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Effect of body composition, feed intake, and ambient temperature on heat production of Vietnamese Sway-back Pigs

Einfluß der Körperzusammensetzung, der Futteraufnahme und der Umgebungstemperatur auf die Wärmeproduktion von Vietnamesischen Hängebauchschweinen

Summary From theoretical considerations animals with a higher protein-fat ratio in the body should have a higher maintenance energy requirement (MEm). The literature on this problem shows a non-uniform picture with deviating results.

From the results of a series of experiments it is possible to compare the heat production (HP) of male and female animals of the Vietnamese Sway-back breed pigs which vary quite widely in their body composition. The protein-fat ratio was 1.2 for the male and 0.2 for the female animals. In the experiments 4 male and 4 female animals in the live weight range of 20-33 kg and 33-42 kg, respectively, were involved. The HP measurements were carried out in climatized respiration chambers on two levels of energy intake at ambient temperatures of 6 °C, 12 °C, 18 °C, 24 °C, 30 °C, and 35 °C. The dependence of HP on the ambient temperature has been described by a cubic regression function. Thermoneutral temperatures are lower in the female animals caused by the better insulation effect of the backfat. The difference in HP which was expected by the large difference in body composition, was not found. The absolute protein mass determined the correlation to HP. Certainly the difference increased after lowering the ambient temperature. The influence of different factors on HP is discussed.

Zusammenfassung Aus theoretischen Betrachtungen heraus sollten Tiere mit einem höheren Protein-Fett-Verhältnis einen höheren Energieerhaltungsbedarf (EEB) haben. Die Literatur zu diesem Problem zeigt ein nicht einheitliches Bild mit von dieser Annahme abweichenden Ergebnissen. Aus den vorliegenden Ergebnissen einer Reihe von Versuchen ist es möglich, die Wärmeproduktion (WP) von männlichen und weiblichen Tieren der Rasse Vietnamesisches Hängebauchschwein zu vergleichen, die sich in ihrer Körperzusammensetzung stark unterscheiden. Das Protein-Fett-Verhältnis betrug für die männlichen Tiere 1,2 und für die weiblichen 0,2. In die Experimente waren 4 männliche und 4 weibliche Tiere im Lebendmassebereich von 20-33 kg bzw. 33-42 kg einbezogen. Die WP-Messungen wurden auf zwei Energieeinnahmeniveaus bei Umgebungstemperaturen von 6 °C, 12 °C, 18 °C, 24 °C, 30 °C und 35 °C in klimatisierten Respirationskammern vorgenommen. Die Abhängigkeit der WP wird durch eine kubische Regressionsfunktion dargestellt. Die thermoneutralen Temperaturen sind bei den weiblichen Tieren niedriger, bedingt durch die höhere Isolationswirkung der Fettauflage. Der durch die stark unterschiedliche Körperzusammensetzung erwartete Unterschied in der WP wurde nicht gefunden. Die absolute Proteinmasse bestimmt im wesentlichen die Korrelation zur WP. Allerdings vergrößert sich die Differenz infolge unterschiedlicher thermoregulatorischer WP bei Absenkung der Umgebungstemperatur. Es werden Einflußgrößen auf die WP diskutiert.

Key words Heat production - body composition - ambient temperature - pig

Schlüsselwörter Wärmeproduktion - Körperzusammensetzung - Umgebungstemperatur - Schwein

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Introduction

In mammals the heat production (HP) is the sum of heat from the energy metabolism in the state of body energy balance (metabolizable energy requirement for maintenance, MEm), the heat losses connected with food energy transformation to energy in body gain and other animals products, heat for maintaining homiothermy (thermoregulatory heat production), and heat resulting from physical activity. MEm contributes to a large extent to the total HP even in growing animals. MEm can be ascertained by measuring the energy metabolism on a nutrition level near the energy equilibrium in a thermoneutral environment at restricted physical activity and following correction of the intake of metabolizable energy (ME) to an energy balance of zero. Otherwise, the MEm can be derived regressively from experiments on different nutrition levels. In the first mentioned experimental estimation at the energy balance near zero, the MEm corresponds to the measured HP of the animal.

