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APPLICATION OF CEREAL BRAN IN PRODUCTION OF PAPER PRODUCTS – INITIAL INVESTIGATIONS

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Abstract. The article presents initial results of investigations on the application of rye and wheat bran in the production of paper products and the effect of such supplementation on the paper strength properties. The performed experiments showed that cereal bran, when applied at appropriate proportions (optimally, 5% in relation to DM) did not cause excessive decrease of the strength properties of the examined packaging and bag papers and products manufactured from waste paper pulp (i.e. containers for eggs and fruit and paper flower pots).

Key words: strength properties, cereal rye and wheat bran, bag paper, maculate

INTRODUCTION

Paper, because of the possibility of the modification of its properties and relatively low price, finds wide application in the economy, technique and every day life. Furthermore, the widespread utilization of paper is possible also because this article is manufactured from available plant raw materials. The renewability of the raw material base, possibility of the recovery as well as multiple utilization of fibres for paper production as well as their biodegradability all contribute, in a significant way, to the fact that paper has found its permanent place among industrial articles applied in developed societies and is sure to sustain its central position as a mass and ecological product also in the 21st century. The observed development of production of paper products is accompanied by the expansion of paper processing and packaging industries.

During the past 20 years methods of flour production, both in Europe as well as in other parts of the world, have undergone significant changes. The main objective during the process of flour manufacture is to obtain the product of the highest possible nutritional properties. That is why the waste produced as a result of this process is deprived completely of nutritive values and, therefore, it can no longer be utilized (as has been done until recently) to manufacture feeds for farm animals. Only in the Mill Enterprise in Gdańsk, about 127 tons (data for the year 2006) of cereal waste is produced daily

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and, therefore, a serious problem arises what to do with such an amount of cereal bran. At the moment, there are two ways these wastes can be utilized: either as eco-fuel (Modni Packaging Paper S.A. in Świecie) or as an additive in the production of chip-boards. There is, however, another possibility of application of cereal bran, namely as a filling material in the production process of paper products.

CEREAL RYE AND WHEAT BRAN

Bran can be described as a by-product obtained during the process of grain milling into flour. It is, by no means, a standardized product of specific chemical composition and texture and constitutes a mixture of various products of milling of the peripheral parts of the kernel containing smaller or grater admixture of endosperm of various degree of comminution.

Table 1. Chemical composition of wheat bran and rye bran [Jankowska 2006]
Tabela 1. Skład chemiczny otrębów pszennych i żytnich [Jankowska 2006]

Name of compound Nazwa związku	Percentage content Zawartość procentowa	
	wheat bran otręby pszenne	rye bran otręby żytnie
Cellulose by Seifert meth. Celuloza met. Seiferta	12.70	10.47
Holocellulose according to PN75/50092 Holoceluzowa wg PN75/50092	43.13	20.80
Tappi lignin Lignina Tappi	10.40	9.33
Pentosans Pentozany	24.07	15.27
Substances soluble in hot water Substancje rozpuszczalne w gorącej wodzie	25.84	44.54
Substances soluble in cold water Substancje rozpuszczalne w zimnej wodzie	25.06	26.60
Furfural Furfural	12.02	8.82
Mineral substances (ash) Substancje mineralne (popiół)	3.67	3.52

Absolute moisture content of raw material = 9 (± 2%).
Wilgotność bezwzględna surowca = 9 (± 2%).

Bran contains the fruit coat as well as the aleuronic layer together with the seed cover and some admixture of comminuted embryo and endosperm. It is difficult to find two bran samples which would have identical chemical composition.

Researchers of the Institute of Chemical Wood Technology determined percentage content of individual fractions.

Table 2. Percentage proportion of individual fractions
Tabela 2. Procentowy udział poszczególnych frakcji otrębów pszennych i żytnich

Fraction size, mm Wielkość frakcji, mm	Wheat bran, % Otręby pszenne, %	Rye bran, % Otręby żytnie, %
Over 2.5 – Powyżej 2,5	0.31	0.52
Over 1 – Powyżej 1	10.91	7.93
Over 0.5 – Powyżej 0,5	25.81	23.89
Over 0.4 – Powyżej 0,4	62.97	67.66

The aim of this study on the utilization of the addition of cereal bran as a filling agent for the production of some selected paper products and articles was to investigate how the addition of bran affects strength properties of the obtained paper products and packaging manufactured from them.

