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Functional stomach chamber strategy of red deer in relation to sex and mating season

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Summary

Stomach chambers of hinds (H), winter (WB) and rutting bulls (RB) of red deer (Cervus elaphus L.) were examined during the fall hunting season and wintertime. The stomach content of bulls was the highest (P>0.01) in winter (WB, 19.0 kg) and the lowest (RB, 3.7 kg) during rutting season. But the relative food content for total stomach (I_R index) as well as for rumen (180.2), abomasum (4.1) and omasum (7.4) was the greatest in hinds (H). However, the total stomach tissue (SCT) weight increased together with the enhancement of carcass weight (C_W), the percentage of participation relative SCT to C_W, thus by contrast the I_W index was the lowest P>0.01 in the heaviest RB (2.23). For WB it equaled 4.03 and for H - 3.99. Moreover, the total stomach volume, I_V index was the highest in hinds (82.90) and differed P>0.01 from that of RB which was the lowest (36.70). Similar trends occurred in the individual stomach chamber areas. The greatest I_T index-expressing ratio of stomach tissue weight to its area was markedly (P>00.5) higher in RB (0.20) in comparison to the remaining groups (WB 0.11, H 0.09), indicating a thicker and shrunken stomach wall.

The study demonstrates that variability in the stomach chambers (its characteristics and indexes) of female and male deer depend upon seasonal physiological changes, including the most important season, which is the mating season. Stomach size and its individual chamber indexes are consequences of diet segregation and different feeding behavior between sexes, including foraging activity of males in the rutting season.

Keywords: red deer (Cervus elaphus L.), stomach

Wild polygynous ruminants, including red deer (*Cervus elaphus* L.), have been recognized as possessing sexual dimorphism that is associated with various spatial occupations and different activity outside the mating season (1, 2, 14, 15, 18, 22). Usually foraging behavior between sexes and the seasonal feed environment change the result in sexual dimorphism correlates with body weight and condition (8, 15, 17, 26). This is important especially since those factors can affect deer performance as well as enable the survival of wild ruminants in the severe winter season. Moreover, a wide range of forage variety and availability has a substantial impact on red deer food intake. Relatively lower food consumption during winter is associated with short photoperiods (16, 18). However, on broader the size of forage intake is scale-determined by other important factors independently of the season. It can be regulated directly by digestive system capacity (5-7, 15). The main fore-stomach chambers of such rumen controls the feeless mechanism of the digestive system in deer, resulting in the intake of energy, dry matter, and, finally, growth and body condition status (7, 12). Selectivity factors expressing how much longer particles are retained in the digestive tract and whether passage rate depends on body size alone are considered by investigations (5, 6, 13, 20, 23). Body size is regarded as a major factor in the nutritional ecology of deer due to the relative energy requirements decreasing with increasing metabolic body size $^{(0.75)}$. Therefore sexual dimorphism and allometric difference between sexes may be related to differences in activity patterns as well as sexual segregation (2, 3, 8, 17). However, whether the behavioral activity between female and male cause body size (mass) of individuals is not clearly proved (2). Moreover, it is assumed that those animals have an adaptation of their morphology and physiology, which is in some way specialized for forage utilization (10-12, 16). This may be explained by the variation in the diet consumed and optimal retention time in the digestive system (26). The rumen volume is isometric with body size with the result that large herbivores like bulls can survive on lower quality forage in comparison with smaller hinds (3, 6, 12, 14). However, the precision of stomach chamber characteristic parameters and differences among deer during mating and out of mating season is not fully known. Thus, the present study was conducted to find out differences in the structure of the digestive tract,

mainly in stomach chambers in deer, in the relation to sexual and physiological status of those animals.

Material and methods

Forty deer were shot by shotgun during the regular hunting season in the Bieszczady mountain area, covered by deciduous forest, in the South-East of Poland. Twenty hinds and ten bulls were killed in the wintertime (November--January) and ten bulls were shot in the fall during rutting season (September-October). Before any measurements were taken each stomach had had the fat and fascias removed. The reticulum was divided into the reticulo-rumen and the reticulo-omasum vent. The omasum and omaso--abomasum vent were excised from the abomasum. Each stomach compartment was weighed together with its contents. Next, the contents were removed, the stomach was rinsed in water, slightly dried with paper, and weighed to the nearest gram. Subsequently, each stomach chamber was dried for six days at 60°C, and then weighed again for dry matter calculation. Each stomach chamber area was measured after the individual chamber had been spread out on paper. The area was measured using planimetria.

