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THE EFFECT OF COLOSTRUM ON THE COMPOSITION AND VOLUME OF THE PLASMA OF NEW-BORN PIGLETS

By R. A. McCANCE and ELSIE M. WIDDOWSON

From the Medical Research Council Department of Experimental Medicine, University of Cambridge

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It is now well established that the resistance of the new-born piglet and ruminant to certain infections depends upon the absorption of γ globulins from the maternal colostrum (McCarthy & McDougall, 1953; Comline, Pomeroy & Titchen, 1953). It has also been pointed out by Widdowson & McCance (1956) and McCance & Widdowson (1956, 1957) that piglets which have been fed by hand for experimental purposes on colostrum and early milk not only have higher concentrations of protein and particularly of globulin in their serum, but also tend to have appreciably and consistently lower haematocrits than those which are given water but no food. The present experiments were designed to give a more quantitative expression to these observations in a relatively simple way.

METHODS

The experiments have been made on three litters of new-born piglets. Some animals in each litter were removed from the mother as soon as they were born, and samples of blood were taken from the cord for the determination of the concentration of serum proteins and the packed cell volume. The animals were weighed when they were dry, and paired according to their body weights. One animal in each pair was placed in a metabolism cage in a chamber at 31° C and given no food or water for 24 hr; the other animal was returned to the sow. After 24 hr had elapsed, Evans Blue (1 ml. of a 1% (w/v) solution) was injected into the heart of each animal in turn after a small control sample of blood had been taken, and 5 min later blood was withdrawn from the heart by a second puncture for the determination of the haematocrit and of the concentrations of Evans Blue and proteins in the serum. The animals were then killed by injecting air into the heart, weighed (with due allowance for the blood removed), and dissected to make sure that no part of the injected Evans Blue had lodged in the pericardial or thoracic cavities. The volume of circulating plasma was then estimated in the usual way by measuring the concentration of Evans Blue in it. The haematocrits of heparinized samples of whole blood, and the total serum proteins, albumin and globulin, were determined as described in the Appendix to Medical Research Council Special Report (1951). By making the assumption that the number of erythrocytes in the circulation had not altered in the 24 hr since birth it was possible from the two haematocrits on each animal and the plasma volume at the end of the experiment to calculate the change which had taken place in the volume of the circulating blood. This assumption is certainly not entirely correct, but the

same assumption was applied both to the animals which were being fed by the mother and to the controls which were not being fed.

Eleven pairs of animals have been used, twenty-two animals in all. Determinations of haematocrit and serum proteins have been made on all piglets, but the measurements of plasma volume with Evans Blue have been made only on seven pairs.

RESULTS

Table 1 shows the haematocrits and serum proteins at birth and death. There was almost no change in the haematocrits of the fasted animals, showing that dehydration and haematocrit concentration were slight or absent. There was, however, a very material fall in the haematocrits of the animals which were left with the sow, and the difference between the haematocrits of the fed and the haematocrits of the fasted animals was highly significant ($t = 4{\cdot}23$, $P = < 0{\cdot}01$).

TABLE 1. The effects of fasting and of maternal colostrum on the haematocrit and concentration of proteins in the serum of new-born piglets (average ± standard deviation)

	Fasted		Fed	
	Initial	Final	Initial	Final
Haematocrit (%)	38·8 ±4·4	37·7 ±3·3	38·1 ±3·4	24·8 ±6·7
Serum proteins, total (g/100 ml.)	2·17±0·14	2·23±0·16	2·17±0·14	4·77±0·70
Serum albumin (g/100 ml.)	1·24±0·06	1·33±0·08	1·24±0·06	1·19±0·23
Serum globulin (g/100 ml.)	0·93±0·10	0·90±0·14	0·93±0·10	3·58±0·74
Ratio $\frac{\text{albumin}}{\text{globulin}}$	1·34±0·09	1·48±0·25	1·24±0·09	0·33±0·11

The concentration of serum proteins at birth, although apparently very low, was at the normal level for a piglet, and the albumin and globulin values and ratios were also normal at birth and changed very little during fasting. Suckling by the mother led to an increase in total protein from just over 2% to nearly 5% in 24 hr, and the whole of the increase was due to globulin. This inevitably led to a gross change in the albumin-globulin ratio.