RESEARCH MATERIALS AND METHODS

The experimental materials comprised paper products and articles as well as various containers and flower pots obtained from ecological paper pulp manufactured in laboratory conditions (on the Rapid-Köthen apparatus) as well as their counterparts available on the market (ADV Krat Świecie-Clupak).

The following paper products were subjected to analyses: plain paper bags, supplemented paper bags (filled with: 1%, 3% and 5% cereal bran – both wheat and rye), egg and fruit containers as well as paper pots manufactured from pulped waste paper without filling and supplemented with wheat bran (5% and 10%) and rye bran (1%, 3% – the aim of broad look on the problem and 5% and 10%).

In addition, the following materials were used in the performed experiments:

– unbleached kraft pulp (sanbl, 30°sr) from which bag paper was manufactured,
– pulped waste paper,
– auxiliary chemical materials, rosin size and aluminium sulfate,
– cereal bran derived from wheat and rye.

The investigations were carried out on the appropriate equipment and with the assistance of appropriate devices in accordance with the current Polish (PN) and branch (BN) as well as PN-EN standards; basis weight ISO 536, thickness PN-65/P-50130, degree of beating – Schopper-Riegler apparatus, breaking strength ISO 1924-2, double folds number PN-73/P-50134, breaking strength – ISO index 1934-2, extensibility – ISO 1924-2, burst on the Mullen's apparatus – PN-75/P-50132, air permeability – Gurley ISO 5636-5, absorbency and $Cobb_{60}$-number – ISO 536, tearing resistance on the Emeldorf apparatus – PN-75/P-50131 and self-breakage.

The results are an average of 50 measurements; the standard deviation = [± 0.05].

RESULTS OF INITIAL INVESTIGATIONS AND THEIR DISCUSSION

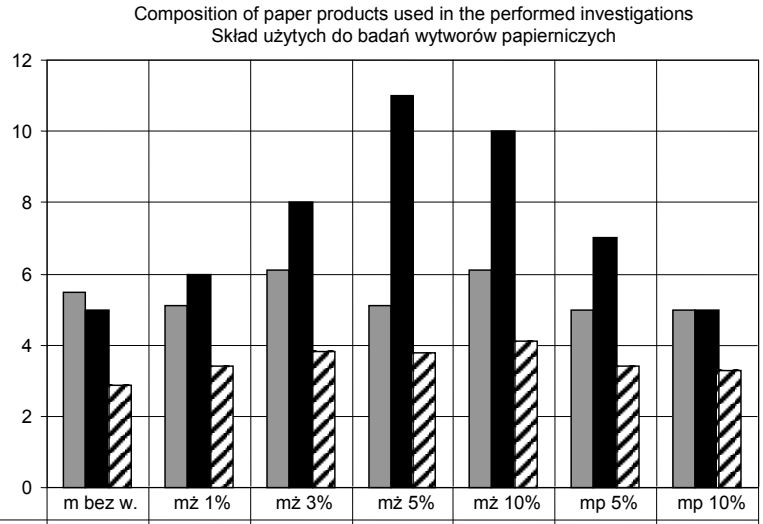
Due to the large number of the performed assays and a very wide scope of the undertaken studies, this paper presents only a part of the obtained results.

The performed experiments revealed that the resistance to self-breakage of packaging and bag papers decreased with the increase of the filling agent. The highest recorded parameters were obtained when testing the ADV KRAFT paper (ordinary, standard bag manufactured by the Mondi Packanging Paper Świecie S.A.) as well as paper bags with the addition of 1% wheat bran and 1% rye bran. The comparison of the self-breakage strength of the paper products manufactured with the addition of cereal bran showed that paper bags manufactured with the addition of rye bran were characterized with the highest parameters (Table 3, Fig. 1).

