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Autumn-winter diet and fat reserves of wild boars (*Sus scrofa*) inhabiting forest and forest-farmland environment in south-western Poland

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Abstract. Diet, carcass weight (dressed weight) and kidney fat index (KFI) in wild boar populations were compared between two different lowland environments in south-western Poland. In the forest-farmland environment of the Lasy Śląskie forest (LS), fodder root crops and cereals made up 67.6 % of the dry weight (d.w.) of stomach content (n = 40). In the large compact forest of the Bory Dolnośląskie forest (BD), 69.6 % of the stomach content (n = 43) was made up of roots and browse. Piglets and older animals harvested in BD were significantly lighter than those harvested in LS (13.6 kg *vs.* 25.6 kg and 47.3 kg *vs.* 55.9 kg respectively). The KFI of piglets and older animals harvested in LS were significantly higher than those in corresponding age classes of wild boars from BD. The metabolized energy of stomach content amounted to 13.2 MJ/kg d.w. in LS and 8.9 MJ/kg d.w. in BD. This is probably the chief cause of the differences in carcass weight and KFI between the wild boars living in the compared study areas.

Key words: agricultural food, forest food, kidney fat index, carcass weight, metabolized energy, stomach content

Introduction

The nutrient composition of food consumed by wild boars affects their body weight and fat reserves which, in turn, determine the age of puberty, rate of reproduction, mortality, and population dispersion (Maguet & Pepin 1991, Fruziński 1992, Groot Bruinderink et al. 1994, Briederman 2009).

Among wild ungulates, production i.e. body growth and deposition of fat can occur if the so-called energetic cost of maintenance (basal metabolism, thermoregulation, cost of activity, calorigenic effect of food) is lower than food intake calculated in units of energy (Parker et al. 2009, Cook et al. 2013). Therefore production depends on voluntary food intake and the values of metabolized energy of particular components and diet of the animals (Hudson & White 1985, Robbins 1993, Worden & Pekins 1995, Vetheraniam et al. 2009). Topical publications on wild boar diet usually provide the types and proportions of particular component of food as percent of volume, sometimes adding which of them have high or low caloric value, which is not tantamount to their metabolized energy values (see review by Schley & Ropper 2003, Mayer & Brisbin 2009, Ballardi et al. 2013). This situation makes it impossible to standardize the stomach contents or to compare nutritive values of diets for wild boars living in different environments.

In wild boar studies, the influence of diet quality upon body weight and fat reserves is poorly documented. Therefore, the objective of this study is (1) to assess the diet of the wild boar based on the proportion of the dry mass of particular diet components so that comparisons can be made between the quantitative composition of the nutritive value and diet for wild boars living in two distinctly different environments and (2) to measure the body weight and kidney fat index in both studied populations of wild boar.

The following hypotheses were tested: (1) The composition of diet in wild boars inhabiting farmland-forest mosaic is significantly different from the composition of diet in wild boars living in a large, solid forest complex, and the quality of wild boar diet is higher in the farmland – forest mosaic environment; (2) The quality of wild boar diet, i.e. nutritive value, determines body weight and the level of fat reserves in these animals.

Study Area

The study area covered two different types of lowland environment inhabited by wild boars, located in south-

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western Poland; namely: (1) large compact forest of the south-western part of the Bory Dolnośląskie forest and (2) the Lasy Śląskie forest characterised by a mosaic of small woods in a farmland type landscape.

