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Morphology of the Stomach and Intestines in Hybrids of European Bison and Domestic Cattle

[With 8 Tables]

Morphological observations and measurements of the stomach and intestines were based on material obtained from 21 hybrids of different generations of European bison crossbred with domestic cattle (15 ♂♂ and 6 ♀♀) from 6 months to 9 years old. The phenomenon of heterosis was found to exist in hybrids of the first generation (F_1), in relation to morphological characters and dimensions; characters of heterosis decrease in B_1 generation. In adult F_1 males stomach capacity is on an average 289.18 l, whereas in B_1 it is only 179.03 l. The small intestine in adult F_1 males is on an average 53.80 m in length and has a capacity of 82.41 l, whereas in B_1 the corresponding values are 43.24 m and 53.61 l. The large intestine in adult F_1 males is on an average 13.52 m long (cecum — 0.94 m) and has a capacity of 53.22 l, whereas in B_1 the corresponding values are 10.25 m and 28.03 l. The relative length of the small intestine in adult F_1 males is on an average 1 : 19.49, but in B_1 — 1 : 17.30; these data for the large intestine are respectively 1 : 4.90 and 1 : 4.10.

I. INTRODUCTION

Experiments on crossbreeding European bison and domestic cattle have been carried out in the Mammals Research Institute of the Polish Academy of Sciences at Białowieża since 1958. Two breeds of domestic cattle were used for crossbreeding — the Polish red and black and white lowland cattle (Dehnel, 1960, 1961; Demiaszkiewicz, 1961; Krasińska, 1963, 1967, 1969; Krasińska & Pucek, 1967). Up to the end of 1970 we obtained a total of 10 F_1 hybrids and 25 of the backcross generation ($^3/_4$ domestic cattle — B_1) and 8 of the B_2 generation ($^7/_8$ domestic cattle). In the earlier phases of the experiment the development of hybrids was traced by studying the results of measurements and body weight (Krasińska, 1969). These studies were supplemented by analysis of the characters of anatomical structure. From 1968—1969 22 hybrids from different generations were chosen in order to analyse the value for use of their meat, and hide, and the structure of internal organs and of the skeleton.

The present study is concerned with morphological analysis of the ventral part of the alimentary tract. Comparison has also been made of the structural characters of the stomach and intestines in hybrids and parental forms. A good knowledge has been obtained in this respect of one of the partners used for crossbreeding, *i.e.*, the European Bison (P i ę k o ś, P i l a r s k i & R o s k o s z, 1958; G i l l, 1968; P y t e l, 1969), but no anatomical data for the given breeds of cattle were found in literature.

II. MATERIAL AND METHODS

The material consisted of the stomach and intestines of 21 hybrids (Table 1) of the following origin: 5 adult individuals from the first generation (F_1), 10 adults

Table 1

Material examined.

No.	Name	Generation	Age, years	Measurements of body cm		Weight
				*A**	*a***	
			Males			
1	Fakir	F_1	5.0	275	210	841***
2	Farad	F_1	6.5	287	220	1015
3	Filip	F_1	8.0	266	188	885
4	Fest	B_1	0.5	184	118	263
5	Felon	B_1	0.5	183	130	286
6	Feld	B_1	1.5	226	150	380
7	Fellach	B_1	2.0	240	165	500
8	Festyn	B_1	2.5	240	171	540
9	Fen	B_1	3.5	261	160	580
10	Feg	B_1	3.5	248	169	552
11	Feb	B_1	3.5	257	160	540
12	Fey	B_1	4.0	248	170	675
13	Fetysz	B_1	4.5	263	171	567
14	Fez	B_1	4.5	249	170	613
15	Fenix	B_1	5.5	226	159	520***
			Females			
1	Filutka	F_1	7.0	229	145	490
2	Fama	F_1	9.0	234	160	532
3	Felly	B_1	1.0	195	130	279
4	Ferma	B_1	1.5	191	134	284
5	Fema	B_1	2.5	222	145	330
6	Fela	B_2	2.5	223	147	429

* Body length (distince between the upper edge of the nosolabial plate and the tail basis).

