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SYMPOSIUM ON 'FEEDING THE NEWBORN: COMPARATIVE PROBLEMS IN ANIMALS AND MAN'

Problems in the nutrition of the preruminant calf

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The purpose of rearing calves is that they should reproduce, lactate and produce meat for human consumption. The problems associated with achieving these aims are twofold; first, that the most economic system of rearing should be used and secondly, that the quality of the diet should fulfil the nutritional requirements of the calf and maintain its health.

Mortality

Perinatal mortality (stillbirths and deaths within 12–24 h of birth) is about 3% and tends to be higher for breeds of extreme size. For large breeds perinatal mortality is associated with difficulties at parturition caused by a disproportionate increase in size of the calf relative to that of the dam (Monteiro, 1969) whereas for small breeds it tends to be associated with weak calves, which would appear to have suffered nutritional deficiencies in utero.

Postnatal mortality during the first 4 weeks is also about 3%, mainly associated with enteric infections and representing about 60% of the mortality to 26 weeks of age.

Systems of rearing

Growth rate. The growth rate of calves during the first 3 months of life is positively related, between breeds, to birth weight and can vary, according to the plane of nutrition, up to a maximum of about 1·5 kg/d. Although with a moderately high plane of nutrition (0·95 kg/d) first oestrus and conception may occur in Friesians at about 6 months of age, there is a wide variation among animals. In commercial practice, conception is not planned to occur before 15 months at the earliest, and often not until about 27 months of age, with over-all growth rates of about 0·70 and 0·45 kg/d respectively. Breeding is delayed because of the fear of difficulties at parturition and of reduced milk yields and longevity, or because the producer does not have the nutritional knowledge to achieve the desired growth rates, or considers them to be uneconomic.

The rate of growth aimed at for meat production is dependent partly on consumer demand for a particular carcass weight and quality and partly on government intervention to encourage carcass weights greater than those desired by the butchery trade, to make best use of a limited supply of calves. A conflict over quality also exists, since traditionally intramuscular fat was considered a necessary criterion, whereas leaner carcasses are now demanded. The type of meat will vary from veal produced at 3 months of age entirely by the preruminant system of digestion, requiring a weight gain of 1·2–1·5 kg/d, to beef produced either intensively, largely from cereals, or semi-intensively from pasture at about 12 and 18 months of age respectively.

Age at weaning. The majority of calves are removed from their dams by 4 d of age and must be reared on liquid diets for at least the first 3 weeks. For all forms of production other than veal, calves are usually given a restricted intake of milk substitute and are weaned onto dry food at the youngest age at which they can still achieve the required over-all growth rate. For breeds of large weight, this will occur at about 35 d. Recent work has shown that limiting the intake of milk may predispose calves to respiratory infections after weaning (Roy, Stobo, Gaston, Ganderton, Shotton & Ostler, 1971; Roy, 1973).

Immunity

Like the newborn infant, the neonatal calf is very susceptible to enteric infections, whereas after 1 month of age, respiratory infections become of increasing importance, especially when calves are reared in large numbers in a limited air space.

The transfer of passive immunity solely via colostrum means that when calves are removed from their dams at birth, as may occur under certain commercial conditions, protection from a septicaemia is very much dependent on the rearer giving the calf sufficient colostrum within the first 24–36 h. After this time, the intestine is no longer permeable to the transfer of intact immunoglobulins (Ig) to the blood stream.

Calves are also very susceptible, like infants, to an overgrowth and adhesion of Enterobacteriacae in the anterior region of the small intestine, with subsequent diarrhoea, and often deaths associated with dehydration. In the normal healthy calf, *Escherichia coli* is one of the first organisms to become established in the large intestine (Smith, 1965). It rapidly colonizes the small intestine and reaches the duodenum at 8·5 h, where peak numbers are observed at 1–4 d of age. The number normally declines thereafter, because of the dominance of the Lactobacilli or because gastric acid secretion increases during the early period after birth. However, in sick calves large numbers of *E. coli* are present in the duodenum at 10 d of age (Ingram, 1962; Contrepois & Gouet, 1973).

Protein digestion

Poor digestion and malabsorption of protein appears to be a major factor in allowing bacterial overgrowth in the small intestine. Substitutes for milk protein may exacerbate this problem.

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Milk protein. In the young calf, fresh milk coagulates in the abomasum within 3–4 min of ingestion. Assisted by the motility of the abomasum, the casein clot, together with the entrapped fat, contracts and the whey is released rapidly into the duodenum during 7–9 h (Mylrea, 1966; Hill, Noakes & Lowe, 1970; Ternouth, 1971). The casein retained in the abomasum is degraded as the result of the action of rennin or pepsin, or both, and HCl, and is released only slowly during the first 6 h after a meal, and thereafter at a more rapid rate as the curd disintegrates.

