Based on the results of surveys collected among the bakeries, it was reported that the consumers choice of bread was mainly driven by the price (64.7%), then flavour and taste (52.9%), appearance (32.4%), composition and addition contents (23.5%) as well as health benefit (20.6%). Among preferred bread additions listed by the respondents, sunflower seeds were mentioned in the first place, then pumpkin seeds, cereal grains and addition-free bread products. Comparable results were reported among the responding manufacturers, what is a confirmation that the assortment produced was tailored to the consumer's expectations. An important element of the research were questions related to the role of bread in the diet. A vast majority of consumers (more than 62%) agreed with the opinion on bread being the basic component of diet, whereas the perception of bread as a product valuable for human health was supported by over 72%. Bakers views on the essential role of bread in the diet

were comparable to those of consumers, however, the perception of bread as a product valuable for human health was more pronounced, because 89.7% of bakers agreed. More than 11% of respondents reported diet-related health problems. There was a strong link between these diseases and age or education level of the consumers. The most common diet-related diseases reported by the respondents were: obesity, arterial hypertension and diabetes.

The results on consumer preferences obtained in this publication are consistent with the assumptions of my achievement. Based on the conducted surveys, it was shown that diverse bread demands of Polish consumers result in a wide range of bread products on the market and a continuing need for their higher quality and promotion of new brands. Although the most popular types are wheat and rye/wheat breads, yet Polish consumers do not avoid other or types of bread and novelties. Moreover, consumers are willing to pay more for bread of higher quality and health benefits and Polish bakers successively try to meet consumers expectations.

Apart from determining consumer preferences, the conducted surveys also refer to a significant social problem which is the growing number of diet-related diseases in recent years. To a large extent, they result from poor eating habits and low-quality food. Raising consumer awareness about the benefits of eating healthy, low-processed foods, including bread, is an important element in the prevention of these diseases.

SUMMARY

The favourable chemical composition of triticale, high production potential and the growing demand for high quality food products indicate the need to utilization this cereal for food production on a larger scale. For this purpose, it is necessary to perform a full characterization of currently available triticale varieties and to indicate these with the most favourable properties and useful for breadmaking. It is also important to observe stability of individual varieties in changing environmental conditions. Enrichment of triticale flour with high-fibre oat product increases the attractiveness of the obtained bread from the nutritional point of view. The presented publications are one of the few original scientific papers so widely describing the chemical characteristics of selected triticale varieties and oat components. In addition, studies on supplementation of triticale flour with oat fibre concentrate and evaluation of the pro-healthy value of bread have not been conducted so far. It should be emphasized that triticale-oat bread, which is a key element of achievement, was created for the first time on a national scale, and probably also in the world. My research introduce a number of interesting information that allowed me to draw some conclusions, important for science, breeding, agricultural practice, industry, as well as a bread consumers. The most important statements summarizing the presented achievement include:

1. Polish triticale varieties are a rich source of nutrients and bioactive components, and the information on the impact of genotype, growing season and G×E interaction on chemical composition is of key importance during selection for consumer purposes.

2. Obtaining the triticale bread with good quality requires choosing the proper variety and individual approach to baking technology that takes into account the properties of a given variety.

3. The Panteon variety was characterized by the most favourable chemical composition and simultaneously high baking performance among analysed triticale varieties.
4. The enrichment of triticale flour with oat fibre concentrate results in an increase in the content of nutrients and bioactive components in bread.
5. The unique chemical composition and high pro-healthy value of triticale-oat bread results from the combination of oat β-glucan and triticale fibre.
6. All triticale-oat breads were a rich source of fibre, and breads containing 5% and 10% of oat fibre concentrate meet the conditions of the health claim regarding β-glucan.
7. In the society there is a need to introduce new types of bread with pro-healthy properties and there is a prospect of implementation the triticale-oat bread developed as a part of my achievement on the Polish market.