The areas inhabited by wild boars in the Bory Dolnośląskie forest covered 780 km^2, of which 690 km^2 were areas administered by five forest inspectorates (Bolesławiec, Pieńsk, Ruszów, Świętoszów, and Węgliniec), whereas the remaining area (i.e. 90 km^2) consisted of farmlands adjacent to forests. The described area is a lowland landscape with low hills in the range of 140-180 m a.s.l. The average annual temperature is 8.3 °C and there are only approximately 49 days with snow cover (Kondracki 2002). The forested area in the Bory Dolnośląskie forest is predominantly covered by fresh coniferous forest (*Leucobryo-Pinetum*) and mixed coniferous forest (*Pino-Quercetum*) comprising 82.6 % of the total area. Scots pine (*Pinus sylvestris*) constitute ca. 93 % of forest stands, whereas ca. 2 % is made up of oak (*Quercus robur*), and beech (*Fagus sylvatica*). The average density of the wild boar population calculated from snow track data is 16.1 individuals/1000 ha of forest area (Kobielski et al. 2007). The farmlands adjacent to the forest are small holdings with an extensive-type of agricultural production. In terms of the structure of crops in farmlands, meadows and pastures dominate (40.4 % of the area), while land on which cereal crops are cultivated is only 22.4 %. A significant portion of land (7.7 %) is fallow (Central Statistical Office 2010).

The area inhabited by wild boars in the Lasy Śląskie forest covers 559 km^2, of which the forests administered by the Rudziniec forest District constitute 204 km^2, whilst the rest (i.e. 65.3 %) comprises farmlands surrounding the forests. The described area is a range of low hills, varying in height from 236 to 252 m a.s.l. Snow cover persists for 60 days and the average annual temperature is 8.1 °C (Kondracki 2002). Deciduous (*Tilio-Carpinetum*) and mixed-deciduous (*Pino-Quercetum*) forest together cover 76.3 % of the forested area. Scots pine covers 50.5 %, whereas oak and beech cover 24.5 % of forest stands. The agricultural landscape is dominated by large farms, where intensive farming prevails, aimed at cereal crop production. The proportion of cereal crops in farmlands is 65.7 %. Meadows and pastures cover only 12.8 % of the area (Central Statistical Office 2010). The density of the wild boar population evaluated by results of the collective hunt data in February 2011 was ca. 45 individuals/1000 hectares of forest (unpublished report of game management plan for Rudziniec Forest District, March 2009).

Material and Methods

During collective hunts held between October 2008 and January 2009, 43 wild boars were harvested randomly and examined in the Bory Dolnośląskie forest, and 40 individuals in the Lasy Śląskie forest. During these hunts, the hunters were permitted to shoot all wild boars without any restrictions pertaining to age or sex.

Stomachs were removed from all harvested animals. Half-litre samples were taken from the stomach contents and then washed over a series of four different sizes of mesh sieves (5 mm, 2 mm, 1 mm, and 0.8 mm). The solid fraction retained by the 5 mm mesh sieve was analysed in full, whereas only randomly chosen sub-samples were analysed from other fractions. Each plant and animal fragment found was separated and identified to the lowest possible taxon by comparing them to a reference collection and using published guides and keys (Bednarz & Koczwańska 1976, Teerink 1991). Next, each type of food was dried in an incubator for 24 hours at 70 °C, and weighed to an accuracy of ± 0.01 g. It was assumed that such food fractions as wood, bark, needles, and leaves jointly constitute browse, i.e. current growths of trees, shrubs, and dwarf shrubs, within reach of wild boars. The grass fraction was included in the ground flora, apples were treated as soft mast, whereas seeds – as hard mast.

The carcass weight, so-called field dressed weight (i.e. eviscerated body weight with head, without internal organs), was taken immediately after shooting. One kidney with fat was dissected from each individual. Next, the amount of fat around the kidney was standardized according to the criterion that the fat deposit adjacent to the kidney should not be larger than the surface of the kidney, calculated by the quotient of its length and width (Caughley & Sinclair 1994). The surplus fat was removed and the kidney was then weighed with fat and without it. The kidney fat index (KFI) was the quotient of the kidney mass with fat and the kidney mass without fat (Riney 1955, Finger et al. 1981, Santos et al. 2013).

