J. Elementol. 2009, 14(1): 135-146

COMPARISON OF CHEMICAL COMPOSITION OF SELECTED WINTER WHEAT SPECIES

Leszek Rachoń, Grzegorz Szumiło

Faculty of Detail Cultivation of Crops
University of Life Sciences in Lublin

Abstract

Chemical composition of common wheat – *Triticum aestivum ssp. vulgare* Vill. Host., hard wheat – *Triticum durum* Desf., and spelt – *Triticum aestivum ssp. spelta* (L.) Thell grains was investigated. Total protein, wet gluten, fiber, ash, carbohydrates, falling number, macronutrients (phosphorus, potassium, calcium, magnesium), and microelements (copper, iron, manganese, zinc) were determined. Also standard deviation, variability and correlation coefficients were calculated. Hard wheat and spelt lines were characterized by much higher contents of total protein, wet gluten, and falling number value than common wheat; however, the highest protein concentration and falling number was recorded in grains of hard wheat. Common wheat was distinguished by low ash content and the highest carbohydrates level. Higher percentage of macronutrients and microelements in grains of spelt and hard wheat, as compared to common wheat, confirms the usefulness of these species for foodstuff production. Among the qualitative traits studied, content of carbohydrates appeared to be the least variable (cv = 2.2%), while the highest variability (cv = 31.1%) was shown by fat content. Significant correlations for the following trait pairs were observed: protein–gluten, protein–carbohydrates, fat–ash, fat–falling number, carbohydrates–gluten, and ash–falling number.

Key words: hard wheat, spelt, grain quality, chemical composition, macronutrients, microelements.

dr hab. Leszek Rachoń, Faculty of Detail Cultivation of Crops, University of Life Sciences, Akademicka 15, 20-950 Lublin, Poland, e-mail: leszek.rachon@up.lublin.pl

PORÓWNANIE SKŁADU CHEMICZNEGO ZIARNA WYBRANYCH GATUNKÓW PSZENICY

Abstrakt

Badano skład chemiczny ziarna pszenicy zwyczajnej – *Triticum aestivum ssp. vulgare* Vill. Host., pszenicy twardej – *Triticum durum* Desf. i orkiszu pszennego – *Triticum aestivum ssp. spelta* (L.) Thell. Określono zawartość białka ogólnego, glutenu mokrego, włókna, tłuszczu, popiołu, węglowodanów, liczby opadania, makroelementów (fosforu, potasu, wapnia, magnezu) i mikroelementów (miedzi, żelaza, manganu, cynku). Obliczono także odchylenie standardowe, współczynniki zmienności oraz współczynniki korelacji. U badanych linii pszenicy twardej i orkiszu pszennego wykazano znacznie wyższą zawartość białka ogólnego, glutenu mokrego oraz wyższą liczbę opadania niż u odmiany pszenicy zwyczajnej, przy czym najwyższą zawartość białka i liczbę opadania stwierdzono w ziarnie pszenicy twardej. Pszenica zwyczajna wyróżniała się niską zawartością popiołu i największym udziałem węglowodanów. Wyższy udział makro- i mikroelementów w ziarnie orkiszu pszennego i pszenicy twardej, w porównaniu z pszenicą zwyczajną, potwierdza dużą przydatność tych gatunków w produkcji żywności. Spośród badanych cech jakościowych zawartość węglowodanów okazała się cechą najmniej zmienną (cv = 2,2%). Największą z kolei zmiennością (cv = 31,1%) charakteryzowała się zawartość tłuszczu. Wykazano istotne korelacje dla następujących par cech: białko–gluten, białko–węglowodany, tłuszcz–popiół, tłuszcz–liczba opadania, węglowodany–gluten i popiół–liczba opadania.

Słowa kluczowe: pszenica twarda, orkisz, jakość ziarna, skład chemiczny, makroelementy, mikroelementy.

INTRODUCTION

Cereal grain is one of the oldest components of human diet. It contains numerous nutrients: proteins, carbohydrates, vitamins, minerals (iron, magnesium, potassium, phosphorus, zinc), and, next to fruits and vegetables, constitutes a source of antioxidants (MARCINIAK, OBUCHOWSKI 2006). Wheat is the species of cereals which, owing to its extremely varied uses and large area of cultivation, constitutes the basic food all over the world. Apart from common wheat, which is the fundamental species in cultivation, more and more importance is gained by hard wheat, an excellent material for production of pasta, and spelt, which in the form of bakery products can be consumed by persons suffering from various kinds of allergy, mainly allergies to wheat-based foods (CAMPBELL 1997).