The presented achievement had also application aspect, related to the implementation of works in the Lider project. The commercial baking by two small bakeries was carried out for Panteon and Preludio varieties supplemented with 5% of COF. The flour was prepared in an industrial mill in Bochnia, and in the bakery, mold breads weighing 500 g were obtained. The chemical composition in obtained bread was comparable to the results obtained in the laboratory. In addition, a sensory evaluation was carried out by a 14-person team, during which it was shown that both types of triticale-oat bread were evaluated more favourably in terms of the examined traits, in comparison to the wheat-rye bread being a reference sample. An overall score of bread was also carried out, and the best result was obtained for Preludio bread with 5% fibre concentrate. The high healthy value and unusual nature of obtained bread caused interest in the new product, both on bakeries and companies related to the cultivation of cereals.

I will continue research in the field of triticale. In cooperation with the Section of Fundamental Technical Sciences in the Department of Fundamental Engineering at the Faculty of Production Engineering of University of Life Sciences in Warsaw I carried out preliminary research for the project, which will investigate different varieties of triticale in terms of physicochemical properties at different stages of mechanical and thermal processing, and a description of the interdependencies occurring within the analysed features. Research will be conducted on a selected group of Polish triticale varieties and will allow for even more complete characterization of this species and for the search for features and dependencies that allow its use for baking purposes. I will apply for the financing of the above project to NCN or NCBIR.

LITERATURE

1. Beccerica S., Torre M. A., Sanchez H. D., Osella A. C. 2011. Use of oat bran in bread: fiber and oil enrichment and technological performance. Food Nutrition Sciences, 2, 553-559.
2. Berski, W., Ptaszek, A., Ptaszek, P., Ziobro, R., Kowalski, G., Grzesik, M., Achremowicz, B. 2011. Pasting and rheological properties of oat starch and its derivatives. Carbohydrate Polymers, 83, 665-671.

3. Boros D., Fraś A., Gołębiewska K., Gołębiewski D., Paczkowska O., Wiśniewska M. 2015. Nutritional value and prohealthy properties of cereal and rapeseed varieties approved for cultivation in Poland. PBAI-NRI Monographs and Dissertations, 49, 1-119.
4. Bratt K., Sunnerheim K., Bryngelsson S., Fagerlund A., Engman L., 2003. Aventhramides in oats (Avena sativa L.) and structure-antioxidant activity relationships. Journal of Agricultural and Food Chemistry, 51, 594-600.
5. Bujak H., Tratwal A., Walczak F. 2012. The reaction of winter triticale varieties, grown using two levels of cultivation intensity to Wielkopolska environmental conditions. Bulletin PBAI-NRI, 264, 141-155.
6. Ceglińska A., Cichy H., Haber T., Sadecka M. 2003. Evaluation of breadmaking quality of some spring triticales. Bulletin PBAI-NRI, 230: 177-185.
7. Ceglińska A., Samborski S., Rozbicki J., Cacak-Pietrzak G., Haber T. 2005. Estimation of milling and baking value for grain of winter triticale varieties depending on nitrogen fertilization. Pamiętnik Puławski, 139, 39-46.
8. Chen H., Rubenthaler G.L., Leung H.K., Baranowski J.D. 1988. Chemical, physical and baking properties of apple fiber compared with wheat and oat bran. Cereal Chemistry, *65*, 244-247.
9. Choi I., Han O., Chun J., Kang Ch., Kim K., Kim Y., Cheong Y., Park T., Choi J., Kim K., 2012. Hydration and pasting properties of oat (*Avena sativa*) flour. Preventive Nutrition and Food Sciences, 17, 87-91.
10. COBORU. 2018. www.coboru.pl
11. Czubaszek A., Karolini-Skaradzińska Z. 2005. Effects of wheat flour supplementation with oat products on dough and bread quality. Polish Journal of Food and Nutrition Sciences, *14/55,* 281-286.
12. Dekić V., Milivojević J., Branković S. 2018. The interaction of genotype and environment on yield and quality components in triticale. Biologica Nyssana, 9, 45-53.
13. Dennett A.L., Trethovan R.M. 2013. Milling efficiency of triticale grain for commercial flour production. Journal of Cereal Science, 75, 527-530.
14. Dennet A.L., Wilkes M.A., Trethovan R.M. 2013. Characteristics of modern triticale quality: The relationship between carbohydrate properties, α-amylase activity, and falling number. Cereal Chemistry, 90, 594-600.
15. Erekul O., Kohn W. 2006. Effect of weather and soil conditions on yield components and bread-making quality of winter wheat (Triticum aestivum L.) and winter triticale (Triticosecale Wittm.) varieties in North-East Germany. Journal of Agronomy&Crop Science, 192, 452-464.
16. Eurostat. 2018. www.ec.europa.eu/eurostat/data/database
17. Fenglert A.M., Marquardt R.R. 1988. Water-soluble pentosans from rye. II. Effects on rate of dialysis and on retention of nutrients by the chick. Cereal Chemistry, 65, 298-302.
18. Gajdosova A., Petrulakova Z., Havrlentova M., Cervena V., Hozova B., Sturdik E., Kogan G. 2007. The content of water – soluble and water – insoluble β-D-glucans in selected oats and barley varieties. Carbohydrate Polymers, 70, 46-52.
19. Gambuś H., Gambuś F., Pisulewska E. 2006. Oats wholemeal as a source of dietary elements in wheat bread. Bulletin PBAI-NRI, 239, 259-267.
20. Gambuś H., Gibiński M., Pastuszka D., Mickowska D., Ziobro R., Witkowicz R. 2011. The application of residual oats flour in bread production in order to improve its quality and biological value of protein. Acta Scientorum Polonorum, Technologia Alimentaria, 10, 313-325.
21. Genc H., Ozdemir M., Demirbas A. 2001. Analysis of mixed-linkage (1-3), (1-4)-β-D-glucans in cereal from Turkey, Food Chemistry, 73, 221-224.
22. Heger J., Eggum B.O. 1991. The nutritional values of some high-yielding cultivars of triticale. Journal of Cereal Science, 14, 63-71.
23. Hoover R., Smith C., Zhou Y., Ratnayake R.M.W.S. 2003. Physicochemical properties of Canadian oat starches. Carbohydrate Polymers, 52, 253-261.