Tabela 3. Results of selected strength tests of the examined papers of different composition
Tabela 3. Średnie wartości wybranych parametrów wytrzymałościowych dla badanych papierów workowych

Type of bag paper Parameters Rodzaj papieru workowego Parametry	Without filling agent (cereal bran) Bez wypełniacza	Wheat bran Otręby pszenne			Rye bran Otręby żytnie			ADV KRAFT Świecie
		1%	3%	5%	1%	3%	5%	
Basis weight, g/m^2 Gramatura, g/m^2	94.73	99.37	101.60	103.20	101.67	99.70	105.60	99.17
Breaking strength, km Samozerwalność, km	7.63	7.56	7.26	6.76	7.73	7.43	7.07	9.19
Extensibility, % Rozciągliwość, %	2.07	2.10	2.03	1.81	2.25	2.31	2.05	2.47
Tearing resistance, mN Przedarcie, mN	984.3	984.7	968	1 078	1 081	1 035	1 060.6	1 048.33
Burst test, kPa Przepuklenie bezwzględne, kPa	404.76	449.53	441.37	441.19	449.77	457.30	486.50	499.26
Air permeability, s Przepuszczalność powietrza, s	49.87	53.40	71.80	54.37	49.00	70.63	47.80	20.53
$Cobb_{60}$	166.37	184.67	183.73	189.57	154.23	122.50	181.73	27.17

After analysing the resistance of all paper bags subjected to analyses, it was found that the Clupak paper bag (elastic) was characterized by the best strength properties. Ordinary, standard papers showed worse resistance, although it did not exceed 2-3%. When comparing the strength of paper bags with wheat and rye filling with that manufactured from standard ADV KRAFT, it can be said that the addition of the bran filler failed to contribute to an excessive reduction of their resistance to stretchability (differences were negligible). Paper bags with the addition of the rye waste were characterized by a higher strength than the products manufactured from the paper supplemented with wheat bran (Table 3).



	m bez w.	mż 1%	mż 3%	mż 5%	mż 10%	mp 5%	mp 10%
air permeability, s przepuszczalność powietrza, s	5.5	5.1	6.1	5.1	6.1	5	5
double folds number liczba podwójnych zgięć	5	6	8	11	10	7	5
breaking strength, km samozerwalność, km	2.85	3.42	3.81	3.78	4.1	3.4	3.3

Fig. 1. List of selected results of strength tests of papers manufactured from paste paper: m bez w. – waste paper pulp without filling materials, mż – waste paper pulp with addition of rye bran, mp – waste paper pulp with addition of wheat bran
Rys. 1. Zestawienie wybranych wyników oznaczeń wytrzymałościowych papierów wykonanych z makulatury: m bez w. – masa makulaturowa bez wypełnienia, mż – masa makulaturowa z dodatkiem otrębów żytnich, mp – masa makulaturowa z dodatkiem otrębów pszennych

The bag paper intended for wrapping should be characterized by very small air permeability and the application of the experimental mill waste increased their resistance to air permeability. Products with the addition of 3% wheat and rye bran as well as 3% filler clay were characterized by the air permeability above 58 s. The standard ADV KRAFT Clupak paper bag has air permeability at the level of 20 s.

The experimental filling materials applied in the paper products did not reduce excessively their tearing resistance. The highest parameters were observed in the bag paper with the addition of 5% rye bran and ADV KRAFT paper; the strength of 1460.6 mN and 1248.33 mN, respectively (Table 3) was needed in order to initiate tearing. On the other hand, bags with no filling material or with 1% and 3% content of wheat bran were characterized by the tearing strength of below 1000 mN. Similarly as in the case of extensibility, papers manufactured using rye bran showed higher resistance than bags manufactured with the addition of wheat bran or.

The absolute burst resistance index which allows to determine the quality of bag papers, similarly to self-breakage, did not depend on the type but the quantity of the introduced filling material. Bags without any filling agents were characterized by the small-

est resistance to absolute burst. The addition of the rye bran resulted in the increase of the resistance to burst (over 450 kPa). The standard ADV KRAFT paper achieved the highest resistance of 449.24 kPa.