** Oblique length of the trunc (distance between the scapulo-humeral articulation and the ischiadic tubercule).

*** Castrates.

backcrosses ($^3/_4$ cattle blood — B_1). The other juvenile individuals were obtained from generation B_1, and one from B_2. There were 15 males in the study material (including 2 castrates) and 6 females. Body measurements were made after P i ę k o ś

et al. (1958) and Liskun (1949). Measurements of stomach and intestinal capacity and length of intestines were made by the method used earlier on for the European bison (Pytel, 1969). The field conditions for analysis made some degree of simplication necessary, for instance separate measurements were made only for total volume of the compartments: rumen-reticulum and omasum-abomasum (Table 3).

III. RESULTS

1. Morphological Observations

The relatively low caudal pillar in the rumen (6 cm) is remarkable. The total number of omasal laminae varies from 141 to 190 (Table 2a). For comparative reasons this table does not include the six-order laminae occurring in 9 cases — folds which are sometimes only visible after removing stratified squamous epithelium, and sometimes attain a width of 0.5 cm. The numbers of these laminae vary greatly (3—71). In two cases the phenomenon was observed of branching of the free margins of the longest laminae usually numbering from 11—12, and the consequent

Table 2

Number of omasal laminae (*a*) and abomasal spiral folds (*b*) in F_1 and B_1 hybrids.

Order of laminae*	♂♂ (N = 15)				♀♀ (N = 6)			
	O. R.	Avg.	S. D.	C. v.	O. R.	Avg.	S. D.	C. v.
				a				
1	10—14	11.60	±1.08	9.31	10—14	12.00	±1.29	10.75
2	11—15	12.67	±1.34	10.58	11—15	13.00	±1.53	11.77
3	21—30	24.54	±2.43	9.91	21—29	25.00	±2.38	9.52
4	40—55	46.67	±2.26	4.84	40—51	47.17	±3.58	7.57
5	49—86	73.67	±9.34	12.66	76—82	79.17	±1.81	2.29
Total	141—190	169.40	±14.27	8.42	159—185	176.33	±8.39	4.76
				b				
	17—25	20.80	±2.01	9.66	16—20	18.00	±1.28	7.71

* Figures from 1 to 5 indicate respectively first to fifth — order laminae.

number of lower laminae is characterized by the highest variability coefficient among the shortest laminae (fifth-order) in males and of laminae second in order of length (second-order laminae) in females.

The average number of spiral folds of the abomasum (Table 2b) is 18 (females) and 20.8 (males), these figures not including the so-called secondary folds encountered in 8 of the individuals examined, in which they number from 1—2. The largest of the folds has an average height of 9.5 cm.

A transverse fold occurs between the folds lying nearest the smaller curvature, in the vicinity of the omaso-abomasal opening. The degree

of its development varies, and it attains a considerable height, up to 4 cm, in 11 hybrids. The extent of mucosa of abomasum on the surface of the fold running towards omasum, is 1—2.8 cm.

Ansa spiralis coli in the majority of cases (17) has two centripetal and centrifugal gyri, in 3 cases (all from generation B_1) — one and a half gyri, in one case (generation F_1) two and a half gyri. In this last case this is confirmed in the exceptionally long large intestine — 14.90 m, of which the colon forms more than 13 m.

On the final most peripherally situated centrifugal gyrus an U-shaped accessory loop was found in two males, while the gyrus itself in 9 cases

Table 3

Capacity of stomach compartments (in litres and % of capacity of whole stomach.

Group	N		Whole stomach	Rumen + Reticulum		Omasum + Abomasum	
				Abs.	%	Abs.	%
Males							
Calves B_1	2	min	41.74	31.98	77	9.76	22
6 month		max	62.22	48.80	78	13.42	23
		$\bar{x}$	51.98	40.39	78	11.59	22
Young B_1	3	min	166.40	136.22	80	30.18	18
1.5—2.5 yrs.		max	210.00	168.75	82	41.25	20
		$\bar{x}$	185.88	150.82	81	35.06	19
Adult B_1	7	min	136.47	101.80	75	31.25	17
3.5—5.5 yrs.		max	215.94	170.50	83	51.24	25
		$\bar{x}$	179.03	141.74	79	37.29	21
Adult F_1	3	min	235.34	189.40	80	45.92	17
5—8 yrs.		max	335.50	280.20	83	57.50	20
		$\bar{x}$	289.18	236.27	82	52.91	18
Females							
Young B_1+B_2	4	min	71.98	50.02	70	17.50	16
1—2.5 yrs.		max	162.34	133.48	84	28.86	30
		$\bar{x}$	117.53	94.00	80	23.54	20
Adult F_1	2	min	162.31	129.91	80	32.40	19
7—9 yrs.		max	213.50	172.02	81	41.48	20
		$\bar{x}$	187.90	150.96	80	36.94	20

parted for 5—10 cm from the whole of *ansa spiralis coli*. In one case *ansa spiralis* takes a form intermediate between a disc and a cone.