Table 2 shows the average body weights of the animals at birth and the effects of fasting and maternal colostrum upon them. The plasma volumes at death and the calculated plasma volumes at birth are also shown. The plasma volume at birth is given in italics, as it was not determined directly but was derived from the volume measured at death and the change in the haematocrit. The last lines in Table 2 show the total amounts of proteins circulating in the plasma at birth and death. The increase in albumin was small and barely kept pace with the expansion of the plasma, whereas the increase in globulin was great. It was due partly to increase in concentration and partly to expansion of the plasma.

Thus the effect of access to maternal colostrum for 24 hr on the body weight of a piglet weighing about 1400 g was to increase it by 70 g, say 5%. The

volume of the circulating plasma increased at the same time by 38 ml. (30%) and the weight of the proteins in it from 1·7 to 5·7 g, or by more than 200%.

TABLE 2. The effects of fasting and of maternal colostrum on the body weights, plasma volumes and total circulating proteins of new-born piglets (average ± standard deviation)

	Fasted				Fed			
	Initial		Final		Initial		Final	
Body weight (g)	1471	±201	1341	±60	1423	±112	1490	±143
Plasma volume (ml./kg birth wt.)	*55*	± *7·3*	53	± 6·6	*55*	± *7·7*	81	± 8·3
Total circulating protein (g/kg birth wt.)	*1·22*	± *0·09*	1·15	± 0·16	*1·20*	± *0·07*	4·02	± 0·82
Total circulating albumin (g/kg birth wt.)	*0·70*	± *0·04*	0·69	± 0·09	*0·69*	± *0·07*	0·99	± 0·18
Total circulating globulin (g/kg birth wt.)	*0·52*	± *0·04*	0·46	± 0·08	*0·51*	± *0·06*	3·03	± 0·80

DISCUSSION

The experiments show what very large amounts of globulin normally enter the circulating plasma of the new-born piglet. They are presumably derived in large part, if not entirely, from the globulins in the maternal colostrum. It is known that these globulins are absorbed unchanged, but they must be absorbed through some highly specific channels for, if not, why are the much smaller albumin molecules not preferentially absorbed? If the albumins are so absorbed, they do not remain in the circulation as the globulins do. If they did they would expand the plasma volume to a far greater extent than do the globulin molecules. Bangham, Ingram, Roy, Shillam & Terry (1958) have discussed problems similar to these as they apply to the calf and the rat.

Although pathological piglet anaemia does not appear till 3–5 weeks of life, piglets often appear anaemic when their haemoglobins are estimated a few days after birth. These experiments not only explain this apparent anaemia, but also show how misleading it may be to compare the concentrations of haemoglobin in the blood at birth with those found a week or so later and to attribute the whole of the change to an iron deficiency.

SUMMARY

1. The effect of ingesting maternal colostrum on the volume and composition of the plasma was studied in new-born piglets.

2. The absorption of globulins increased the plasma volume by 30%, and the concentration of globulins in the plasma at the same time rose from 0·93 to 3·58 g/100 ml.

3. The absorption of intact protein must have important physiological as well as immunological effects.

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REFERENCES

APPENDIX (1951). Studies of undernutrition, Wuppertal 1946–9. *Spec. Rep. Ser. med. Res. Coun., Lond.*, No. 275.

BANGHAM, D. R., INGRAM, P. L., ROY, J. H. B., SHILLAM, K. W. G. & TERRY, R. J. (1958). The absorption of ^{131}I-labelled serum and colostral proteins from the gut of the young calf. *Proc. Roy. Soc.* B, **148**, 184–191.

COMLINE, R. S., POMEROY, R. W. & TITCHEN, D. A. (1953). Histological changes in the intestine during colostrum absorption. *J. Physiol.* **122**, 6*P*.

McCANCE, R. A. & WIDDOWSON, E. M. (1956). Metabolism, growth and renal function of piglets in the first days of life. *J. Physiol.* **133**, 373–384.

McCANCE, R. A. & WIDDOWSON, E. M. (1957). Physiology of the newborn animal. *Lancet*, **273**, 585–589.

McCARTHY, E. F. & McDOUGALL, E. I. (1953). Absorption of immune globulin by the young lamb after ingestion of colostrum. *Biochem. J.* **55**, 177–182.

WIDDOWSON, E. M. & McCANCE, R. A. (1956). The effect of development on the composition of the serum and extracellular fluids. *Clin. Sci.* **15**, 361–365.