Problems arise when milk is heat-treated in the production of milk powders, if the time–temperature relationship is such that the whey proteins, including the Ig, are denatured. Such milk powders have a slow rate of clotting and, instead of a firm curd, a flocculent precipitate is produced (Tagari & Roy, 1969). Gastric acid production and proteolysis are reduced and undigested casein passes into the duodenum. Pancreatic secretion and protease outflow are also reduced (Ternouth & Roy, 1973). As a result, a lower over-all digestibility of protein, and also of fat and ash, is observed. If calves have received only a marginal passive immunity or are exposed to an adverse microflora, such diets may predispose to enteric infection.

The formation of antibodies in the blood has also been associated with the absorption of only partially degraded proteins from a milk substitute that showed poor coagulation (Frens, 1961; Frens, van der Grift & Dammers, 1961) although the association with milk protein has not been confirmed (Boogaerdt & van Koetsveld, 1961).

Non-milk protein. None of the alternatives to milk protein, namely fish, soya-bean and single-cell protein, produce a 'normal' coagulum in the abomasum and all have a lower digestibility than milk protein, especially during the first 3 weeks of life. The reduced proteolysis in the abomasum appears to be associated in the instance of soya bean with reduced gastric acid and enzyme production (V. Williams, unpublished results). Similarly pancreatic secretion and protease production appear to be reduced (Ternouth & Roy, 1973).

Various processing treatments of soya bean with acid, alkali or alcohol in conjunction with heat, to destroy trypsin inhibitor, haemagglutinins and other detrimental factors, have been claimed to give a product comparable with milk protein. However, apparent digestibility of the protein of soya-bean flour (530 g protein/kg) or soya-bean protein concentrate (600–650 g protein/kg) has not been greater than 0·75–0·79 (Nitsan, Volcani, Hasdai & Gordin, 1972; Paruelle, Toullec, Frantzen & Mathieu, 1972). Although 70% of dietary protein has been replaced satisfactorily by fish-protein concentrate in calves from 48 h old, similar replacement by soya-bean flour resulted in much poorer performance and death of some calves (J. H. B. Roy, I. J. F. Stobo, P. Ganderton & S. M. Shotton, unpublished results). Production of antibodies to soya bean appears to be associated with gastric stasis, followed by rapid passage through the intestine, and diarrhoea (Smith, Hill & Sissons, 1970; Smith & Wynn, 1971) and may be a similar phenomenon to coeliac disease in man. Treatment of soya bean with alcohol may overcome the problem (Smith & Sissons, 1973). Similarly, soya-bean protein has been reported as causing flattening of the villi in the intestinal mucosa of an infant (Ament & Rubin, 1972) and some evidence of the same

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phenomenon has been found in calves (J. H. B. Roy & I. J. F. Stobo, unpublished results). Since excessive proliferation of some micro-organisms may cause flattening of the villi (Mebus, Stair, Rhodes, Underdahl & Twiehaus, 1973) and such proliferation seems to be associated with the death of calves given soya bean, the production of antibodies may arise following the ingress of partially degraded protein through a damaged mucosa.

Carbohydrate digestion

The only carbohydrates that can be utilized efficiently by the young calf are lactose and glucose, but too high an intake may result in the development of fermentative diarrhoea. The calf is unable to utilize sucrose because of the complete lack of intestinal sucrase activity (Dollar & Porter, 1957) and appears to absorb fructose poorly or not at all (Velu, Kendall & Gardner, 1960).

Lactose. Lactase activity is high at birth and declines with age, but even at 8 weeks the lactase activity is ten times that in the adult animal (Siddons, 1968). Lactase activity appears to adapt to the diet, either when milk is supplemented with additional lactose (Huber, Rifkin & Keith, 1964) or when calves are maintained as preruminants rather than being weaned (Toofanian, Hill & Kidder, 1973).

Starch and its degradation products. Only small amounts of starch or its degradation products are digested during the first 4 weeks of life. Pancreatic amylase activity, however, increased 42-fold from 24 to 63 d in Ayrshire calves, but at a slower rate with Friesians (Ternouth, Siddons & Toothill, 1971). Maltase and isomaltase activity increase during the first 1–4 weeks of life, but thereafter the values are similar to those in adult animals, the isomaltase activity being half that of maltase (Coombe & Siddons, 1973; Toofanian *et al.* 1973). The lack of intestinal sucrase and palatinase and the low maltase and isomaltase activities in the calf have been considered comparable to the syndrome of sucrose malabsorption in man (Coombe & Siddons, 1973).

Recent work has shown that starch tends to be retained in the abomasum for several hours after feeding. At 6 weeks of age, about 50% of dietary starch was found to be digested and absorbed from the small intestine (Coombe & Smith, 1973). Extensive studies in France have shown that inclusion of 75 g starch or dextrins/kg in liquid diets from 13 d of age markedly depressed growth. Raw starch or poorly soluble dextrins were costive, whereas hydrothermically-treated starches or soluble dextrins caused diarrhoea (Mathieu & Thivend, 1968; Mathieu, Thivend & Barré, 1970).