2. Results of Measurements

2.1. Stomach. As can be seen from the date in table 3 the average capacity of the stomach in adult B_1 males is 179 l and is 38% lower than in adult F_1 males, the rumen and reticulum being 40% smaller, omasum and abomasum — 30%.

Table 4

Relative capacity of stomach and intestines: data obtained from ratio of absolute capacity to oblique trunk length obtained by measurement α — ml/cm (1); absolute capacity to body weight l/kg (2).

Group	N		Stomach						Intestine						Alimentary tract	
			r+re		o+ab		Total		Small		Large		Total			
			1	2	1	2	1	2	1	2	1	2	1	2	1	2
Males																
Calves B_1	2	min	271	0.12	83	0.04	354	0.16	200	0.09	81	0.04	295	0.13	649	0.29
6 months		max	375	0.17	103	0.05	479	0.22	243	0.11	96	0.04	324	0.15	802	0.37
		$\bar{x}$	326	0.15	93	0.04	419	0.19	222	0.10	88	0.04	310	0.14	729	0.33
Young B_1	3	min	863	0.27	197	0.06	1060	0.34	322	0.12	134	0.05	456	0.17	1566	0.51
1.5—2.5 yrs.		max	1023	0.36	250	0.08	1273	0.44	367	0.13	179	0.06	546	0.18	1776	0.62
		$\bar{x}$	931	0.32	216	0.07	1147	0.39	347	0.12	157	0.05	504	0.17	1651	0.56
Adult B_1	7	min	636	0.18	185	0.06	853	0.24	262	0.07	134	0.03	433	0.13	1358	0.38
3.5—5.5 yrs.		max	997	0.30	301	0.08	1270	0.38	451	0.11	219	0.07	587	0.15	1857	0.52
		$\bar{x}$	854	0.25	226	0.07	1079	0.32	322	0.09	169	0.05	492	0.14	1571	0.46
Adult F_1	3	min	1007	0.21	244	0.05	1252	0.26	360	0.08	226	0.05	586	0.13	1838	0.39
5—8 yrs.		max	1274	0.28	274	0.07	1525	0.35	444	0.11	286	0.06	702	0.18	2203	0.53
		$\bar{x}$	1147	0.26	257	0.06	1404	0.32	400	0.09	258	0.06	658	0.15	2062	0.47
Females																
Young B_1+B_2	4	min	385	0.18	131	0.06	554	0.26	268	0.10	101	0.04	370	0.14	972	0.44
1—2.5 yrs.		max	920	0.40	199	0.09	1120	0.49	303	0.14	147	0.06	420	0.19	1540	0.68
		$\bar{x}$	676	0.28	169	0.07	845	0.35	282	0.11	120	0.05	402	0.17	1247	0.52
Adult F_1	2	min	812	0.26	202	0.07	1174	0.33	228	0.08	144	0.05	372	0.12	1386	0.45
7—9 yrs.		max	1075	0.32	259	0.08	1334	0.40	544	0.16	306	0.09	850	0.26	2178	0.65
		$\bar{x}$	943	0.30	231	0.07	1174	0.37	386	0.12	225	0.07	611	0.19	1785	0.56

Abbreviatons: r — rumen, re — reticulum, o — omasum, ab — abomasum

In respect of the index — capacity: oblique length of the trunk (Table 4) of adult males of the generations compared this is 23% lesser in B_1 (rumen and reticulum — 26%, omasum and abomasum — 12%). The index — capacity: body weight differs in adult males of the two generations, if the stomach as a whole is taken into consideration (rumen and reticulum in B_1 are 4% smaller than in F_1, while omasum and abomasum are 17% larger in B_1 than in F_1).