The age of harvested animals was determined after assessing the degree of tooth eruption and wear and tear of teeth on the lower jaw (Matschke 1967, Briedermann 2009). Because the number of yearlings and adults was low, the two age classes were considered: (1) piglets – under 12 months old, including 20 individuals in the Bory Dolnośląskie forest and 18 individuals in the Lasy Śląskie forest, and (2) wild boars older than 12 months, (yearlings and adults together), including 23 animals in the Bory Dolnośląskie forest and 22 animals in the Lasy Śląskie forest.

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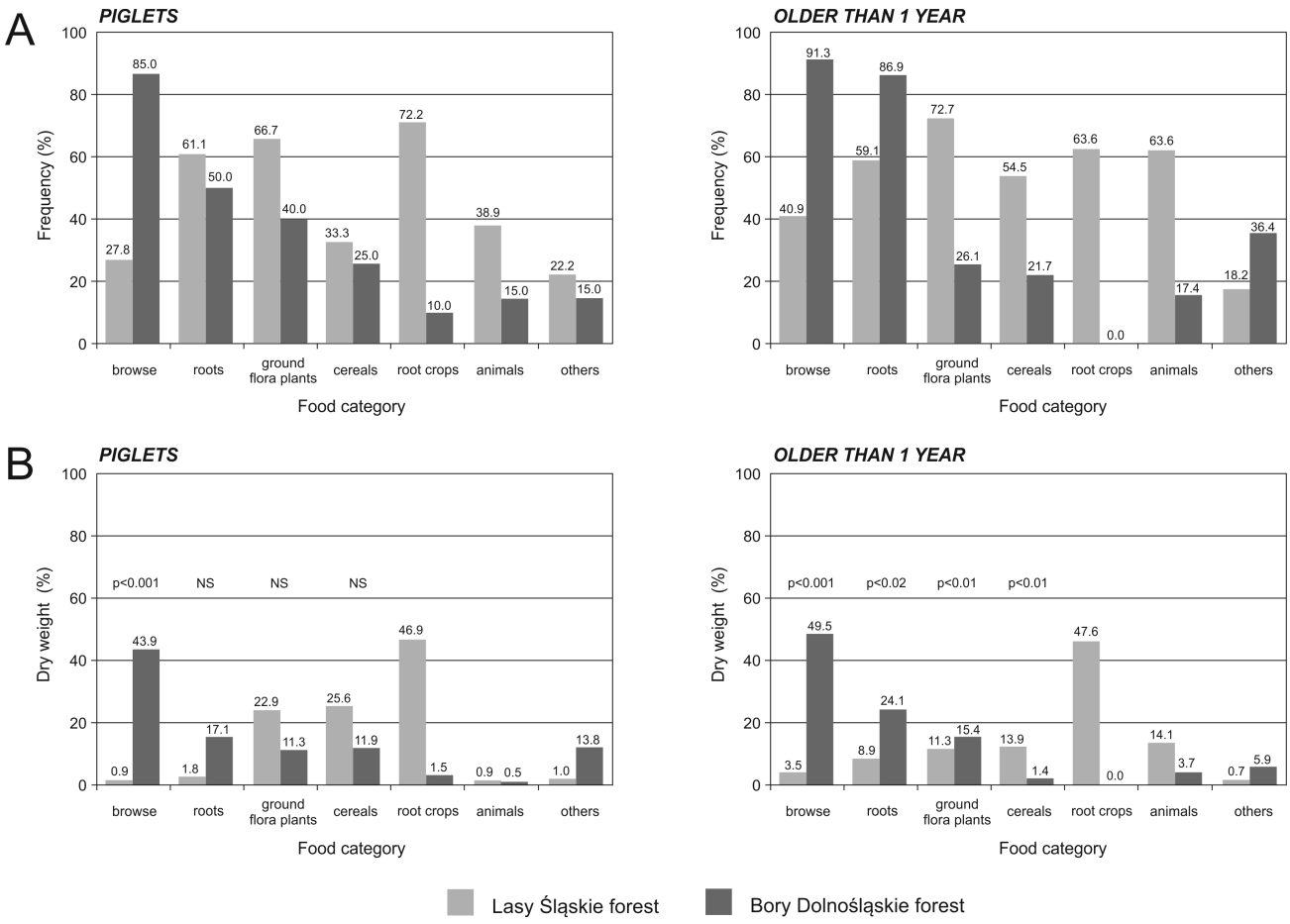


