CXCVI. CHANGES IN THE COMPOSITION OF COW'S BLOOD AT THE TIME OF CALVING AND A COMPARISON OF THE BLOOD OF THE CALF WITH THAT OF ITS DAM.

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RELATIVELY little information is available in the literature as to changes which may occur in the composition of the blood of the cow about the time of calving or as to the relationship between the composition of the blood of the calf and of that of its dam. In a recent paper Hodgson, Riddell and Hughes [1932] state that the calf at birth has a high blood-sugar level, the average being 100 mg. per 100 cc. at 1-6 days old, and that this value falls steadily to about 55 mg. at 2 years, and similar results were obtained by Anderson, Gayley and Pratt [1930]. They give no comparison between individual calves and their dams. Schwarz and Metzler-Andelberg [1928] found no significant alteration in the sugar of cow's blood immediately after calving.

Bogert and Plass [1923] found that, in the human being, the serum-Ca of the newborn child was higher than that of the mother and usually exceeded the upper limit for normal adults, the values for the child and mother at birth being 10.9 and 9.1 mg. per 100 cc. respectively. They state that at the end of labour the maternal serum-Ca is below the normal level for non-pregnant women. Robinson and Huffman [1926] also report a higher figure for serum-Ca of the calf than of the dam and state that during the first week after calving the dam's serum-Ca rises whilst that of the calf falls. Green and Macaskill [1928] could find no significant difference between the calf and its dam with respect to serum-Ca. Wilson and Hart [1932] report a fall in the serum-Ca level of cows within 3 days of calving, stating it to be more usual in cows which have lactated before. According to Robinson and Huffman [1926] the inorganic P is lower in the dam's blood than in the calf's blood at birth, but rises to a maximum within 18 hours and then falls again, whilst that of the calf tends to rise throughout the first week. Green and Macaskill [1928], working with veld-bred cattle of low milk yield, found that the inorganic P of the blood of the calf at birth was appreciably higher than that of the mother and rose sharply in the first week, beginning to fall during the second month. Wilson and Hart [1932] note a fall in inorganic P at calving, but state that it is not so consistent as the fall in serum-Ca. Green and

Macaskill [1928] observed no significant difference between the blood-Cl of the cow and its calf, whereas Robinson and Huffman [1926] note a high blood-Cl in the cow at calving followed by a steady fall, and a lower blood-Cl level for the calf than for its dam.

In the course of work in progress here, designed to obtain normal figures for dairy cows at different stages in their life cycle and to determine the factors responsible for variations in the different values, advantage was taken of the calving period to obtain further information on (1) the changes occurring in the chemical composition of the blood of the cow, immediately prior to, at the time of, and subsequent to calving; (2) the relationship between the chemical composition of the blood of the calf and of that of its dam at calving and during the first week after calving.

METHOD.

The results recorded in this communication were obtained from the study of 12 normal calvings. All the cows were 6 years old and dropping their fifth calf, except Cow No. 20 which was 8 years old. They had all been on a steady diet and regime for 3 years. As far as possible, blood samples were drawn on successive days for 2-3 days before calving was expected, immediately after calving in all cases, and then daily for 6-7 days, all bleedings being made at a regular hour each day, except for the sample immediately prior to and as near to the time of calving as possible. When the calves were strong enough to stand bleeding, samples were taken at birth, and thereafter every second day for one week. Owing to the fact that some of the cows did not calve exactly on the expected date and did not always give clear enough indication of approaching labour, the data for the period prior to calving are not quite so complete as had been hoped for.

The blood samples were drawn from the jugular vein in the case of both cows and calves. The following analytical methods were adopted.

Blood-sugar. Hagedorn and Jensen's method [1920].

Serum-Ca. Kramer and Tisdall's method [1921; Tisdall, 1923].

Inorganic P. Briggs's modification [1922] of the Bell-Doisy method. The precipitation of the proteins for this and the blood-sugar was done in the byre immediately after the samples were drawn, all other work being done in the laboratory.

Chlorine. Whitehorn's method [1920-21] modified by filtering off the silver chloride precipitate through a dry filter and titrating an aliquot portion of the filtrate with thiocyanate, using a ferric indicator, prepared by boiling ferric alum with nitric acid, instead of the solid salt.

Non-protein-nitrogen (N.P.N.). Folin's method [1922].