Capacity of the stomach in adult females is 187.9 l, which forms 65% of the stomach capacity of males of this same generation (F_1) and 84% of relative capacity (ml/cm). The index — capacity: body weight exhibits

Table 5

Length of different parts of the intestine in m. Observed ranges and averages are given.

Group	N	Small intestine		Large intestine		Whole intestine	Small/large intestine
		Abs.	%	Abs.	%		
Males							
Calves B_1	2	33.96—35.93	82—85	6.42— 7.53	15—18	41.49—42.35	4.51:1—5.60:1
6 months		34.94	83	6.98	17	41.92	5.00:1
Young B_1	3	36.91—46.89	81—84	8.50—10.32	16—19	45.60—57.21	4.25:1—5.13:1
1.5—2.5 yrs.		42.47	82	9.17	18	51.64	4.63:1
Adult B_1	7	40.28—45.98	79—82	9.52—11.38	16—21	49.80—55.84	3.75:1—4.73:1
3.5—5.5 yrs.		43.24	81	10.25	19	53.49	4.22:1
Adult F_1	3	50.33—60.40	79—80	12.47—14.90	20—21	63.14—75.30	3.81:1—4.06:1
5—8 yrs.		53.80	80	13.52	20	67.32	3.98:1
Females							
Young B_1+B_2	4	33.78—39.07	79—82	7.37— 9.88	18—21	41.15—48.95	3.83:1—4.69:1
1—2.5 yrs.		36.31	81	8.59	19	44.90	4.23:1
Adult F_1	2	41.79—42.18	77—79	11.24—12.68	21—23	53.24—54.47	3.30:1—3.75:1
7—9 yrs.		41.98	78	11.96	22	53.94	3.51:1

completely different behaviour: in females it is 16% greater than in males, the compartments of the stomach measured forming almost identical percentages of the total value.

2.2. Intestines. The small intestine in adult F_1 males is 53.8 m long and capacity is 82.4 l, whereas in generation B_1 the results of these measurements are lower, by respectively 20% and 35% (Table 5 and 7). Complete confirmation of this is provided by relative length of the intestine (Table 6) and partially by relative capacity, which is 20% lower in generation B_1 than in F_1 (ml/cm), with almost equal capacity accepted according to weight criteria — l/kg (Table 4).

The large intestine in adult F_1 males is 13.52 m long (0.94 m of which is formed by the cecum) and in the second generation (B_1) is 24% shorter

Table 6

Ratio of body length obtained from measurement *A* and oblique length of trunk (measurement *a*) to intestinal length.

Group	N		*A*			*a*		
			Small intestine	Large intestine	Whole intestine	Small intestine	Large intestine	Whole intestine
Males								
Calves B_1	2	min	1:18.46	1:3.51	1:22.55	1:27.64	1:4.94	1:32.58
6 months		max	1:19.63	1:4.09	1:23.14	1:28.78	1:6.38	1:35.16
		$\bar{x}$	1:18.99	1:3.79	1:22.78	1:28.18	1:5.63	1:33.81
Young B_1	3	min	1:16.33	1:3.54	1:20.18	1:24.61	1:4.97	1:30.40
1.5—2.5 yrs.		max	1:19.54	1:4.30	1:23.84	1:28.42	1:6.25	1:34.67
		$\bar{x}$	1:18.07	1:3.90	1:21.97	1:26.22	1:5.66	1:31.88
Adult B_1	7	min	1:16.18	1:3.82	1:20.00	1:23.69	1:5.60	1:29.29
3.5—5.5 yrs.		max	1:18.71	1:5.04	1:23.75	1:28.09	1:7.16	1:34.90
		$\bar{x}$	1:17.30	1:4.10	1:21.40	1:26.05	1:6.17	1:32.22
Adult F_1	3	min	1:17.54	1:4.60	1:22.14	1:22.88	1:6.00	1:28.88
5—8 yrs.		max	1:21.96	1:5.42	1:27.38	1:26.95	1:7.10	1:35.86
		$\bar{x}$	1:19.49	1:4.90	1:24.39	1:26.12	1:6.56	1:32.68
Females								
Young B_1+B_2	4	min	1:15.74	1:3.78	1:19.85	1:23.88	1:5.67	1:30.11
1—2.5 yrs		max	1:19.52	1:4.45	1:23.68	1:27.82	1:6.81	1:33.76
		$\bar{x}$	1:17.46	1:4.13	1:21.59	1:26.12	1:6.18	1:32.30
Adult F_1	2	min	1:17.86	1:4.91	1:23.28	1:26.12	1:7.03	1:33.39
7—9 yrs.		max	1:18.42	1:5.42	1:23.33	1:26.36	1:7.92	1:34.04
		$\bar{x}$	1:18.09	1:5.16	1:23.25	1:26.24	1:7.48	1:33.71