24. Hu X., Zheng J., Li X., Xu C., Zhao Q. 2014. Chemical composition and sensory characteristics of oat flakes: a comparative study of naked oat flakes from China and hulled flakes from western countries. Journal of Cereal Science, 60, 297-301.
25. Hüttner E. K., Dal Bello F., Arnedt E. K., 2010. Rheological properties and bread making performance of commercial wholegrain oat flours. Journal of Cereal Science, 52, 65-71.
26. Inman J.J., Winter R.S., Ferraro R. 2009. The interplay among category characteristics, customer characteristics and customer activities on in-store decision making. Journal of Marketing, 73, 19-29.
27. Iwański R., Wianeczki M., Tokarczyk G., Stankowski S. 2009. The influence of conventional and ecological tillage system method of triticale bakery value of flour and quality of bread. Folia Pomer. Univ. Technol. Stetin., Agric. Aliment., Pisc. Zootech. 269 (9), 19-32.
28. Jeżewska-Zychowicz M. 2014. Determinants of consumer acceptance of innovative food products. Food. Science. Technology. Quality, 6, 5-17.
29. Jonnala R.S., Irmak S., MacRitchie F., Bean S.R. 2010. Phenolics in the bran waxy wheat and triticale lines. Journal of Cereal Science, 52, 509-515.
30. Jonnala R.S., MacRitchie F., Herald T.J., Lafiandra D., Margiotta B., Tilley M. 2010. Protein and quality characterization of triticale translocation lines in breadmaking. Cereal Chemistry 87(6): 546-552.
31. Kacen J.T., Lee J.A. 2002. The influence of culture on consumer impulsive buying Behavior. Journal of Consumer Psychology, 12, 163-176.
32. Kawka A. 2010. Present trends in bakery production – use of oats and barley as non-bread cereals. Food. Science. Technology. Quality, 3, 25-43.
33. Kendall C.W., Esfahani A., Jenkins D.D.J. 2010. The link between dietary fibre and human health. Food Hydrocolloids, 24, 42-48.
34. Kociuba W., Kramek A., Ukalski K. 2012. Stability estimation of selected yielding traits of Polish winter triticale varieties. Bulletin PBAI-NRI, 264, 127-140.
35. Kopeć A., Bać A. 2013. Effect of lupine flour addition on quality of triticale flour bread. Food. Science. Technology. Quality, 5, 142-153.
36. Kowieska A., Lubowicki R., Jaskowska I. 2011. Chemical composition and nutritional characteristics of several cereal grain. Acta Scientarum polonorum Zootechnica, 10, 37-50.
37. Levy Haner L., Stamp P., Kreuzer M., Bouguennec A., Pellet D. 2013. Viscosity of triticale varieties differs in its response to temperature after flowering. Fields Crops Research, 149, 347-353.
38. Luhaloo M., Mårtensson A-C., Andersson R., Åman P., 1998. Compositional analysis and viscosity measurements of commercial oat brans. Journal of the Science of Food and Agriculture 76, 142-148.
39. Marlett J. A. 1993 Comparisons of dietary fibre and selected nutrient compositions of oat and other grain fractions. *in*: Oat Bran, (ed. Wood P. J.) American Association of Cereal Chemists, St Paul, MN, USA, pp. 49-82.
40. Martinek P., Vinterova M., Buresova I., Vyhnanek T. 2008. Agronomic and quality characteristics of triticale (X Triticosecale Wittmack) with HMW glutenin subunits 5+10. Journal of Cereal Science, 47, 68-78.
41. McGoverin, C.M., Snyders, F., Muller, N., Botes, W., Fox, G., Manley, M., 2011. A review of triticale uses and the effect of growth environment on grain quality. Journal of the Science of Food and Agriculture, 91, 1155-1165.
42. Mergoum M., Singh P.K., Pena A.J., Lozano del Rio A.J., Cooper K.V., Salmon D.F., Gomez-Macpherson H. 2009. Triticale: A "New" Crop with Old Challenges. In M.J. Carena. Cereals. Handbook of plant breeding (pp.267-287). Springer.
43. Naeem H.J., Darvey N.L., Gras P.W., MacRitchie F. 2002. Mixing properties, baking potential, and functionality changes in storage proteins during dough development of triticale-wheat blends. Cereal Chemistry, 79, 332-339.
44. Niewczas M. 2013. Food choice criteria. Food.Science.Technology.Quality, 6, 204-219.