The addition of wheat bran and filler clay increased the water absorbency of the manufactured paper bags. On the other hand, the inclusion of rye bran, presumably due to the higher content of molecules of dimensions > 2.5 mm, allowed to obtain paper of increased resistance to the absorbance of water vapour.

In the course of later experiments, paper products manufactured from waste paper containing different proportions of rye and wheat bran were examined (Fig. 1, 2, 3).

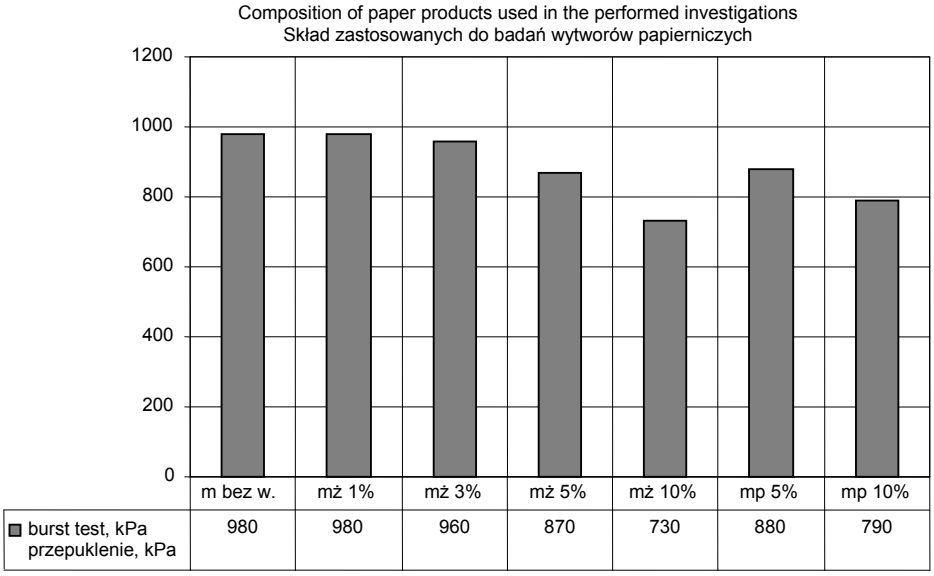


Fig. 2. Results of the absolute bursting test of papers manufactured from waste paper supplemented with different levels of cereal bran: m bez w. – waste paper pulp without filling materials, mż – waste paper pulp with addition of rye bran, mp – waste paper pulp with addition of wheat bran

Rys. 2. Wyniki oznaczeń na przepuklenie bezwzględne papierów wykonanych z makulatury z różnym dodatkiem otrębów zbożowych: m bez w. – masa makulaturowa bez wypełnienia, mż – masa makulaturowa z dodatkiem otrębów żytnich, mp – masa makulaturowa z dodatkiem otrębów pszennych

Analysing the results of air permeability according to Gurley presented in the above Figure 1, it is quite evident that they are very similar. Irrespective of the composition of the applied paper, its average air permeability ranged from 5-6.1 s.

The lowest resistance to double folding was observed in the papers without the addition of the bran and with 10% addition of wheat bran, when it reached 5 on average (at the depth of sticking – 100 mm and the width of the examined ribbon – 15 mm). The maximum number of double folds (11) was recorded in the case of waste paper filled with wheat bran in the amount of 5% (Fig. 1). Papers filled with rye bran revealed increased resistance to the simultaneous folding and stretching with the increase of bran

supplementation. However, once the inclusion of bran exceeded 5%, the resistance of the examined papers declined, both in the case of the wheat and rye mill wastes. The addition of rye bran showed a more favourable impact on the number of double folds that the addition of wheat bran.