Table 7

Capacity of different parts of intestines (l). Observed ranges and averages are given.

Group	N	Small intestine		Large intestine		Whole intestine	Small/large intestine
		Abs.	%	Abs.	%		
Males							
Calves B_1	2	23.59—31.56	68—75	10.51—11.27	25—32	34.86—42.07	2.09:1—3.00:1
6 months		27.58	72	10.89	28	38.46	2.53:1
Young B_1	3	48.30—62.77	67—71	20.18—30.59	29—33	68.48—93.36	2.05:1—2.39:1
1.5—2.5 yrs.		56.28	69	25.36	31	81.64	2.22:1
Adult B_1	7	44.82—76.69	54—77	21.25—37.46	23—46	71.82—99.80	1.20:1—3.32:1
3.5—5.5 yrs.		53.61	65	28.03	35	81.64	1.91:1
Adult F_1	3	86.35—93.20	58—63	42.56—62.91	37—42	110.23—149.26	1.37:1—1.72:1
5—8 yrs.		82.41	61	53.22	39	135.63	1.55:1
Females							
Young B_1+B_2	4	35.97—41.78	65—73	13.59—21.35	27—35	54.39—60.97	1.86:1—2.65:1
1—2.5 yrs.		39.20	70	16.63	30	55.82	2.36:1
Adult F_1	2	36.49—87.02	61—64	23.04—48.92	36—39	59.53—135.94	1.58:1—1.78:1
7—9 yrs.		61.76	63	35.98	38	97.74	1.72:1

(Table 5). The relative length of this intestine also confirms this (Table 6). In respect of capacity, however, this is 47% less in the second generation than in the first — absolute measurement and 44% and 17% — relative measurements (Table 7 and 4).

When adult males are compared with females of the first generation (F_1) it will be seen that the latter have a shorter small intestine (22% shorter) and large intestine (12% shorter), as far as absolute measurements are concerned (Table 5). In respect of absolute capacity this is 25% less in females than males (small intestine) and 32% (large intestine) — Table 7, whereas all indices of relative capacity of the small and large intestine (Table 4) and length of large intestine (Table 6) are greater in females than in males of the same age group and the same generation.

IV. DISCUSSION

The omasum in hybrids differs from that in European bison, not only as the result of six-order laminae occurring in some cases, but primarily because of the greater number of laminae in the various orders. The

Table 8

Comparison of stomach and intestinal capacity and intestinal length in adult bisons, hybrids and domestic cattle (European bison = 100%).

Species or generation	Stomach		Small intestine			Large intestine			Ref.
	Capacity		Length	Capacity		Length	Capacity		
	l	ml/cm	m	l	ml/cm	m	l	ml/cm	
European bisons	100	100	100	100	100	100	100	100	(12)
Hybrids F_1 ♂♂+♀♀	191	172	120	132	121	106	122	112	
♂♂	217	187	131	145	125	109	141	122	
Hybrids B_1 ♀♀	143	166	102	114	113	100	91	92	
♂♂	133	143	105	94	100	83	75	80	
Domestic cattle	155*	—	100	111	—	81	72	—	(1)

* Acc. to Frank (from Schmaltz, 1894).

transverse fold at the omasoabomasal opening, which has been described in the European bison (Pytel, 1969), occurred in half of all cases in hybrids. The number of spiral folds of the abomasum in hybrids is far greater than in cattle, and is only slightly higher than in the European bison (Pytel, 1969). The number of gyri in *ansa spiralis coli* in hybrids allocates them to an intermediate position between the European bison and domestic cattle (Smith & Meadows, 1956).