After the internal organs had been removed, the carcass was weighed. Data were subjected to analysis by the ANOVA procedure (SAS, 1995) (25). The differences between means were determined by t-test of Student on two levels of significant $P < 0.05$ and $P < 0.01$.

Results and discussion

The study indicates large differences in stomach structure between hinds and bulls both in winter and mating season (tab. 1). The variability of stomach characteristics, including its volume, absorption area or total weight, reflects drastic seasonal changes: thus the explanation of variation between sexes needs special verification. As an example, in hinds rumen size decreased by 30-40% during pregnancy, but reached its previous size just after the delivery of the calf, that is in 3-4 weeks (11, 12). The most drastic change among bulls takes place during the rutting season, when males spend only 5% of their time foraging. It is almost seven fold less than in spring and summer (9). Bobek et al. (4) have reported that because bulls lose their appetite during the rutting season, they markedly reduce daily food consumption. Changes in behavior are responsible for the drastic differences in stomach structure and its content in bulls shot in the regular hunting and rutting season, as well as in hinds (tab. 1). The food content of the stomach was the largest in bulls of the winter (WB; ca 19.0 kg), but the least in males during rutting season (RB; ca 4.0 kg). Thus that parameter was much lower even than that of hinds (H), where total food content in H stomach was approximately 16 kg. The content of food in each stomach chamber relative to its content in the total stomach (%) in examined deer differed with markedly greater amount shown both in hinds and winter bulls, formative for rumens on above 91% (tab. 1). The least food content of rumen was found in rutting bulls (69.5%).

Tab. 1. The percentage of total stomach contents, area and weight represented by individual stomach chambers

Item	Hinds		Winter bulls		Rutting bulls	
	g	%	G	%	G	%
Stomach Chamber Content (SCC)						
Reticulum	480	2.8[b]	760	3.8[b]	270	11.9[a]
Rumen	14 700	91.1[a]	17 300	91.2[a]	3200	69.5[b]
Omasum	610	3.9	480	2.4	50	4.6
Abomasum	350	2.2[b]	430	2.8[b]	190	14.0[a]
Total stomach	16 140	100	18 970	100	3710	100
Stomach Chamber Tissue weight (SCT)						
Reticulum	242	7.5	299	6.8	270	7.2
Rumen	2496	75.1	3545	76.1	2790	72.2
Omasum	285	8.4	401	8.8	289	7.5
Abomasum	309	9.2	364	8.3	483	12.6
Total stomach	3332	100	4609	100	3776	100
Stomach Chamber Surface (SCS)						
	cm^2	%	cm^2	%	cm^2	%
Reticulum	703	10.1	855	10.2	657	10.6
Rumen	5042	73.6	6148	75.0	4447	68.8
Omasum	339	5.0	387	4.7	304	4.7
Abomasum	788	11.3	819	10.1	992	15.9
Total stomach	6872	100	8209	100	6400	100
Water Content in Chamber Tissue (WCCT)						
	%		%		%	
Reticulum	81.2		80.4		77.5	
Rumen	80.7		81.3		72.5	
Omasum	80.0		82.0		72.4	
Abomasum	79.7		78.0		74.5	
Total stomach	80.3[a]		81.0[a]		70.1[b]	

Explanations: a, b – $P < 0.05$ in the same line

However, RB had relatively high contents of food in the reticulum (11.9%) and omasum (14%), which were in contrast to low values of these indicators in the rest of the animals (tab. 1).

Some earlier investigations reported by British scientists indicate that bulls (thus heavier individuals) had more feed in the rumen relative to their body weight (g of food content per kg carcass) than hinds (23), whereas our study shows that heavier rutting bulls and winter males had relatively less food in the rumen than lighter hinds (fig. 1). Thus the highest rumen content expressed by I_R index was found in hinds. Index I_R shows the ratio of stomach chamber content (SCC) of individual compartments to carcass weight (C_W) that was the highest for rumen in the lightest hinds in comparison to winter bulls, whereas in rutting bulls only the heaviest individuals had the lowest (fig. 1). Compared to other groups, the lowest I_R rumen values were