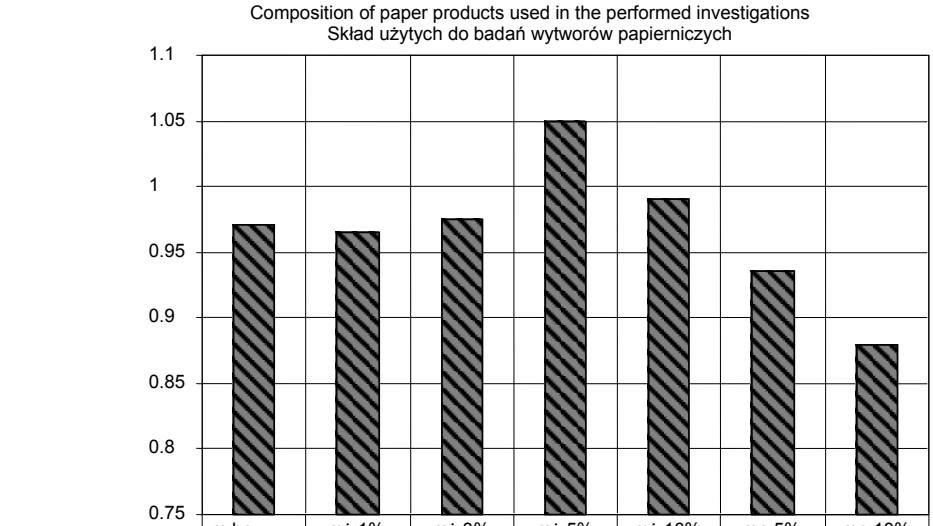


Fig. 3. Results of extensibility tests of papers manufactured from waste paper supplemented with different levels of cereal bran: m bez w. – waste paper pulp without filling materials, mż – waste paper pulp with addition of rye bran, mp – waste paper pulp with addition of wheat bran
Rys. 3. Wyniki oznaczeń na rozciągliwość papierów wykonanych z makulatury z różnym dodatkiem otrębów zbożowych: m bez w. – masa makulaturowa bez wypełnienia, mż – masa makulaturowa z dodatkiem otrębów żytnich, mp – masa makulaturowa z dodatkiem otrębów pszennych

With regard to self-breakage, the obtained results did not exceed the value of 3 km. Paper filled with rye bran in the amount of 5% turned out to be the most resistant (2.84 km), whereas the least resistant was the paper filled with wheat bran in the amount of 10%, reaching the result of 2.37 km.

The resistance to self-breakage increased together with level of the addition of bran up to 5% and at the bran content of 10%, the resistance to self-breakage began to decline (Fig. 1). Therefore, it can be concluded that the inclusion of 5% of rye bran in relation to dry matter turned out to be the most favourable level of bran supplementation.

It is evident from Figure 2 that the resistance of the examined papers to bursting decreased with the increase in the supplementation with cereal bran. The resistance of paper containing 5 and 10% addition of the experimental filler turned out similar, both in the case of supplementation with rye or wheat bran. Papers with no bran supplementation and those which contained the smallest percentage addition of the experimental cereal filler turned out to be the most resistant to bursting and their results reached 980

kPa. The lowest values were recorded in the case of paper supplemented with 10% rye bran (730 kPa).

Figure 3 shows results of extensibility tests of paper products containing different percentage proportions of cereal bran which were manufactured from pulped waste paper. Differences in the susceptibility to extensibility were very small. All the examined papers showed resistance to elongation of about 1% in relation to their initial dimensions,

Similarly as in the case of the resistance to self-breakage, also in the case of tensile strength it was the paper with 5% addition of rye bran that turned out to be the strongest reaching the value of 1.05%, whereas papers supplemented with 10% wheat bran were the weakest and their resistance amounted to 0.88%. Resistance to elongation increased together with the increase in the amount of incorporated bran up to 5%.

CONCLUSIONS

After the analysis of the result of the initial investigations, it can be concluded that cereal bran applied at appropriate proportions in relation to DM does not reduce excessively the strength properties of the examined paper products, although it can lead to the deterioration of some characteristics. In situations when mill dust applied as a filling agent in greater quantities (over 5%) will lead to the reduction of some strength properties, it is recommended to grind the material finely and add some binding substance or increase the amount of the added glue.