Stomach capacity in adult F_1 hybrids is almost twice greater than that of European bison (Table 8); it also exceeds data for domestic cattle, approaching that in the group of old bullocks with trunk length of 170—205 cm (Schmaltz, 1894). In the second generation of hybrids (B_1) stomach capacity is smaller than in cattle. Stomach capacity per 100 kg of body weight is about 6—8 l greater in hybrids than in European bison (Wróblewski, 1927; Gill, 1968; Pytel, 1969).

The small intestine in F_1 hybrids considerably exceeds data for cattle and European bison in respect of males, while differences are smaller in respect of females (Table 8). The relative length of the small intestine confirms the above conclusion. Adult males of the second generation (B_1) have a shorter and less capacious small intestine than in the first generation, but even so it is longer than in F_1 females, and than also in European bison and cattle. The capacity of the small intestine in B_1 hybrids decreases below the values characteristic of cattle.

The large intestine in adult F_1 females occupies an intermediate position between European bison and cattle in respect of capacity, but is greater (males) or equal (females) in respect of length to European bison and greatly exceeds that of cattle (Table 8). The relative length of the large intestine in F_1 hybrids is greater than in European bison and cattle in respect of the ratio to body length (measurement *A*) for males and females; it is only in relation to the oblique length of the trunk (measurement *a*) in female F_1 hybrids that the large intestine is longer than in European bison. The large intestine in second generation males (B_1) is considerably reduced but even so is longer and more capacious than in domestic cattle.

The ratio of the small intestine to the large in F_1 hybrids was on an average 3.80 : 1 (length) and 1.60 : 1 (capacity), occupying a position nearer the European bison — correspondingly 3.38 : 1 and 1.50 : 1 (Pytel, 1969) than domestic cattle — correspondingly 4.60 : 1 and 4.24 : 1 (Schmaltz, 1894).

The phenomenon of heterosis characteristic of inter-genera hybrids has already been observed previously in the first generation of Białowieża European bison and cattle hybrids (Krasińska & Pucek, 1967; Krasińska, 1969). One of the characters of this heterosis was intensive intrauterine development, manifested in considerable body weight at birth and rapid rate of development during the first year of life. Other characters in which heterosis of hybrids was revealed is their resistance to disease, great strength and capacity to withstand unfavourable climatic conditions. It should therefore be expected that the phenomenon of heterosis would be reflected in the internal structure of hybrids, and this is in fact the case. All results obtained from measure-

ments of stomach and intestinal capacity and of measurements of intestinal length in hybrids in generation F_1 exceed data for the parental forms. An exception to this is formed by some data for the large intestine, which are smaller in female hybrids than in female European bison, but this may be due to the small numbers in the groups compared.

Some of the morphological structures observed also point to the existence of the phenomenon of heterosis in the hybrids examined.

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MORFOLOGIA ŻOŁĄDKA I JELIT MIESZAŃCÓW ŻUBRA I BYDŁA DOMOWEGO

Streszczenie

Obserwacje morfologiczne oraz pomiary żołądka i jelit oparto na materiale pochodzącym od 21 sztuk różnych mieszańców żubra z bydłem domowym (15 ♂♂ i 6 ♀♀) w wieku od 6 miesięcy do 9 lat (Tabela 1).

U badanych mieszańców w pierwszym pokoleniu (F_1) stwierdzono istnienie wybujałości cech morfologicznych i pomiarów przewodu pokarmowego. W drugim pokoleniu (B_1) cechy heterozji zmniejszają się. U dorosłych samców F_1 pojemność żołądka wynosi średnio 289,18 l, podczas gdy u B_1 już tylko 179,03 l (Tabela 3). Długość jelita cienkiego osiąga średnio 53,80 m (F_1) i 43,24 m (B_1), natomiast jelita grubego — odpowiednio: 13,52 m i 10,25 m (Tabela 5). Względna długość jelita cienkiego samców F_1 wynosi średnio 1 : 19,49, zaś u B_1 — 1 : 17,30; dane te dla jelita grubego wynoszą odpowiednio: 1 : 4,90 oraz 1 : 4,10 (Tabela 6). Pojemność jelita cienkiego osiąga średnio 82,41 l (F_1) i 53,61 l (B_1), natomiast jelita grubego — odpowiednio: 53,22 l i 28,03 l (Tabela 7).