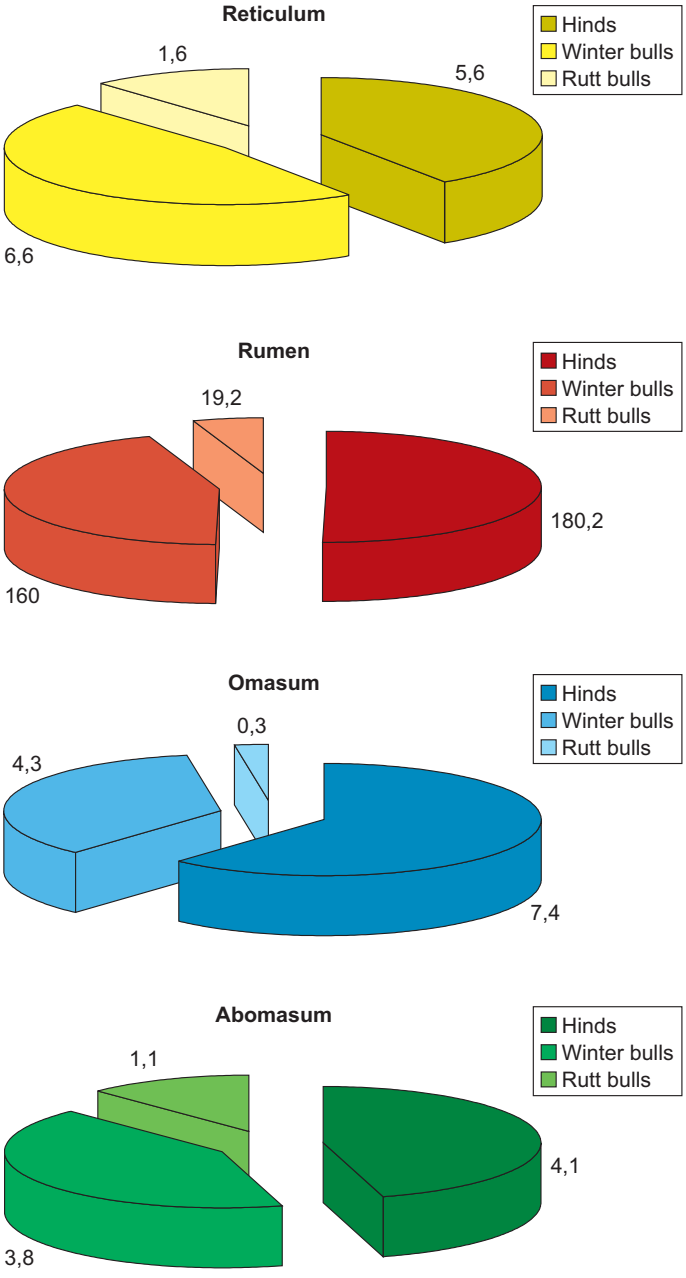

Fig. 1. Stomach chamber indexes I_R = SCC x $(C_w)^{-1}$ (Ratio SCC stomach chamber content, g to C_w carcass weight, kg)