A multitude of investigations verifies that the MEm related to metabolic body weight depends on a variety of endogenous and exogenous factors. The prominent among them are age, genetic origin, sex, chemical body composition, chemical composition of feed, nutrition level as well as short-term changes of it, seasonal environmental variations, changes of physiological conditions (lactation, pregnancy), and adaptation effects. These problems are described in detail by Hoffmann (4). Here the question comes as to what extent contradictory results can be due to interactions between different factors mentioned above. For example, studies with growing rats showed that at thermoneutral ambient temperature (temperature at which the animals do not need to produce additional heat for maintaining body core temperature) MEm increased with higher crude protein content of the diet (2). After lowering the ambient temperature below the thermoneutral temperature contrary results were obtained. This fact is explainable by the proved dependence of thermoneutral temperature on the crude protein content of the diet in growing rats (3). The example shows that the choice of the experimental conditions, especially in this case the ambient temperature, can influence the interpretation of results.

One possible factor affecting MEm can be the chemical composition of the animals body, especially the protein-fat ratio (PFR). The results in the literature concerning this problem are contradictory. From the theoretical consideration that protein rich tissue has more intensive metabolism than fat rich, a higher MEm could be expected in animals with larger PFR. Results of corresponding experiments are different depending on the chosen experimental conditions. Hoffmann (4) discussed to what extent factors producing different PFR cause variations in the results of comparable studies. Considering these problems the interpretation of the results should be done with regard to differences in PFR caused genetical or nutritional factors. Because a correlation can be expected between the altitude of the thermoneutral temperature and the body PFR, it is necessary to choose in these experiments such ambient temperatures at which thermoregulatory heat is not produced. Aim of the present paper is to study the influence of ambient temperature on HP of male and female animals of the Vietnamese Sway-back breed of pigs which have highly variable body PFR. Based on the results relations between body composition and thermoneutral temperature should be obtained, and also relations between body composition and HP which reflects differences in MEm at certain experimental conditions.

Materials and methods

The experiments were carried out with 4 male and 4 female pigs of the Vietnamese Sway-back breed. At beginning of the experiments the animal's age was 6 - 7 months. The live weights amounted to 32.5 ± 5.0 kg for females and 20.0 ± 5.8 kg for males. The composition of the ration is given in Table 1 and the mean energy and nutrient content in Table 2.

The measurements of HP were done in 2 climatized respiration chambers with a volume of 16 m^3. Two experiments were carried out, one followed by the other with nutrition levels semi ad libitum and about 90 % of that level. In each experiment HP was measured in succession at ambient temperatures of 6, 12, 18, 24, 30, and 35 °C for 4 days at each temperature. HP was calculated from respiration data according to Brouwer (1). Four animals of each group were kept in one chamber but in individual cages and fed twice daily (7^{30} and 14^{00}). At

Table 1 Composition of the ration (% of DM)

Barley	61.8 %
Maize	19.5 %
Soy bean meal	4.9 %
Fish meal	8.4 %
Casein	2.2 %
Vitamin mixture for piglets	1.0 %
Mineral mixture	2.2 %

Table 2 Chemical composition of the ration (% of DM)

Crude ash	7.0 %
Crude protein	19.1 %
Crude fiber	3.2 %
Crude fat	4.0 %
Crude cellulose	3.5 %
N-free extractives	66.7 %
Watersoluble carbohydrates	2.6 %
Starch	49.7 %
Gross energy	18.064 MJ/kg DM
Metabolizable energy	15.1 MJ/kg DM

the end of the experiments the animals were slaughtered. Water, fat, and protein content were analysed in the carcass, in the muscles longissimus dorsi and semitendinosus. Significance of slaughter data was tested by means of t-test. Different letters show significant differences (<p 0.05). The ± values of the tables give the standard deviations.