Hard wheat (*Triticum durum* Desf.) is a wheat species with hard and vitreous kernels, high content of proteins and gluten, and of carotenoid pigments. Due to its values, this species of wheat is frequently referred to as "pasta wheat", and the coarse-grains grits obtained from it, known as semolina, is especially recommended for the production of pasta of various kinds. It is grown mainly in countries with dry climate, where unfavourable moisture conditions restrict the cultivation of common wheat (RACHOŃ 2001).

In turn, the grain of spelt (*Triticum aestivum ssp. spelta* (L.) Thell), in spite of its relation with common wheat, is superior to it in terms of its nutritional and health qualities. It has a higher content of proteins and gluten, and also contains vitamins A, E, D. Moreover, the composition of vitamin E in spelt is dominated by gamma- and alpha-tocopherols (GRELA 1996, PAŁYS, KURASZKIEWICZ 2003, WAGA 2003, SULEWSKA et al. 2005).

The objective of this study was to evaluate grain quality of new lines of hard wheat and spelt as compared to common wheat, in terms of the chemical composition and the content of macro- and microelements in the grain.

MATERIAL AND METHODS

In 2005–2007, a field experiment was conducted at the Experimental Farm at Felin, the University of Life Sciences in Lublin. The experimental field was located on soil classified as good wheat complex, with high level of nutrients: P–76, K–119 and Mg–55 (in $mg \cdot kg^{-1}$ of soil). The reaction of the soil in KCl solution was 6.3 (RACHOŃ 2001).

The experiment was set up in random blocks design, in four replications, on a stand after rapeseed. The experiment comprised two winter spelt lines (STH 3 and STH 715) and winter hard wheat lines (STH 716 and STH717), originating from the Plant Breeding Station at Strzelce, and a single cultivar of common wheat (Tonacja – a cultivar in quality group A acc. to the COBORU, constituting a model cultivar for technological quality of winter wheat grain). The area of the harvest plots was $10m^2$. The soil tillage was conventional, plough system. Pre-sowing fertilisation was applied as follows: phosphorus in the dose of 26.2 kg P?ha^{-1} and potassium in the dose of 66.6 kg K ?ha^{-1}. Nitrogen fertilisation was applied as top dressing, after the start of vegetative growth (N – 70 $kg \cdot ha^{-1}$) and in the phase of the third node (N – 30 $kg \cdot ha^{-1}$). A total of 5 million germinating kernels of common wheat, hard wheat and spelt (threshed from chaff) were sown per 1 ha. Plant protection treatments (herbicide, fungicide, insecticide, retardant) were applied as suggested by the relevant recommendations.

Every year of the study, chemical analyses were made on samples of grain from the plots. Following wet mineralisation (concentrated sulphuric acid + 30% solution of H_2O_2), determinations were made of the content of fibre (gravimetric method), fat (Soxhlet method) and ash (gravimetric method at 580°C). The content of proteins was determined according to the Kjeldahl method (N% · 5.75). The level of carbohydrates was obtained after the deduction of the remaining dry matter components. Also, determination was made of the concentration of the following macro- and microelements: N and P (flow spectrophotometry), K (emission of flame spectrometry), Ca, Mg, Cu,

Fe, Mn and Zn (atomic absorption spectrometry). Wet gluten content was determined with the elution method (acc. to standard PN-A-74041:1977), and the falling number with the method of Hagberg-Perten, acc. to standard PN-ISO 3093:1996.

The results of the experiment were processed statistically with the method of analysis of variance, the significance of differences being estimated by means of Tukey test at 0.05 level of significance. The results are given as mean values for the three years of the study, with standard deviation (SD). Variability of the studied quality parameters of wheat grain was determined on the basis of coefficient of variation, while relationships between them were determined through calculation of coefficients of correlation for significance level of 0.05.

In the years of the study (2005–2007), October and April were characterised by notable deficit of precipitation and by temperatures that considerably exceeded the long-term average (Table 1). The years 2005 and 2006 had cool and wet March, and rainfall level in June below the long-term mean value. Additionally, in 2006 a considerable deficit of rainfall was recorded in July. In the final season of the study the lowest rainfall sum was recorded, and the highest air temperature, exceeding the long-term average for each month – from September 2006 to August 2007. The year 2007 was also characterised by excessive rainfalls in May and June.