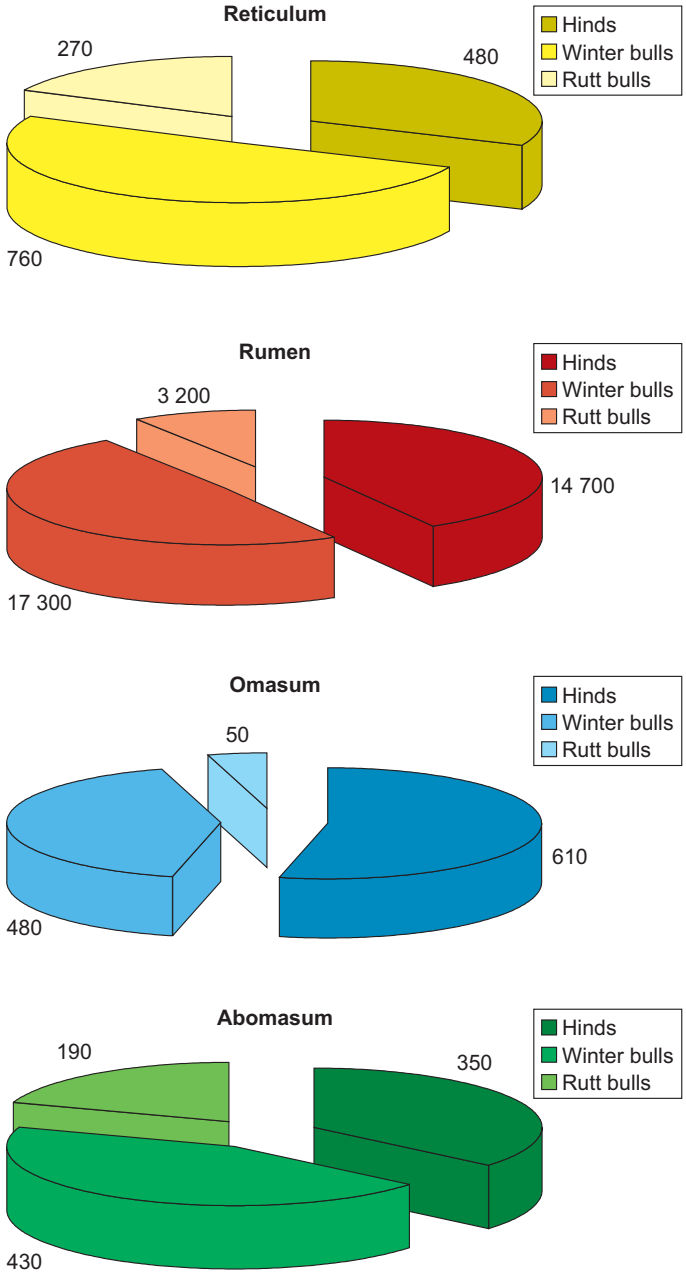

Fig. 2. The individual stomach chamber content (g)

recorded for bulls in the rutting season (fig. 1). The highest value was in hinds followed by bulls in winter. A similar pattern was found in relative abomasum and omasum size. The relative weight of food contents in the abomasum and omasum were the largest in hinds, respectively 4.1 and 7.4, in comparison to the winter bulls (3.8 and 4.3) and rutting bulls (fig. 1).

These results could have been caused by various levels of water content in rumen contents in hinds and bulls. The higher water amount could indicate greater food intake (23). Staines et al. (23) report that bulls, thus heavier individuals, had more feed in the rumen relative to their body weight than hinds. They suggested that higher water content in bull's food influences its greater intake. However, our study has provided different results. It may be a feature characteristic for hinds of the Bieszczady mountains that most of them still produce milk in early winter. This explains their stomach indexes and its characteristics. Moreover, lactating hinds can possess similar or even higher relative rumen content mass to that of bulls (23). It is not excluded as a possibility that those factors had a decisive effect on the hinds' stomach characteristics and its indexes.

Lower food content (3710 g) and relatively higher empty (net) weight of stomach (3776 g) in rutting bulls in comparision to hinds (respectively 16 140 g and 3332 g) are more likely associated with the activation of energetic reserves contained in the stomach walls, which shrunk and became thicker.

Similar differences were found between the individual stomach chambers (tab. 1). The feed mass contents of the rumen, reticulum and abomasum were the highest in bulls of the winter season in comparison to hinds, but males of the rutting season had the lowest levels, even smaller than hinds (fig. 2). The opposite results were found concerning the omasum chamber, the contents of which were the highest in hinds (610 g) relative to the rest of the examined group of deer, respectively in winter (480 g) and rutting (50 g) bulls (tab. 1, fig. 2). Those variations can be explained by the different category of food consumed by those animals. Moreover, feed particles were smaller in hinds' stomach contents, which suggests that hinds consumed better quality food (5, 7-9). It suggests that heavier individuals should have a better-developed rumen and reticulum, but worse omasum and abomasum relative to their body weight. Our results are supported by other studies (23) conducted on the comparison of hind's and bull's forage intakes. They have shown that in contrast to bulls, hinds consume less heather but more grasses and forage originating from the region of better-fertilized soil, thus rich in nutrients. Therefore they have an intake of better food quality. Such characteristics of deer diet again suggest differences in stomach size and its determined parameters, indicating a larger rumen and reticulum food content in the heavier males than in hinds (10, 15, 16, 20, 23).

The relative area of the rumen (SCS) to the total stomach surface was the highest in WB but the lowest in RB bulls (tab. 1). The lower SCS of rumen in RB in comparison to H and higher rumen tissue weight (SCT) in rutting bulls equal 2790 vs. 2496 g in hinds indicates differences in stomach wall thickness (tab. 2). The highest I_T index presenting the ratio of stomach chamber tissue mass (SCT) to stomach chamber surface (SCS) points to much thicker individual stomach walls in rutting bulls (0.20) in comparison to the rest of the group of deer, i.e. in winter bulls 0.11 and in hinds 0.09 (tab. 2). It adds evidence that the rumen wall in rutting bulls was much thicker and shrunken. There were found differences $P < 0.05$ between examined deer (tab. 2).