Results

Results on composition of the carcasses and muscles are given in Table 3 and about energy intake and HP at the different ambient temperatures in Tables 4 and 5. Because of the slightly different energy intake between the single steps of temperature data of HP, were corrected to equal ME intake. Base of correction was ME intake at 4 °C and efficiency coefficient of utilization of ME above maintenance for growth (k_{pf}) of 0.7. HP data were analyzed regressively in dependence on ambient temperature in order to estimate thermoneutral temperatures. The best fit of the experimental data was obtained by a cubic function. The equations are shown in Table 6. The thermoneutral temperatures were calculated as the minimum of the cubic regression function. Likewise, it was possible to calculate the temperature of equality between energy intake and HP (energy deposition (ED)=0). In Table 7 data about thermoneutral temperatures, corresponding HP and temperatures for ED=0 for all energy intakes are shown. In males the thermoneutral temperatures are higher by 3 K, but the difference of temperatures at which ED would be 0 is markedly higher. The composition of carcasses is quite different between males and females. The essentially higher fat content of the females is obvious in all demonstrated parameters, what is also expressed in PFR of 1.2 in the females as against 0.2 in males (Table 3). The higher fat content is caused not only by back fat but is also reflected by muscle composition. The reason for the differences between sexes are not explainable considering the knowledge of prehistory of the experimental animals. It should be mentioned, that the animals both males and females were derived from two different breedings.

Table 3 Selected parameters of the composition of the carcass. M. longissimus dorsi and M. semitendinosus in male and female Vietnamese Sway back Pigs (in each case n =4)

	male (%)	female (%)
Carcass		
Water	59.3 ± 1.1 [a]	30.9 ± 2.7 [b]
Fat	17.2 ± 2.9 [a]	56.6 ± 4.9 [b]
Protein	20.0 ± 1.9 [a]	10.5 ± 2.0 [b]
Protein: fat ratio	1.2	0.2
Portion of meat	38.7 ± 1.0 [a]	24.9 ± 2.5 [b]
Back fat	9.7 ± 1.6 [a]	26.3 ± 2.3 [b]
M.log.dorsi		
Fat	1.0 ± 0.2 [a]	5.3 ± 1.3 [b]
Protein	23.3 ± 0.4 [a]	22.9 ± 0.3 [a]
M. semitendinosus		
Fat	0.9 ± 0.3 [a]	3.45 ± 3.4 [a]
Protein	22.9 ± 0.6 [a]	22.9 ± 1.0 [a]

Discussion

The aim of the experiments was to investigate the influence of a strongly different body composition on the heat production. Independent, of the reason for the different PFR (different feeding in the time before the experiments, sex) it should be possible to make conclusions on the problem. The PFR is different by the factor 6 between the male and female animals caused above all by the substantial higher proportion of fat in the females. The absolute protein mass was little different at the time of slaughter (females: 6.67 kg, males: 7.72 kg). HP-values, related to kg metabolic body mass, of the male animals are higher at comparable ME-intake at all temperatures, caused possibly by a higher MEm. A part of this higher HP could be explained by the observed (not measured) physical activity.

The HP at thermoneutral temperature, calculated from the regression function, is higher in the male animals independently of the feeding level (maximum 9.4 %, Table 7). Because the energy intake was different

Table 4 Intake of metabolizable energy (ME) heat production (HP) and corrected heat production (HP_{corr}) (all in kJ/kg$^{0.62}$d) of male Vietnamese Sway back Pigs at different ambient temperatures

	Trial 1			Trial 2		
T (°C)	ME_1	HP_1	HP_{corr1}	ME_2	HP_2	WP_{corr2}
6	1244 ± 4	1653 ± 46	1653	980 ± 5	1444 ± 16	1444
12	1218 ± 16	1402 ± 23	1410	967 ± 2	1227 ± 23	1231
18	1221 ± 7	1137 ± 20	1144	960 ± 3	1030 ± 52	1036
24	1193 ± 17	839 ± 26	854	947 ± 18	859 ± 22	869
30	948 ± 40	728 ± 8	817	946 ± 13	760 ± 40	770
35	1088 ± 13	744 ± 89	793	967 ± 12	779 ± 16	783

Table 5 Intake of metabolizable energy (ME) heat production (HP), and corrected heat production (HP_{corr}) (all in $kJ/kg^{0.62}\cdot d$) of female Vietnamese Sway back Pigs at different ambient temperatures