RESULTS AND DISCUSSION

Analysis of the chemical composition of grain of the wheat lines and cultivars under comparison revealed significant differentiation of most of the features and traits examined (Table 2).

One of the more important quality features of wheat is the content and quality of proteins in grain. The lines of hard wheat and wheat spelt were characterised by notably higher content of total protein in grain compared to the common wheat cultivar. The highest content of protein (14.1%) was found for hard wheat line STH 716, and the lowest one (11.0%) – for common wheat cultivar Tonacja. The lines of wheat spelt attained intermediate values among all the cultivars tested (mean 12.1%). Numerous authors point out to a higher protein content in grain of hard wheat in comparison to that of common wheat. In the studies by Rachoń and Kulpa (2004) as well as Rachoń and Szumiło (2006), hard wheat contained on average 2.3-2.6% more protein, while in the research by Szwed-Urbaś (1993) and Segit and Szwed-Urbaś (2006) those differences were even higher reaching 4.6%.

Grain of spelt wheat, compared to common wheat, has a higher protein content. This is verified by our own study (spelt – 12.1%, common wheat – 11.0%) and by other authors. Bojňanská and Frančáková (2002) recorded val-

Table 1

Rainfalls and air temperatures according to the Meteorological Observatory at Felin

Year	Month												IX-VIII
	IX	X	XI	XII	I	II	III	IV	V	VI	VII	VIII	
Rainfalls (mm)													sum
2004/2005	14.2	19.1	58.2	17.1	41.6	26.0	48.0	18.6	98.0	55.9	109.8	108.7	615.2
2005/2006	18.0	8.6	21.7	54.5	15.7	26.7	47.0	30.3	59.5	37.9	6.8	198.3	525.0
2006/2007	11.0	14.2	41.2	18.6	51.5	22.3	30.2	17.4	81.5	87.8	87.0	37.6	500.3
Mean for 1951-2000	52.1	40.3	39.1	31.5	21.7	24.8	25.8	40.6	58.3	65.8	78.0	69.7	547.7
Temperature (^{o}C)													mean
2004/2005	12.8	9.7	3.1	1.5	0.0	-3.9	-0.1	9.1	13.2	16.0	19.8	16.9	8.2
2005/2006	14.9	8.8	2.7	-0.8	-7.6	-4.3	-1.0	8.7	13.6	16.9	21.9	17.4	7.6
2006/2007	15.8	10.1	5.3	3.0	2.6	-1.6	6.2	8.7	15.0	18.1	19.2	18.4	10.1
Mean for 1951-2000	12.9	7.9	2.5	-1.4	-3.6	-2.8	1.0	7.5	13.0	16.5	17.9	17.3	7.4

Table 2

The chemical composition of wheat (% d.m.)

Cultivar and lines		Total protein	Fiber	Crude fat	Ash	Carbo-hydrate	Wet gluten (%)	Falling number (s)
Tonacja *T. aestivum ssp. vulgare*	M	11.0	2.4	1.9	1.6	83.1	24	215
	SD	1.02	0.13	0.84	0.07	3.44	3.5	56.4
STH 716 *T. durum*	M	14.1	2.4	1.4	2.0	80.1	30	285
	SD	1.78	0.11	0.23	0.11	3.56	8.2	72.3
STH 717 *T. durum*	M	12.9	2.2	1.5	1.8	81.6	25	276
	SD	1.82	0.08	0.37	0.14	3.57	5.3	70.5
STH 3 *T. aestivum ssp. spelta*	M	12.1	2.9	2.0	1.7	81.3	28	258
	SD	1.44	0.37	0.20	0.17	3.20	8.7	70.0
STH 715 *T. aestivum ssp. spelta*	M	12.1	2.1	2.1	1.7	82.0	27	272
	SD	1.08	0.11	0.42	0.13	3.29	8.7	54.0
$LSD_{(p=0.05)}$		1.04	0.20	0.33	0.11	1.03	4.3	40.4
CV (%)		13.9	13.1	31.1	10.3	2.2	27.0	26.0

M – mean for the years 2005-2007

SD – standard deviation

$LSD_{(p=0.05)}$ for cultivar and lines

CV – coefficient of variation

ues in the range of 12.5-19.4% in the studied genotypes. Lacko-Bartosova and Redlova (2007) reported 14.8-18.6% protein content, and Sulewska et al. (2005) determined 15.5-19.7%.