The data for each individual cow and calf are shown in Table I. These figures have been averaged for the cows and the calves (omitting the calves from Cows Nos. 11, 12 and 16, from which samples could not be obtained at

Table I. *Composition of the blood of cows and their calves just before, at, and for the first week after calving.*

All values are stated in mg. per 100 cc.										
Days before or after calving	Blood- sugar	Serum- Ca	Inor- ganic P	N.P.N.	Chlorine	Blood- sugar	Serum- Ca	Inor- ganic P	N.P.N.	Chlorine
Cow No. 4.						Calf No. 4.				
2 before	75.88	11.45	3.63	30.78	334					
1 "	90.84	10.90	3.44	23.08	331					
Calving	88.20	10.95	3.33	23.90	313	133.96	14.30	6.37	24.39	312
1 after	77.64	9.45	3.55	33.15	335					
2 "	60.04	9.75	5.40	34.09	318	106.68	12.50	4.82	32.43	292
3 "	65.32	9.95	5.44	32.97	323					
4 "	56.52	10.00	6.03	24.19	332	95.24	12.40	5.97	35.08	286
5 "	67.08	10.45	5.58	25.44	333					
6 "	69.72	11.00	6.03	25.86	329					
Cow No. 5.						Calf No. 5.				
2 before	60.04	11.05	4.41	27.65	336					
1 "	60.04	11.50	4.38	28.15	339					
Calving	70.60	9.15	2.25	29.85	328	117.24	13.70	5.58	40.27	284
1 after	70.60	9.15	2.55	27.53	330					
2 "	60.04	9.05	3.63	30.61	340	104.92	11.15	5.58	40.81	278
3 "	57.40	9.30	4.96	26.68	302					
4 "	67.08	8.90	5.15	32.36	301	83.80	11.40	4.96	29.41	291
5 "	50.36	9.05	5.49	27.77	313					
6 "	49.48	8.85	6.49	28.99	309	89.96	11.85	6.43	31.58	301
7 "	53.00	8.85	5.62	24.49	316					
Cow No. 7.						Calf No. 7.				
1 before	59.16	11.05	2.52	24.00	335					
Calving	77.64	10.05	2.36	20.83	325	90.84	12.75	5.62	24.19	313
1 after	69.72	11.15	3.00	20.40	315					
2 "	60.04	10.45	4.62	26.66	328	100.32	11.90	5.58	25.97	306
3 "	59.16	11.70	5.97	24.00	327					
4 "	65.32	11.20	5.15	25.22	326	95.24	12.30	5.40	29.13	291
5 "	53.88	11.40	7.03	26.20	322					
6 "	60.04	10.90	5.36	25.00	331	92.60	12.40	5.82	28.99	306
Cow No. 10.						Calf No. 10.				
2 before	76.76	11.00	4.47	38.22	324					
Calving	67.96	8.35	3.01	35.08	320	106.68	13.75	5.00	43.38	282
1 after	61.80	9.05	3.67	31.41	320					
2 "	79.40	10.10	5.58	30.30	314	124.78	12.50	4.19	35.08	265
3 "	67.96	10.10	5.58	31.41	316					
4 "	60.92	10.50	5.92	34.09	321	124.28	14.05	5.53	34.68	270
5 "	53.00	10.05	6.68	34.09	322					
6 "	69.72	10.20	6.13	36.58	322	97.88	12.15	5.92	35.29	293
Cow No. 11.						Calf No. 11.				
2 before	72.36	11.55	6.31	24.89	335					
1 "	60.04	11.40	5.87	34.68	347					
Calving	90.84	8.65	3.75	28.02	330					
1 after	70.60	9.45	4.93	31.41	325					
2 "	68.84	9.50	4.85	33.15	325					
3 "	73.24	10.45	5.67	33.15	331	128.28	13.20	5.62	34.48	297
4 "	58.28	11.35	6.68	29.55	314					
5 "	66.20	—	7.10	29.13	313	132.20	—	6.55	39.73	295
6 "	78.52	11.25	6.37	27.15	324					
7 "	64.44	10.95	6.32	27.15	324					
Cow No. 12.						Calf No. 12.				
2 before	52.12	11.30	4.78	30.30	344					
1 "	52.12	10.45	—	30.61	345					
Calving	69.72	9.75	3.67	27.15	334	152.44	—	6.37	—	—
1 after	64.44	10.30	8.42	25.75	345	125.16	11.90	4.50	34.48	302
2 "	72.36	8.65	7.84	25.97	331					
3 "	63.56	9.05	6.61	26.90	339	118.12	11.85	4.75	39.20	298
4 "	66.20	10.30	5.97	25.97	333					
5 "	—	—	—	—	—	114.60	11.90	4.85	35.39	293
6 "	72.36	10.95	4.82	25.75	325					

Table I (*cont.*).