It is also recommended to employ larger quantities of the sizing agent in the case of the incorporation of the rye bran because, as it was shown in the course of its fraction examination, this type of bran contains considerable quantities of particles exceeding 2.5 mm. In the case of poorly sized paper, these particles lead to fuzzing of paper products (fine, loose particles, e.g. filler fibres, separate easily) which can also affect the aesthetic value of these paper products.

With regard to the products manufactured from the waste paper pulp, it was found that the addition of bran causes loosening of the paper structure which affects air permeability. This type of paper offers only a slight resistance. This phenomenon is advantageous in the case of paper flower pots. Thanks to good air permeability, there is a natural aeration of the root systems of plants growing in this type of pots.

Paper products and articles manufactured from waste paper pulp (such as fruit or egg containers and trays) supplemented with mill wastes, when compared with the identical products which do not contain such additives, do not show a significant drop in their strength properties and, in some cases, these properties are even improved.

There is no doubt that starch, which constitutes one of the major components of bran, favours and supports in a natural way binding processes of individual elements of the paper pulp.

Another important factor is the size of the employed fraction of the mill waste. From the point of view of properties of the paper end product, it is important that the particle dimensions should not exceed 2.5 mm. The recommended quantity of the incorporated cereal bran is 5%, since higher quantities frequently resulted in the decline of strength properties of the obtained paper materials.

It was found that cereal bran could be applied as fillers for the production of paper bags or sleeves employed in forestry as protective covers in the course of establishment of forest nurseries. In the case of these products, the incorporation of cereal bran does not reduce significantly the strength properties of the above-mentioned products and, additionally, enhances their biodegradability. Until recently, foresters used for their purposes PCV-based bags which are ecologically unfriendly and practically non-degradable.

Bag papers as well as ecological wrappings manufactured from paper pulp form part of the group of packing papers which constitute 38% of the total production of the world paper products. The main task of this group of papers is to provide the best wrapping and protection for a wide range of products from the cosmetic or food industries (e.g. flour, sugar, gelatine desserts, powdered soups, spices, eggs etc.), building and construction (e.g. cement, lime) gardening (paper pots for seedlings) as well as pharmaceutical industry. The replacement of fillers currently employed during the production of the above-mentioned articles by cereal bran would allow production of ecologically friendly paper. This is particularly important in the case of papers intended for packaging of food and pharmaceutical products where components contained in the wrapping paper can react with the wrapped product.

Economical aspects of the application of cereal bran constitute an additional advantage of this type of paper articles. Cereal bran is a by-product of grain milling. The application of gluten in the production of packaging and bag papers as well as wrappings from waste paper pulp would reduce production costs due to the totally free filler. Furthermore, such utilization of the milling waste product is also advantageous for the milling industry which has problems with the excess of such by-products.

It is predicted that continuous investigations of this problem will bring about further improvement of the developed method of production of paper articles containing the investigated cereal waste as filler.

The appropriate utilization of bran produced as a by-product in the course of grain milling is a very important problem both for the food and pulp and paper industries and appears to be particularly important for Polish manufacturers.

The application of cereal bran as filler during the production of paper products and articles is justified in the case of the following articles:

– wrapping and bag papers as well as paper sleeves used by forestry and gardening industry,
– pre-formed egg trays and fruit containers manufactured from waste paper pulp,
– paper flower and seedling pots.

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ZASTOSOWANIE OTRĘBÓW ZBOŻOWYCH DO PRODUKCJI WYTWORÓW PAPIERNICZYCH – BADANIA WSTĘPNE

Streszczenie. W artykule przedstawiono wstępne wyniki badań nad zastosowaniem otrębów żytnich i pszennych w produkcji wytworów papierniczych i wpływem ich dodatku na właściwości wytrzymałościowe. Badania wykazały, iż otręby zbożowe zastosowane w odpowiednich proporcjach (optymalnie 5% w stosunku do s.m.) nie przyczyniają się do nadmiernego spadku właściwości wytrzymałościowych badanych papierów pakowych, workowych oraz wytworów z pulpy makulaturowej (tj. wytłoczek do jajek i owoców oraz donic papierowych).

Słowa kluczowe: właściwości wytrzymałościowe, otręby zbożowe żytnie i pszenne, papier workowy, makulatura

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