According to Ceglińska et al. (2004) and Segit and Szwed-Urbaś (2006), gluten of good quality should be strong, elastic and plastic, and its content should fall within the range of 30-40%. Wheat grain for processing is required to contain at least 25% of gluten in kernels. However, particular species and cultivars vary, sometimes considerably, in this properties. As Gąsiorowski and Obuchowski (1978) report, hard wheat grain is characterised by gluten that is more suitable for pasta products than for bakery products, due to somewhat different structure and composition compared to common wheat. Similar conclusions were reached Rachoń (2001). In turn, according to Sulewska et al. (2005), gluten of wheat spelt is sensitive to overly intensive mechanical treatment in the course of dough formation.

In our own study, the content of gluten oscillated within a relatively low level (24-38%) compared to the results obtained by other authors (Achremowicz et al. 1999, Bojňanská, Frančáková 2002, Rachoń, Szumiło 2002, Sulewska

et al. 2005, SEGIT, SZWED-URBAŚ 2006). These authors, who studied various wheat genotypes, obtained results spread over a fairly broad range (30.6--50.6%). Among the tested objects, the highest content of gluten was found in hard wheat (line STH 716-30%), and the lowest one – in the common wheat (24%).

The falling number enables us to conclude whether a given product originated from grain with increased enzymatic activity, frequently due to a hidden process of grain germination. In this study a considerable variation of this index was found with relation to the wheat lines under comparison (Table 2). Among the tested lines and cultivars, significantly higher values of this parameter were obtained for hard wheat (285-276 s) and wheat spelt (272-258 s) compared to common wheat (215 s). In turn, ACHREMOWICZ et al. (1999) and RACHOŃ (2001) claimed that the falling number of common wheat was higher in relation spelt lines and hard wheat they examined. However, most authors emphasize that climatic conditions have a very strongest effect on the value of the falling number, especially such weather factors as rainfall during the period of ripening and harvest of grain (RACHOŃ 2001, BOJŇANSKÁ, FRANČÁKOVÁ 2002, SEGIT, SZWED-URBAŚ 2006). Analogous relations were observed in our own study.

In a comprehensive analysis of quality parameters of wheat grain it is important to determine the content of ash and the level of mineral components, which affect technological possibilities of transforming grain into final products, i.e. pasta products. Cereal products, which constitute 40-50% of the human diet, are one of the primary sources of mineral components. In our study, the highest ash content was recorded in the grain of hard wheat (1.8-2.0%) – Table 2, significantly lower in common wheat grain (1.6%) and in spelt (1.7%). Higher ash content in hard wheat grain compared to common wheat is also indicated by GĄSIOROWSKI and OBUCHOWSKI (1978), MAKARSKA et al. (2001), and RACHOŃ (2001). PAŁYS and KURASZKIEWICZ (2003), SCHMITZ (2005) and SEIFERT (2005), on the other hand, demonstrated a higher content of that component in spelt wheat lines than in common wheat.

Among the other components we investigated, notable is the highest content of fat in wheat spelt, much higher than in common and durum wheat cultivars (Table 2), high content of fibre in one of the spelt lines (STH 3), and also the highest level of carbohydrates in common wheat. At the same time, the level of carbohydrates displayed the least variation (cv = 2.2%). The highest variation among all the examined components was shown by the content of fats (cv = 31.1%).

In the present research (Table 3), notably higher levels of such macroelements as phosphorus, potassium and calcium were determined in hard wheat as compared to common wheat, with the greatest variation being found in the case of calcium (cv = 24.5%). The grain of spelt assumed intermediate values. A less pronounced variation was demonstrated in the case of magnesium.

Table 3

The macroelements content of wheat (% d.m.)