Days before or after calving	Blood- sugar	Serum- Ca	Inor- ganic P	N.P.N.	Chlorine	Blood- sugar	Serum- Ca	Inor- ganic P	N.P.N.	Chlorine
Cow No. 13.						Calf No. 13.				
1 before	67.08	10.75	4.02	25.54	338					
Calving	89.08	9.60	2.60	29.85	325	139.24	14.20	4.85	40.27	311
1 after	50.36	10.05	5.32	—	—					
2 "	70.60	10.25	5.15	34.09	312	130.44	12.55	5.58	29.55	299
3 "	62.68	9.85	4.93	32.26	318					
4 "	57.40	9.80	3.82	33.15	328	99.64	12.45	5.11	32.78	294
5 "	54.76	10.00	4.47	33.89	319					
6 "	56.52	10.45	3.55	33.89	345	94.36	12.00	6.49	32.97	288
7 "	56.52	10.50	4.32	29.85	324					
Cow No. 14.						Calf No. 14.				
Calving	65.32	9.55	4.89	27.41	337	122.52	14.10	5.07	40.27	301
1 after	52.12	8.75	6.75	27.65	336					
2 "	56.52	8.00	5.53	26.90	340	119.88	13.90	5.58	33.51	290
3 "	71.48	9.70	5.82	29.95	333					
4 "	55.64	9.60	5.72	31.41	324	111.08	14.00	5.77	35.08	278
5 "	55.64	9.40	5.87	30.61	329					
6 "	60.92	9.45	5.77	29.70	328	117.24	13.15	5.92	40.27	299
7 "	62.68	9.45	6.03	33.89	32					
Cow No. 15.						Calf No. 15.				
1 before	67.08	10.05	2.96	25.86	331					
Calving	88.20	8.30	2.28	27.03	335	111.96	12.25	4.78	34.48	291
1 after	55.64	7.20	1.76	33.15	343					
2 "	56.52	8.75	3.31	30.30	344	111.08	13.00	5.62	36.14	283
3 "	64.44	10.65	5.67	26.08	330					
4 "	45.08	10.15	6.37	20.13	337	97.00	13.30	6.31	28.57	289
5 "	56.52	9.60	5.58	29.27	331					
6 "	55.64	9.65	5.67	30.61	343					
Cow No. 16.						Calf No. 16.				
1 before	82.92	9.90	2.68	32.43	333					
Calving	83.80	9.80	2.36	29.70	344	130.44	—	5.62	—	—
1 after	71.48	9.75	4.30	29.85	347	119.00	11.80	5.19	45.80	285
2 "	54.76	9.20	5.19	33.15	345					
3 "	59.16	9.40	5.58	29.85	346	116.36	12.70	5.44	40.27	276
4 "	63.56	9.35	4.38	29.13	335					
5 "	70.60	9.30	4.62	25.00	334	125.16	12.80	4.75	46.51	274
Cow No. 19.						Calf No. 19.				
1 before	63.56	11.55	3.84	31.41	320					
Calving	71.48	10.05	2.61	36.14	315	143.64	12.85	5.23	45.11	276
1 after	57.04	10.00	4.47	34.09	344					
2 "	56.52	9.45	4.41	35.08	326	113.72	12.95	5.15	39.20	259
3 "	53.88	10.65	4.12	—	—					
4 "	53.00	11.05	5.36	36.36	319	105.80	12.55	5.53	36.36	273
5 "	52.28	9.65	4.41	32.97	321					
Cow No. 20.						Calf No. 20.				
Calving	94.36	10.10	2.79	37.02	327	120.76	12.95	5.00	49.85	301
1 after	68.84	9.75	3.92	35.08	331					
2 "	64.44	10.70	5.44	34.88	338	124.28	13.40	5.36	42.55	291
3 "	67.08	10.75	5.36	34.09	333					
4 "	56.52	10.80	6.43	37.26	331	108.44	14.20	6.03	38.22	298
5 "	53.88	10.95	6.55	35.71	336					
6 "	60.04	10.50	5.04	37.74	339	117.24	13.65	6.25	42.55	293

birth) and are shown on the curves in Fig. 1. On the left-hand side of the curves there is shown the average level of each constituent in the blood of the cows about one month prior to calving, when the cows were dry: these points are joined to the curves by dotted lines. Whilst these values cannot be taken as strictly mathematical averages, the curves clearly indicate the types of change which occur with the different blood constituents.

DISCUSSION OF RESULTS.

Whilst there are variations in behaviour between individual cows, the results on the whole are fairly uniform in character. A possible exception is Cow No. 12 and it must be noted that this cow was off her food for 2 days after calving. The blood-sugar level of the cows showed a definite and marked increase at the time of parturition, followed by a rapid fall to a low level

Fig. 1. Changes in the average composition of the blood of the calf and its dam about the time of parturition.