Fig. 1. Frequency of occurrence in percent (A) and dry weight percentages (B) compared by Mann-Whitney test of particular categories of food identified in samples of stomach contents obtained from piglets and adults of wild boars (*Sus scrofa*) harvested in the Bory Dolnośląskie forest (n = 43) and Lasy Śląskie forest (n = 40) between October 2008 and January 2009.

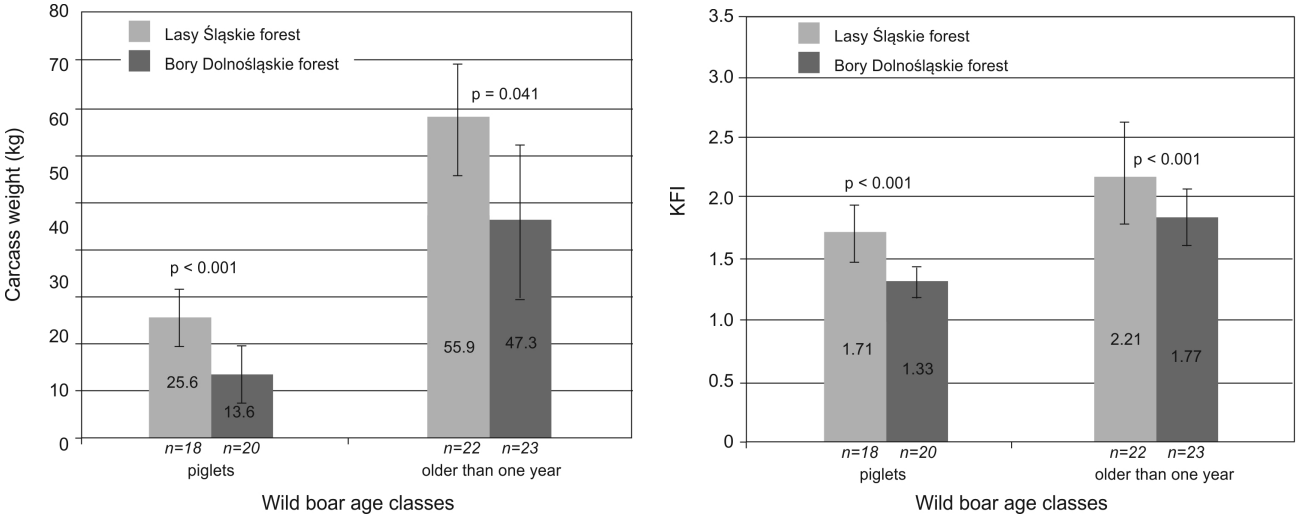


Fig. 2. Average dressed weight (left) and kidney fat index (right) in particular age classes of wild boars (*Sus scrofa*) harvested in the Lasy Śląskie forest (n = 40) and Bory Dolnośląskie forest (n = 43) between October 2008 and January 2009 compared by Mann-Whitney test. Mean, standard deviations and sample size (n) are given.

The diet of the wild boar was calculated as: (1) frequency of occurrence, and (2) % of dry matter of each food category or fraction. The results of feeding trials performed in domestic pigs and wild boar were used for calculations of estimates of metabolic energy of the stomach contents. The proportions of

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Table 1. Composition of winter-autumn diet of wild boars in various regions of Europe estimated with the use of stomach content analysis (S) and fecal analysis (F). Diet composition in % of volume (V), % of dry weight (DW) and % of fresh weight (FW). "+" denotes the presence of a given fraction of food, but in lesser quantity thus it is accounted for together as "others". A – rich mast year, B – poor mast year, N – number of samples per one autumn-winter season.