Cultivar and lines		Phosphorus	Potassium	Calcium	Magnesium
Tonacja *T. aestivum ssp. vulgare*	M	0.38	0.42	0.034	0.13
	SD	0.042	0.017	0.002	0.014
STH 716 *T. durum*	M	0.50	0.53	0.053	0.13
	SD	0.040	0.033	0.011	0.014
STH 717 *T. durum*	M	0.42	0.52	0.055	0.11
	SD	0.043	0.027	0.014	0.006
STH 3 *T. aestivum ssp. spelta*	M	0.46	0.44	0.042	0.13
	SD	0.059	0.028	0.002	0.022
STH 715 *T. aestivum ssp. spelta*	M	0.42	0.43	0.047	0.13
	SD	0.041	0.031	0.007	0.019
$LSD_{(p=0.05)}$		0.048	0.062	0.041	0.016
CV (%)		13.2	11.6	24.5	14.5

* explanations under Table 1

Among the analysed microelements (Table 4), the significantly lowest content of all micronutrients was found in common wheat, while the highest content of copper and zinc was determined in hard wheat, and that of iron and manganese in the spelt lines. A high content of phosphorus, calcium and iron in spelt wheat lines was obtained also by SCHMITZ (2005) and SEIFERT (2005). The smallest content variation among all the microelements was found in the case of manganese (cv = 14.3%), and the greatest one – for copper (cv = 25.4%).

The suitability of a given trait of grain is determined by the degree of its correlation with other quality features which specify the technological value of grain. One such feature is the content of proteins. In this study significant correlations were demonstrated between protein content and the levels of gluten and carbohydrates (Table 5). This parameter was positively correlated with wet gluten, r = 0.78, and negatively correlated with the content of carbohydrates, r = -0.94. A strong positive correlation between the levels of proteins and gluten was also demonstrated by SZWED-URBAŚ (1993) and RACHOŃ (2001). Significant negative correlations were found for the couples: fat–ash (r = -0.57), fat–falling number (r = -0.67) and carbohydrates–wet gluten (r = -0.81). On the other hand, there was a positive correlation between ash content and the falling number (r = 0.64).

Table 4

The microelements content of wheat (mg·kg^{-1} d.m.)

Cultivar and lines		Copper	Iron	Manganese	Zinc
Tonacja *T. aestivum ssp. vulgare*	M	2.84	30.9	36.9	34.9
	SD	0.61	4.62	1.57	2.37
STH 716 *T. durum*	M	3.86	33.7	41.5	43.7
	SD	1.00	4.98	6.25	6.89
STH 717 *T. durum*	M	3.18	29.0	31.1	29.7
	SD	0.73	6.99	4.72	5.17
STH 3 *T. aestivum ssp. spelta*	M	2.99	32.2	41.6	31.5
	SD	0.72	5.05	2.31	5.31
STH 715 *T. aestivum ssp. spelta*	M	2.85	33.9	37.0	37.0
	SD	0.43	4.62	2.79	2.45
$LSD_{(p=0.05)}$		0.477	3.22	3.20	4.01
CV (%)		25.4	16.9	14.3	19.1

* explanations under Table 1

Table 5

Values of correlation coefficients

Correlation coefficients	Total protein	Crude fat	Ash	Carbohydrate
Ash	0.367	-0.573 *	-	-0.311
Carbohydrate	-0.937 *	-0.157	-0.311	-
Wet gluten	0.783 *	0.301	-0.170	-0.814 *
Falling number	0.106	-0.674 *	0.639 *	0.048

* values of significant correlation coefficients at p=0.05

CONCLUSIONS

1. The lines of hard wheat and wheat spelt were characterised by notably higher content of total proteins and wet gluten, and higher values of falling number, compared to the common wheat cultivar, with the highest protein content and falling number being recorded for hard wheat grain.

2. Common wheat was characterised by low ash content and the highest level of carbohydrates.

3. The higher level of macro- and microelements in grain of wheat spelt and hard wheat compared to common wheat provides supporting evidence for the applicability of those wheat lines to food production.

4. Among the grain quality traits studied, the content of carbohydrates proved to be the feature with the smallest variation (cv = 2.2%). The greatest variability (cv = 31.1%), in turn, was characteristic for the fat content.

5. Significant correlations were demonstrated for the following feature couples: protein–gluten, protein–carbohydrates, fat–ash, fat–falling number, carbohydrates–gluten, and ash–falling number.

REFERENCES

ACHREMOWICZ B., KULPA D., MAZURKIEWICZ J. 1999. *Technologiczna ocena ziarna pszenic orkiszowych*. Zesz. Nauk. AR w Krakowie, 360: 11-17.