45. Oleksiak T., Mańkowski D.R. 2006. Stability analysis of winter triticale cultivars yielding in agriculture area od Poland. Folia Universitatis Agriculturae Stetinensis, 247, 133-140.
46. Pal S., Khossousi A., Binns C., Dhaliwal S., Ellis V. 2011. The effect of a fibre supplement compared to a healthy diet on body composition, lipids, glucose, insulin and other metabolic syndrome risk factors in overweight and obese individuals. British Journal of Nutrition, 105, 90-100.
47. Pattison A. 2013. Genetic improvement of grain quality for bread making in triticale. PhD Thesis, The University of Sydney, Australia.
48. Pattison A.L., Trethowan R.M. 2013. Characteristics of modern triticale quality: commercially significant flour traits and cookie quality. Crop & Pasture Science, 64, 874-880.
49. Pena R.J., Amaya A. 1992. Milling and baking properties of wheat-triticale grain blends. J. Sci. Food Agric., 60, 483-487.
50. Peterson D.M. 2001. Oats antioxidants. Journal of Cereal Science, 2, 115-129.
51. Rakha A., Aman P., Andersson R. 2011. Dietary fibre in triticale grain: Variation in content, composition, and molecular weight distribution of extractable components. Journal of Cereal Science, 54, 324-331.
52. Rakha A., Aman P., Andersson R. 2013. Rheological characterisation of aqueous extracts of triticale grains and its relation to dietary fibre characteristics. Journal of Cereal Science, 57, 230-236.
53. Rossel C., Santos E., Collar C. 2010. Physical characterisation of fiber-enriched bread doughs by dual mixing and temperature constraint using the Mixolab. European Food Research Technology, 231, 535-534.
54. Rubel I.A., Perea E.F., Manrique G.D., Genovese D.B. (2015). Fibre enrichment of wheat bread with Jerusalem artichoke inulin: Effect on dough rheology and bread quality. *Food Structure, 3,* 21-29.
55. Sabanis D., Lebesi D., Tzia C. 2009. Effect of dietary fibre enrichment on selected properties of gluten-free bread. LWT – Food Science Technology, 142, 1380-1389.
56. Seguchi M., Ishihara C., Yoshino Y., Nakatsuka K., Yoshihira T. 1999. Breadmaking properties of triticale flour and relationship to amylase activity. Journal of Food Science, 64, 582-586.
57. Tohver M., Kann A., That R., Mihhalevski A., Hakman J. 2005. Quality of triticale cultivars suitable for growing and bread-making in northern conditions. Food Chemistry, 89, 125-132.
58. Varughese G., Pfeiffer W.H., Pena R.J. 1996. Triticale: A successful alternative crop (Part 1). Cereal Foods World, 41, 6, 474-482.
59. Woś H., Banaszak Z., Mikulski W. 2008. Triticale yesterday, today and tomorrow. Wieś Jutra, 4, 31-33.
60. Wójcik M., Dziki D., Różyło R., Biernacka B., Łysiak G., Aridhee J. 2017. Changes of dough and wheat bread physical properties as a result of black oat flour addition. Acta Agrophysica, 24, 163-172.
61. Yaseen A.A., Shouk A.A., Selim M. 2007. Egyptian blady bread biscuit quality of wheat and triticale flour blends. Polish Journal of Food and Nutrition Sciences, 57, 25-30.
62. Zhu F. 2018. Triticale: Nutritional composition and food uses. Food Chemistry, 241, 468-479.