Location habitat and methods	Cereals (grains)	Root crops	Ground flora	Browse	Under ground parts of flora	Hard mast	Soft mast	Animals	Others	References
French Alps, forest-meadow S-F, DW; N = 29	+	-	+	+	61.0	8.0	15.0	+	16.0	Baubet et al. 2004
Spain, Southwestern Pyrenees, forest-meadow S,V; N = 72	-	-	3.3	5.5	23.8	58.8	3.4	3.8	1.4	Herrero et al. 2005
Spain, Ebro Valley, farmland S,V; N = 14	82.2	-	5.5	-	-	-	-	3.9	8.4	Herrero et al. 2006
Luxembourg, whole country S,V; N = 267	48.7	+	18.4	+	6.1	17.6	4.0	1.0	4.2	Cellina 2008
Spain, Coastal Mediterranean marshland, S,V; N = 24	29.7	-	11.2	-	34.4	7.4	-	4.8	12.5	Gimmenez-Anaya et al. 2008
Western Poland lowland, forest-farmland S, FW; N = 52	11.5	34.5	6.9	-	-	38.9	5.0	3.2	-	Wlazełko et al. 2009
The Netherlands, Veluwe area mixed forest heathlands S,V, A; N = 46	-	-	12.1	-	7.5	75.8	0.7	3.1	0.8	Groot Bruinderink & Hazebroek 1994
The Netherlands, Veluwe area mixed forest heathlands S,V, B; N = 46	-	-	55.3	-	14.2	25.4	1.2	2.5	1.5	Groot Bruinderink & Hazebroek 1994
Southern Poland, Lasy Śląskie forest, forest-farmland, S, DW; N = 40	20.3	47.2	17.7	2.1	5.0	0.6	-	6.8	0.3	This study
South-western Poland, Bory Dolnośląskie forest S, DW; N = 43	4.7	0.5	14.1	47.8	21.8	0.1	6.2	2.7	2.1	This study

particular categories in the diet was then multiplied by relevant values of metabolic energy of corresponding fodders (grains of corn and other species of cereals, acorns, potatoes, beets, grasses, and alfalfa) which were obtained in the experiments (van Wieren 2000, Hodgkinson et al. 2008, Śliwiński et al. 2010). A weighed average of metabolic energy of the stomach contents analysed was thus obtained.

The differences between mean carcass weights and KFIs between the study areas for animals in the same age classes, and between food composition were evaluated with the use of the non-parametric Mann-Whitney test (Sokal & Rholf 1995), using the Statistica 10 software package. The differences between frequencies of particular food categories were calculated by use of Chi-square test.

Results

Diet composition and frequencies of food categories

A total of 18 various food categories were identified in the stomach contents of wild boars, of which 14 were common for animals harvested in both study areas (beets, maize, ground flora plants, roots of ground flora plants, grains of various species of cereals, grasses, tissue of vertebrates i.e. deer, wild boar and other unidentified species, insects, twigs of browse, seeds of wild species, bark, mushrooms, leaves and needles of coniferous trees). In the Bory Dolnośląskie forest, the wild boar diet did not include potatoes, carrots, and snails, whereas in the Lasy Śląskie forest the content of analysed stomachs did not contain apples.

In the stomach content material of piglets from the Bory Dolnośląskie forest the frequencies of browse

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were higher than those found in animals from the Lasy Śląskie forest ($\chi^2 = 12.73$, $p < 0.001$) (Fig. 1A). In adults, browse and roots showed a higher frequency of occurrence in the Bory Dolnośląskie forest, but cereals and ground flora plants were significantly more frequent in wild boars living in the Lasy Śląskie forest (Fig. 1A).