BOJŇANSKÁ T., FRANČÁKOVÁ H. 2002. *The use of spelt wheat (Triticum spelta L.) for baking applications*. Rostlinná Výroba, 48(4): 141-147.

CAMPBELL K. G. 1997. *Spelt: agronomy, genetics and breeding*. Plant Breeding Revievs, 15: 188-213.

CEGLIŃSKA A., CACAK-PIETRZAK G., ROMANOWSKI H., NITA Z. 2004. *Wartość technologiczna polskiej pszenicy twardej*. Prz. Zboż.-Młyn., 8: 4-6.

GĄSIOROWSKI H., OBUCHOWSKI W. 1978. *Pszenica makaronowa durum*. Post. Nauk Rol., 1 (166): 35-52.

GRELA E. R. 1996. *Nutrient composition and content of antinutritional factors in spelt (Triticum spelta L.)*. J. Sci. Food. Agric., 71: 399-404.

LACKO-BARTOSOVA M., REDLOVA M. 2007. *The significance of spelt wheat cultivated in ecological farming in the Slovak Republic. Proc. of the conference „Organic farming 2007"*.

MAKARSKA E., KOWALCZYK A., RACHOŃ L. 2001. *Zawartość mineralnych składników pokarmowych w ziarnie wybranych linii pszenicy twardej (Triticum durum Desf.) w warunkach zróżnicowanego nawożenia azotem i ochrony chemicznej*. Biul. Magnezol., 6(1): 28-35.

MARCINIAK A., OBUCHOWSKI W. 2006. *Prozdrowotne właściwości ziarna zbóż*. Prz. Zboż.-Młyn., 5: 11-13.

PAŁYS E., KURASZKIEWICZ R. 2003. *Wpływ terminów siewu na wybrane cechy i plon ziarna orkiszu (Triticum aestivum ssp. spelta)*. Biul. IHAR, 228: 71-80.

RACHOŃ L. 2001. *Studia nad plonowaniem i jakością pszenicy twardej (Triticum durum Desf)*. Rozpr. Nauk., Wyd. AR, Lublin, 248 ss.

RACHOŃ L., KULPA D. 2004. *Ocena przydatności ziarna pszenicy twardej (Triticum durum Desf.) do produkcji pieczywa*. Ann. UMCS, E., 59 (2): 995-1000.

RACHOŃ L., SZUMIŁO G. 2002. *Plonowanie i jakość niektórych polskich i zagranicznych odmian i linii pszenicy twardej (Triticum durum Desf.)*. Pam. Puł., 130: 619-624.

RACHOŃ L., SZUMIŁO G. 2006. *Plonowanie a opłacalność uprawy pszenicy twardej (Triticum durum Desf.)*. Pam. Puł., 142: 404-409.

SCHMITZ K. 2005. *Dinkel ein Getreide mit Zukunft für die Bäckerei*. Getreidetechnologie, 59 (1): 48-51.

SEGIT Z., SZWED-URBAŚ K. 2006. *Ocena cech jakościowych ziarna wybranych linii pszenicy twardej*. Biul. IHAR, 240/241: 75-82.

SEIFFERT M. 2005. *Herstellung von Dinkelspezialitäten mit Vorteigen*. Getreidetechnologie, 59 (1): 26-35.

SULEWSKA H., NITA Z., KRUCZEK A. 2005. *Zróżnicowanie cech jakościowych wybranych genotypów orkiszu (Triticum aestivum ssp. spelta L.)*. Biul. IHAR, 235: 65-74.

SZWED-URBAŚ K. 1993. *Zmienność ważniejszych cech użytkowych jarej pszenicy twardej z uwzględnieniem interakcji genotypowo-środowiskowej*. Wyd. AR, Lublin, 159 (rozprawa habilitacyjna).

WAGA J. 2003. *Zmienność niektórych frakcji ω-gliadyn a zawartość białka ogółem w potomstwie orkiszu i odmiany Elena*. Biul. IHAR, 228: 61-69.

Ziarno zbóż i przetwory zbożowe. Oznaczanie ilości i jakości glutenu. Polski Komitet Normalizacyjny. PN-A-74041:1977.

Zboża. Oznaczanie liczby opadania. Polski Komitet Normalizacyjny. PN-ISO 3093:1996.