E. AN OVERVIEW OF OTHER SCIENTIFIC-RESEARCH ACHIEVEMENTS

1. LIST OF PUBLICATIONS ISSUED PRIOR AND AFTER RECEIVING DOCTOR DEGREE

	Before receiving doctor degree	*After receiving doctor degree*	*Sum*
Journals from list A	7	7	14
Journals from list B	0	9	9
Monographs	0	1	1
Conference materials	13	30	43
Oral presentation at conferences	2	8	10
Popular science publications	0	4	4

2. BIBLIOMETRIC INDICES

	Before receiving doctor degree	*After receiving doctor degree*	*Sum*
Ministry of Higher Education points	226	314	540
Impact Factor (IF)	18,442	12,377	30,819
Citations(WoS)		499	
Hirsch Index (WoS)		8	

3. SCIENTIFIC EXPERIENCE

My scientific activity started in 2001 as a student of Gdańsk University of Technology, Department of Edible Fats Technology and Lipid Biotechnology at the Faculty of Chemistry. Under the supervision of Maria Tynek PhD, I conducted research on the enzymatic transesterification of olive oil with behenic acid, which formed the basis of my master's thesis that I defended in 2002 with a very good result.

After defending my master thesis, I worked in the Edible Oils and Fat Refinery, Elstar Oils S.A. in Czernin. During three years of work, I had the opportunity to use the analytical skills acquired during my studies, related to controlling the quality of the raw material at every stage of the production process and creating new products. I also participated in the process of implementing ISO and HACCP quality control systems. A very important element of the work in the industry in the context of my future scientific work was the opportunity to work on modern specialized laboratory equipment. I conducted analyses using nuclear magnetic resonance (NMR), gas chromatography and atomic emission spectroscopy with inductively coupled plasma (ICP-OES).

Since 2006 I am an employee of the Independent Laboratory of Quality Evaluation of Plant Materials (SPOJPR) at the Plant Breeding and Acclimatization Institute - National Research Institute in Radzików.