Piglets living in the Bory Dolnośląskie forest showed lower proportion of cereals in stomach content, than piglets from the Lasy Śląskie forest, but this difference was not significant (Fig. 1B). The amount of browse in diet of these animals was significantly higher than that in diet of piglets living in the Lasy Śląskie forest. In adults inhabiting the Bory Dolnośląskie forest the percentage share of browse, roots and ground flora plants was higher, but the amount of cereals was significantly lower than in animals older than 1 year living in the Lasy Śląskie forest (Fig. 1B).

Carcass weight and kidney fat index

Piglets in the Bory Dolnośląskie forest were significantly lighter than those in the Lasy Śląskie forest ($Z = –4.129$; $p < 0.001$) (Fig. 2A). Among older wild boars we found a similar results ($Z = –2.044$; $p < 0.001$).

The Mann-Whitney U-test also showed significant differences in fat reserves between piglets from the compared study areas, as well as between the groups of older wild boars (yearlings and adults). The kidney fat index was significantly higher in both piglets ($Z = –4.415$; $p < 0.001$), and in older wild boars ($Z = –3.989$; $p < 0.001$) from the Lasy Śląskie forest (Fig. 2B).

Discussion

The significant differences between the composition of diets of wild boars living in the Lasy Śląskie forest and the Bory Dolnośląskie forest result from the different trophic conditions prevailing in these two study areas. The Lasy Śląskie forest consists of small size woodlands surrounded by large farmlands, where 76.5 % of cultivated fields provide wild boars with large quantities of high quality food (cereals and root crops) and good hiding and thermal cover (Keuling et al. 2009). The farmland/forest boundary index is 3.3 km/1000 hectares of forest (Kopeć 2012), therefore the wild boars living there have very good access to cultivated fields.

Unlike the latter, the Bory Dolnośląskie forest is a large compact forest complex where adjacent farmlands offers much less high quality food because the proportion of cereals and roots crops there is low (24.5 %) and 48.1 % of the agricultural land are meadows, pastures and fallows. The access of wild boars to cultivated fields is limited – the farmland/forest boundary index is only 0.46 km/1000 hectares of forest (Furtek 2013).

The differences in the quality of food consumed, between piglets and animals older than 1 year in both study areas, can be explained via analyzing energy expenditure by these animals. The resting metabolic rate in wild boars depends on the body mass raised to power whose value ranges from 0.57 to 0.86 (Jezierski & Myrcha 1975). The energy expenditure in piglets calculated per 1 kg of body mass is higher than the energy expenditure in adult wild boars, and the digestibility and supply of metabolized energy to their bodies is also higher when the animals consume food of higher quality. For this reason, the differences in the proportion of cereals in the diets of piglets living in the Lasy Śląskie forest, and the Bory Dolnośląskie forest were smaller than those among the relevant groups of adult wild boars.

The different composition of forest habitats improves the foraging conditions of wild boars in the Lasy Śląskie forest compared with those faced by the animals living in the Bory Dolnośląskie forest as the potential food resources for wild boars are higher in deciduous and mixed forests than those in coniferous forest habitats (Grodziński et al. 1984). Therefore, the wild boar population living in the Lasy Śląskie forest have in both the farmland and forest environments much better foraging conditions than the wild boar populations in the Bory Dolnośląskie forest.

The cereal found in the stomach of wild boars in both study areas comes from cultivated fields as well as from baiting stations used by hunters. In winter, wild boars can probably consume the remnants of food plants left on unploughed fields where crops had earlier been harvested. In the Lasy Śląskie forest, hunters bring in 5.1 tonnes of cereal grain, chiefly maize, per 1000 hectares of forest, and somewhat less of such fodder (3.2 tonnes/1000 hectares) of forest is supplied to the baiting stations in the Bory Dolnośląskie forest (unpublished game management reports from local forest districts: Bolesławiec, Pieńsk, Ruszów, Rudziniec, Świętoszów, and Węgliniec). It seems therefore that the amount of cereal grains supplied to the baiting stations has only limited effect on the diet of wild boars. The amount of cereals in stomach content of wild boar living in the Lasy Śląskie forest and in the Bory Dolnośląskie forest is not directly proportional to amount of cereals in baiting stations (see above).