T (°C)	Trial 1 ME_1	HP_1	HP_{corr1}	Trial 2 ME_2	HP_2	HP_{corr2}
6	1340 ± 140	1369 ±39	1369	1135 ± 3	1138 ± 35	1138
12	1418± 10	1195 ± 23	1172	1107 ± 3	976 ± 30	984
18	1304 ± 58	947 ± 32	958	1091 ± 19	812 ± 24	825
24	1335 ± 87	806 ± 26	804	1087 ± 19	710 ± 11	724
30	1387 ± 29	753 ± 18	739	1086 ± 13	716 ± 49	730
35	1365 ± 45	846 ± 27	838	1083 ± 20	742 ± 7	757

Table 6 Dependence of heat production (HP) ($kJ/kg^{0.62}d$) on ambient temperature (T)- Regression equations

	ME-intake ($kJ/kg^{0.62}\cdot d$)		
Male	980	$HP = 1615 - 24.1T - 0.96T^2 + 0.028T^3 \pm 7$	$r^2 = 1.0$
	1244	$HP = 1835 - 20.3T - 1.85T^2 + 0.045T^3 \pm 34$	$r^2 = 0.996$
Female	1135	$HP = 1316 - 28.2T - 0.23T^2 + 0.05\ T^3 \pm 7$	$r^2 = 1.0$
	1340	$HP = 1483 - 8.7T - 2.0T^2 + 0.0017T^3 \pm 18$	$r^2 = 0.995$

Table 7 HP ($kJ/kg^{0.62}d$) in dependence on energy intake at thermoneutral temperature (°C) and temperatures for energy deposition (ED) = 0

	ME-intake ($kJ/kg^{0.62}d$)	$T_{thermoneutral}$	HP	T (ED = 0)
Male	980	32.2	767	19.8
	1244	31.9	778	15.5
Female	1135	28.7	711	6.2
	1340	29.1	743	7.0

Table 8 To equal ME-intake corrected heat production, related to metabolic body fresh mass, heat production related to metabolic body dry mass and metabolic protein mass (all at thermoneutral temperature)

ME-intake ($kJ/kg^{0.62}d$)	1135		1340	
	female	male	female	male
Heat production ($kJ/kg^{0.62}d$)	711	814	743	807
Heat production (DM) ($kJ/kgTS^{0.62}d$)	894	1421	933	1408
Heat production (Protein) ($kJ/kgProtein^{0.62}d$)	2875	2208	3004	2189

between the two groups at both levels it was necessary to correct the HP-values to equal ME-intake for a direct comparison. This is possible because no dependence of the thermoneutral temperature on the feeding level was established. By correction of HP-values of the males to the energy intake of the females, the difference of HP between males and femals increases to 14.4 % (Table 8), but the consideration of the higher physical activity would lead again to a reduction of the difference. Consequently, from the data related to metabolic body mass it is impossible to derive an essential correlation between HP and PFR.

It seems, however, that the relation to metabolic body mass is not correct, because the difference in the ingested dry matter between the both groups was quite high (Table3). The relation of HP to water-free metabolic body mass leads to an increase of the difference to 59 % (Table 8). This value expresses a marked difference in HP and corresponds with the strongly different PFR. It can be concluded that for the comparison of HP-values at different body composition the different dry matter contents of the body must be considered. Webster (5) opined that the metabolic protein mass is a better base for the comparison of fat and protein rich animals. By using this base for fat and lean rats the differences in HP disappeared, which were found in relation to metabolic body mass. When the HP-values of the presented experiments are related to metabolic protein mass, the ratio changed to a higher HP of the female animals of about 28 % (Table 8). This finding can be interpreted that the fat contributes partly to the metabolic activity. However, the absolute fat content of the female animals was the 5.6 fold of the males (females: 35.9 kg, males: 6.6 kg). Consequently, the part of HP/kg fat tissue can be only small in comparison to protein. The main part is determined by the protein, that means, the absolute protein mass. So, the correlation of the HP with the PFR is not justified.

The influence of the ambient temperature on the HP is smaller in the female animals (Table 5) than in the males (Table 4). The higher part of back fat causes a better insulation, which leads to a lower thermoneutral temperature and at low temperatures (lower than the thermoneutral temperature) to a smaller part of thermoregulatory HP than in male animals. So, the decrease of the temperature leads to an increase of the difference in the HP between male and female animals. At 0 °C the difference would be 30 %. This result shows, that the observance of thermoneutral conditions is important, when the influence of the body composition on HP is investigated or interpreted.

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