In SPOJPR I was hired as the main contractor in the EU Healthgrain project, implemented in 2005-2010 (**Annex 5.II.I.1**). At the same time, I conducted research as part of the SPUB project, which was a contribution to the Healthgrain project (**Annex 5.II.I.2**). In both projects, I was responsible for analysis of the content of nutrients: protein, lipids, ash, starch and free sugars, and estimation of the content of dietary fibre from their difference by indirect method. The development of a new indirect method for the determination of fibre was an important element of the work carried out in this project. In addition, the content of lignin, alkylresorcinols, amylose content in starch and grain as well as viscosity of water extracts were investigated. In the first year of the project, screening research was carried out in order to search for genotypes of particular cereal species with a high content of dietary fibre and other bioactive components. The research material included 203 genotypes and varieties of different cereal species. In the following years, the influence of environmental conditions on the content of individual components was examined in 26 varieties of wheat and 5 rye, grown for 3 years in one location, and next during one year in four locations. The result of the work was 8 publications (**Annex 5.II.A.1.1-1.7**, **Annex 5.II.A.2.2**), three oral presentations (**Annex 5.II.K.1.1-1.3**) and six conference proceedings (**Annex** 5**.III.B.1.1-1.6**). The obtained results were also the basis of my doctoral dissertation, which I defended in 2011 with honours.

In parallel with the Healthgrain project, I was the main contractor of the subject within the statutory activities (**Annex 5.II.I.3**), in which I conducted research related with the influence of environmental conditions on the content of nutrients, dietary fibre and alkylresorcinols in the grain of 22 varieties and 2 breeding lines of winter wheat. The research was conducted in cooperation with Plant Breeding Strzelce Ltd., Co. During the work, I analysed the material cultivated during three years of cultivation in one locality. Obtained results were also included into my doctoral dissertation.

In the years 2007-2011 I was a coinvestigator in the AVEQ project (**Annex 5.II.I.4**), that was aimed to assess the genetic resources of oats of European origin in terms of characteristics conditioning high nutritional value. In this project I was involved in the analyses of protein, fat, starch, mineral substances, and non-starch polysaccharides, including β-glucan. The own contribution to this project was the dehulled grain of the local landraces of oat, harvested by the National Centre for Plant Genetic Resources in Radzików. In this material, research on broadening sources of high nutritional and bioactive value was continued. In the above studies, I participated in the analysis of the content of basic nutrient and bioactive components, viscosity of water extracts and calorific value. The result of the research were presented as conference proceedings (**Annex 5.III.B.1.8**, **Annex 5.III.B.2.1**).

After defending a doctorate and a break in work, caused by maternity leave I became the head of the statutory project (**Annex 5.II.I.5**), in which I started research on the analysis of the chemical composition of selected triticale varieties, in cooperation with Plant Breeding Strzelce Ltd. Co. An important element of the work carried out in this project were activities related to adaptation and launching the Laboratory of Cereal Technology,

which has been transferred from the Cracow Research Centre of PBAI-NRI and included in SPOJPR, as a result of the of the Institute reorganization. As part of my research, I took part in the development and implementation of analytical methods related to the analysis of the technological value of grain and flour such as milling, falling number, gluten amount, Zeleny sedimentation value, farinograph and extensograph analysis. Furthermore, I implemented the laboratory baking method for wheat and triticale flour, and the procedure of bread evaluation described by Klockiewicz-Kamińska and Brzezinski (1997) and the ICC/131 standard. The above studies were a new and very important aspect of my scientific work.

In 2013, I became a laureate in the Lider IV competition (NCRD), receiving funding for research related to the development of a recipe for triticale - oat bread with an increased pro-healthy value (**Annex 5.II.I.6**). During the implementation of this project I had the opportunity to make full use of the acquired skills related to chemical and technological analysis of triticale. The results obtained during this project were the basis of the presented habilitation achievement. Besides the scientific publications, the results were presented at 9 national and 6 international conferences as oral presentations (**Annex 5.II.K.2.1-2.16**) and posters (**Annex** 5**.III.B.2.3-2.11**) and also published in industry magazines (**Annex 5.II.D.2.7**, **Annex** 5**.III.I.1,4,5**).