NOTE. There is a change in the ordinates scale above 40, values 50–125 being the ordinates for blood-sugar.

which was maintained throughout the first week after calving. The rise at calving is of such short duration that it is probably due to emotional hyperglycaemia. On the basis of the views of Kaufmann and Magne [1906] and of Blackwood and Stirling [1932] the lower blood-sugar level after calving may be explained by the requirements of the animal for milk-production.

Serum-calcium underwent in all cases a definite fall either just at or within 24 hours of calving, a fall which, in the majority of cases, was followed by a return to the normal level within the next 4 or 5 days. An exception to this

was Cow No. 5 in which recovery was not apparent within the week. Cow No. 12 was very irregular, which was probably due to the fact, already noted, that she was off her food for 2 days. On the day after calving her serum-Ca, which had dropped at calving, was well up again and this was accompanied by an abnormally high value for the inorganic P (8.42 mg./100 cc.). On the second day the serum-Ca was down well below the calving level after which it slowly rose again, whilst the inorganic P showed a fairly steady decline all this time. It may be noted that this cow was off her food again on the ninth day after calving, and a blood sample drawn then showed a low serum-Ca and a high inorganic P. These results are of interest in reference to the changes in the composition of the blood of the cow, which occur during milk fever. In the light of these observations it would appear that the abnormal fall in the value of serum-Ca during milk fever may be only an exaggeration of the normal physiological change which occurs in the blood of the cow at or immediately after calving.

The most noticeable feature of the data was the unfailing low value for inorganic P just prior to calving, the lowest level usually being reached actually at calving. Cow No. 15 was exceptional in showing a further drop the day after calving, when the inorganic P reached the abnormally low level of 1.76 mg./100 cc., the lowest level we have yet encountered for any healthy cow. This regular fall in blood-inorganic P prior to calving was in most cases a better index of approaching parturition than the outward and visible signs. Normally the inorganic P level rose rapidly after calving and after a peak period at about the fourth or fifth day fell again to about the pre-parturition level.

Whilst individual cows showed considerable fluctuations in the level of chlorine and non-protein-nitrogen, an examination of the data shows no decided tendency in any one direction, the fluctuations being such as could be readily accounted for by variations due to the strain of labour.

A comparison of the values obtained for the blood of the calf with those for the blood of its dam reveals that at birth the calf has a much higher blood-sugar level than that of its dam, the difference being of the order of 30–50 mg. per 100 cc., but although the value falls rapidly and evenly in the first 6 days it still remains well above that of the maternal blood. The calf also starts its life with a high serum-Ca level, higher than the normal level of its dam, and an inorganic P level almost equivalent to the dam's normal. Within the first week the serum-Ca falls slightly while the inorganic P continues to rise steadily and slowly. The chlorine content of the blood of the calf is on an average about 30 mg. per 100 cc. lower than that of its dam, this difference being maintained during the first week. The non-protein-nitrogen level on the other hand is much higher in the calf's blood at birth than in that of the cow.

SUMMARY.

1. Blood-sugar showed a definite rise in the cow at the time of parturition: this was followed by a fall to a low level maintained for at least one week.
2. Serum-Ca fell definitely either just at, or within 24 hours of, calving and returned to normal within 4 or 5 days.
3. A sharp fall in inorganic P just prior to calving was invariably indicative of the onset of labour.
4. The blood of the calf at birth had higher levels of blood-sugar, serum-Ca, inorganic P and non-protein-nitrogen and a lower chlorine level than had that of its dam.

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REFERENCES.

- Anderson, Gayley and Pratt (1930). *J. Dairy Sci.* **13**, 336.
Blackwood and Stirling (1932). *Biochem. J.* **26**, 357.
Bogert and Plass (1923). *J. Biol. Chem.* **56**, 297.
Briggs (1922). *J. Biol. Chem.* **53**, 13.
Folin (1922). Laboratory manual of biological chemistry, 235.
Green and Macaskill (1928). *J. Agric. Sci.* **18**, 384.
Hagedorn and Jensen (translation by Höst and Hatlehol) (1920). *J. Biol. Chem.* **42**, 347.
Hodgson, Riddell and Hughes (1932). *J. Agric. Res.* **44**, 357.
Kaufmann and Magne (1906). *Compt. Rend. Acad. Sci.* **143**, 779.
Kramer and Tisdall (1921). *J. Biol. Chem.* **47**, 475.
Robinson and Huffman (1926). *J. Biol. Chem.* **67**, 257.
Schwarz and Metzler-Andelberg (1928). *Biochem. Z.* **194**, 362.
Tisdall (1923). *J. Biol. Chem.* **56**, 439.
Whitehorn (1920-21). *J. Biol. Chem.* **45**, 449.
Wilson and Hart (1932). *J. Dairy Sci.* **15**, 116.