This can explain and confirm male foraging behaviors during rutting season, which is limited. As mentioned earlier, bulls lose their appetite during the rutting season thus markedly reducing their daily food consumption (4). Therefore, such a change in foraging behavior is reflected in stomach structure and its characteristics. As expected, the relative mass of rumen tissue (SCT) increased with enhanced body mass (tab. 1). Although in the case of rutting bulls only the heaviest individuals SCT had lower value than had had them of winter bulls, respectively 2790 g and 3545 g. Total stomach and rumen increases do not necessarily mean an increase in total stomach and rumen volume, but only an enhancement in wall thickness (I_T index; tab. 2), because the relative total stomach area and

Tab. 2. Stomach chamber indexes. Average carcass weight of hinds 83.5 kg, winter bulls 112.3 kg and rutting bulls 166.5 kg

Item	Hinds	Winter bulls	Rutting bulls
I_W SCT × 100 C_W %			
Reticulum	0.29	0.26	0.16
Rumen	2.97	3.10	1.70
Omasum	0.34	0.35	0.18
Abomasum	0.37	0.32	0.29
Total stomach	3.99^A	4.03^A	2.23^B
I_V SCS $cm^2 \times kg^{-1}$ C_W			
Reticulum	8.5	7.6	3.9
Rumen	61.4	54.9	27.3
Omasum	4.1	3.4	1.9
Abomasum	9.4	7.4	6.0
Total stomach	82.90^A	73.40^A	36.70^B
I_T SCT SCS g × $(cm^2)^{-1}$			
Reticulum	0.06	0.07	0.10
Rumen	0.09	0.11	0.20
Omasum	0.17	0.18	0.28
Abomasum	0.08	0.10	0.13
Total stomach	0.09^a	0.11^a	0.20^b

Explanations: C_W – carcass weight (kg), a, b – $P < 0.05$ in the same line, A, B – $P < 0.01$ in the same line

rumen surface were in reverse proportion to the carcass weight (I_V index, tab. 2). The well known index of relative tissue stomach mass or its individual chambers I_V are not always properly and accurately indicative of stomach size (volume) as it has been suggested (6, 11, 24). This was confirmed by the I_W and I_V indexes for hinds, and WB as well as RB (tab. 2). The relative total stomach area to carcass weight (I_V) was the greatest in hinds and significantly ($P < 0.01$) lower in rutting bulls (tab. 2). The same total stomach I_V value in winter bulls (73.40) was markedly higher than for rutting bulls. The use of relative tissue stomach weight or its individual chamber as well as stomach content weight relative to carcass do not necessarily provide a good indication of volume as it was suggested by some authors (24). Similarly, like I_M index not always stomach size expressed by I_T index have to be a good indicator of the proper stomach volume in deer.

Moreover, the stomach content relative to carcass does not necessarily make a good indicator of stomach volume as it has been suggested by some authors earlier (10, 24), because the relative area of the total stomach and rumen I_V index were not in linear proportion to body weight (tab. 2). The general rule is that together with increases of age and body weight, the rumen and reticulum are proportionally enhanced (6, 24, 26). The present results confirmed that with the exception of rutting bulls, the combined percentage of the rumen and reticulum, both in its weight and

absorption area in relation to the total stomach, were the largest in winter bulls (95% and 85.2% respectively) followed by hinds (tab. 1).

The results show some differences in water content in the total stomach tissue as well as in its individual compartments (tab. 1). The water content in the individual chamber tissue (WCCT) was varied by 72.4 to 82% in individual stomach chambers and generally its amounts were the lowest in rutting bulls. Differences between bulls of the rutting season (70.1) and the remaining group of animals were significant: $P < 0.05$ (tab. 1). Moreover, water content of each individual stomach chamber tissue was similar within each group. These data support other indexes presented earlier.

During the fall/winter season red deer inhabiting the Bieszczady mountain environments rich in nutrients, forage on feed consisting of leafy browsers, bushes and green leaves of blackberries (19, 21). The food availability and quality markedly influence stomach structure, consequently determining the degree of fatness in deer living in different environments, thus indirectly effecting the reproductive efficiency of individuals.

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