Since 2016, I am a performer in the Energyfeed project (**Annex 5.II.I.7**), where main goal is to study modern varieties of rye in terms of their yielding potential, profitability of production and usefulness in feeding livestock. As part of this project, the SPOJPR team under the direction of prof. Danuta Boros participate in the task: „Determination and comparative analysis of the endogenous anti-nutrients in grains of different cereal species and varieties and feed mixtures intended to be used in animal trials". The research includes analysis of a total of 525 trials in terms of the content of dietary fibre and its individual components, including non-starch polysaccharides, lignin, β-glucan, resistant starch, oligosaccharides, uronic acids, alkylresorcinols, phenolic compounds and trypsin inhibitor. Viscosities of water extracts and viscosity in acid buffer are also analysed. The results obtained so far have been presented in the form of a scientific publication (**Annex 5.II.A.2.4**) and two conference reports (**Annex** 5**.III.K.2.12; 2.14**).

Presently I am the head of the statutory project for 2018-2019 (**Annex 5.II.I.8**), where my research is related to rye analysis. In cooperation with the Department of Cereal Processing and Bakery of the Institute of Agricultural and Food Biotechnology in Warsaw, I conduct research on obtaining rye flour with an increased content of pro-healthy ingredients. For this purpose, I study the content of non-starch polysaccharides and the viscosity of water extracts of grain, bran and rye flour obtained from various milling passages of a laboratory mill. In the above topic, I also conduct research related to the extension of the scope of analyses related to the technological value of wheat flour.

Besides realization of research projects, during my scientific career I actively participated in the research conducted by the team of Independent Laboratory of Quality Evaluation of Plant Materials where I work. I participated in the process of implementing a new, alternative method of protein determination in plant products, using the Rapid N Cube (Elementar) apparatus. The result of this work was the publication (**Annex** 5**.II.D.2.1**) and the conference report (**Annex** 5**.III.B.1.7**). As part of other work carried

out in the Laboratory I was involved in the assessment of the brewing value of spring barley and genotypic-environmental diversity in this area. The obtained results have been described in the publication (**Annex 5.II.D.2.2**) and in the conference report (**Annex 5.III.B.2.2**). I have been very active in compiling and interpreting the results obtained by the SPOJPR team as part of the realization of the Multi-annual IPBA-NRI Program for the years 2008-2013. As a result of my work, two publications were created (**Annex 5.II.D.2.3-2.4**), including one monograph, which I am a co-editor and co-author. In 2015, in two articles (**Annex 5.II.D.2.5-2.6**), I published a part of the results of my doctoral thesis on the impact of environmental conditions on the variability of dietary fibre and alkylresorcinols content in material from Strzelce Plant Breeding Ltd., Co. During the research conducted in the Independent Laboratory of Quality Evaluation of Plant Materials I was responsible for determining the content of non-starch polysaccharides in oat grain, as part of the realization in the Biological Progress in Plant Production program. The result of work on this species were two publications (**Annex 5.II.2.8-2.9**) and a conference report (**Annex 5.III.B.2.13**).

An important aspect in my scientific career was international cooperation, both during the implementation of the above-mentioned EU grants, as well as established after their completion. In 2010, the Independent Laboratory of Quality Evaluation of Plant Materials established cooperation with scientists from the University of Agriculture in Jeglava (Latvia), under which changes in the content of non-starch polysaccharides were examined in confectionery products with the addition of Jerusalem artichokes. The result of this cooperation was the publication (**Annex 5.II.A.2.1**) and the conference report (**Annex 5.III.B.1.9**). In 2013, continuing cooperation with the Healthgrain project partners, the results obtained during its realization were published, regarding the content of dietary fibre components and their relationship to bioactive components of whole wheat grain (**Annex 5.II.A.2.2**). I also collaborated with scientists from the University of Ljubljana (Slovenia) as part of the analysis of the content of dietary fibre in buckwheat and wheat germ sprouts after addition of highly mineralized water. On the basis of the obtained results, one publication was prepared (**Annex 5.II.A.2.3**).

The other scientific, didactic and organising achievements I presented in the „List of published scientific papers and information on didactic achievements, scientific cooperation, and popularization of science" constituting Annex 5 of the documentation.

Signature

Anna Fraś