The diet quality of wild boars living in the Lasy Śląskie forest is very similar to the diet of the species found in

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farmland areas in the valley of the River Ebro (Herrero et al. 2006), in the coastal marshlands of Spain (Gimenez-Anaya et al. 2008), in various habitats in Luxembourg (Cellina 2008), and in a farmland-forest mosaic within western Poland (Wlazełko et al. 2009) (Table 1). The proportion of high-quality food (cereal grain, root crops, hard and soft mast, animal material) in these areas fluctuated from 41.9-86.1 %, and results from our study area (74.9 %) fall within this range. On the other hand, the quality of diet of wild boars in the Bory Dolnośląskie forest is similar to the diet of the animals of the species living in the French Alps (Baubet et al. 2004) and in the forests of the Netherlands in a poor mast year (Groot Bruinderink et al. 1994) (Table 1).

The wild boar diet in both study areas differs markedly from the stomach contents of wild boars living in the Pyrenees and those in the forests of the Netherlands during a rich mast year (Groot Bruinderink et al. 1994, Herrero et al. 2005). These differences probably stem from the lack of a heavy mast year in 2008 in both our study areas.

Therefore, by comparing data on the diet of wild boars living in diverse environments with the diet of wild boars living in the Bory Dolnośląskie forest (Table 1) it can be demonstrated that it is the worst in terms of quality because of the highest proportion of ground flora and browse.

The high proportion of animal food found in the diet of wild boars in the Lasy Śląskie forest is mainly carrion of deer and wild boar which likely died as a result of shot wounds from hunters in collective hunts. The lack of earthworms in the diet of these wild boars, which constitute an important component of the animal's diet (Baubet et al. 2004), is caused by the fact that during spells of cold weather these animals live in deeper layers of soil. A significant proportion of soft mast in the diet of wild boars from the Bory Dolnośląskie forest (Table 1) were apples from orchards abandoned after II World War in the areas adjacent to the forest.

In ungulates, the nutritional condition is defined as amount of some body components (e.g. fat, protein, nutrients) obtained by ingestion of metabolized energy and nutrients (Harder & Kirkpatrick 1994). Assuming that the value of metabolized energy of the components of the wild boar diet obtained in this study is close to the values of the same components used in feeding trials with domestic pigs and wild boar (van Wieren 2000, Hodgkinson et al. 2008, Śliwiński et al. 2010), 1 kg dry weight of stomach content of animals in the Lasy Śląskie forest is 13.2 MJ/kg dry weight, while the corresponding value for wild boar living in the Bory Dolnośląskie forest is much lower and amounts to only 8.9 MJ/kg dry weight. The value of metabolic energy, higher by 48.5 % of food in the stomachs of wild boars living in the Lasy Śląskie forest, allow the animals living there to attain a higher body mass and fat reserves. Such a phenomenon was confirmed by the results of this study. Similarly to our results, intake of digested energy showed significant impact upon body weight and fat reserves in collared peccaries *Tayassu tajacu* (Corn & Warren 1985), in white tailed deer *Odocoileus virginianus* (Brown et al. 1995) and in rocky mountain elk *Cervus elaphus nelsoni* (Cook et al. 2001).

The study presents a new approach to the methods used in studies of wild boar diet, as the analysis of stomach contents based on the proportion of dry mass for particular food fractions enables the diet to be expressed in units of metabolic energy, the levels of which determine body growth and fat reserves. It opens up extensive possibilities for the simulation and modeling of energy budgets in wild boars living in different trophic conditions including also supplemental feeding applied in game management. Therefore, the analysis of wild boar diet should be based on the proportion of particular food fractions expressed in dry mass rather than on their volumes. The latter method does not permit the nutritive value of the diet to be calculated in metabolic energy units. The extensive use of such an assessment of the nutritive value of the diet as presented in this study will be of great assistance in interpreting mortality and reproduction rates in wild boar population studies.

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