Fat digestion

Fat incorporation. Unless correctly emulsified, dietary fat tends to cause both diarrhoea and loss of hair during the first 3 weeks of life (Kastelic, Bentley & Phillips, 1950; Huff, Waugh & Wise, 1951). This alopecia may occur as a result of direct contact of the hair with either diet or faeces (Roy, Shillam, Thompson & Dawson, 1961), or with the secretion of unphysiological fat components through the sebaceous glands, especially with diets containing a large amount of unhydrogenated oil (de Man, 1951; Grunder & Musche, 1962). In particular C12:0 and C14:0 acids appear to be metabolized or excreted through the skin (Amich Gali, 1965; Molnar, ter Meulen & Neumann, 1970).

Small fat-globule size and thus high digestibility is most easily obtained by mechanical homogenization of fat into liquid skim milk before spray-drying. However, modern equipment for atomizing fat and emulsifying agents into skim milk powder has produced diets in which 86% of the fat globules had a diameter of less than 4 μm (Toullec & Mathieu, 1970). Mean globule size should not be more than 3–4 μm for the neonatal calf, although older calves can probably tolerate larger fat globules (Roy *et al.* 1961).

Gastric digestion. Immediately after a feed, there is some passage of fat through the pylorus, but most of the fat is entrapped in the casein coagulum. Within 30 min of a feed, about 50% of the triglycerides in the abomasum are hydrolysed, presumably by pregastric esterase (PGE) produced in the saliva, which acts preferentially on the butyrate groups (Ramsey, 1962; Otterby, Ramsey & Wise, 1964; Grosskopf, 1965; Siewert & Otterby, 1968) at an optimum pH of between 4·5 and 6·0 (Siewert, 1969). After 6 h there is a considerable increase in fat flow through the pylorus associated with the disintegration of the curd (Ternouth, Roy & Siddons, 1974).

Intestinal digestion. Pancreatic lipase activity, which is of major importance in the hydrolysis of long-chain fatty acids, increases with age (Ternouth *et al.* 1971). The majority of fatty acids containing more than 10–12 carbon atoms are transported through the lymphatic system (Toullec, 1968; Wadsworth & Shannon, 1971), the peaks of lipid flow reflecting the speed of release from the casein curd (Shannon & Lascelles, 1967, 1969; Gooden, Brandon, Hartmann & Lascelles, 1972).

Changes in the processes of emulsification, hydrolysis, solubilization and absorption of fat markedly affect its utilization. If malabsorption occurs, particularly of long-chain fatty acids, insoluble calcium and magnesium soaps may be formed (Raven & Robinson, 1958) and this may affect the susceptibility of calves to hypomagnesaemia (Thomke, 1963) and increase the requirement for Ca. Although with rats given dietary tallow an increase in Ca intake resulted in a decrease in serum lipids and an increase in faecal lipids (Fleischman, Yacowitz, Hayton & Bierenbaum, 1966), studies involving the inactivation of lipase in the calf indicated that the reduced absorption of Ca appeared to be caused by the reduced digestibility of fat rather than vice versa (Ternouth, Roy, Stobo, Ganderton, Gillies & Shotton, 1974).

Digestibility of fatty acids decreases with increase in chain length and increases with the degree of unsaturation at any given chain length (Niesar, 1964; Veen, 1971; Flatlandsmo, 1972). The position of the fatty acid in the triglyceride molecule may be important, since C16:0 acid seems to be better utilized when it occupies the centre position, as in lard (Toullec & Mathieu, 1969); a similar finding was reported for the infant (Filer, Mattson & Fomon, 1969; Anonymous, 1970).

Tallow is usually the cheapest fat, but the digestibility of its C16:0 and C18:0 acids is only about 0·84 and 0·78 respectively, compared with 0·97 and 0·98 for the same acids in butterfat (Toullec & Mathieu, 1969; Raven, 1970). The higher digestibility of these acids in butterfat may be due to the ease of solubilization as a result of a plentiful supply of monoglycerides from short-chain fatty acids, or to its higher content of unsaturated relative to saturated long-chain fatty acids, or to the increased production of lysolecithin in the intestine. In rats, increasing quantities of C18:1 acids improved micelle formation from C16:0 acid until the micelles were saturated and any further increase in C18:1 acids had a diminishing effect (Savary & Constantin, 1967). It is pertinent that the addition of lecithin to homogenized tallow had a marked effect in improving its digestibility, but little or no effect on the digestibility of fat or on the performance of calves when a milk substitute containing a fat of high inherent digestibility was given (Roy *et al.* 1961; Raven & Robinson, 1964*a*, *b*; Raven, 1970).

In the calf, it seems probable that the production of large amounts of faecal fat is a reflection of malabsorption associated with disturbances of protein or carbohydrate digestion rather than a primary failure of fat absorption.

Polyunsaturated fatty acids (*PUFA*). There appears to be a critical level of PUFA above and below which increased susceptibility to enteric and respiratory infection occurs. At a high level of PUFA, the vitamin E intake may need to be increased to keep it to the recommended requirement of 1·5–2·5 mg vitamin E/g linoleic acid (Hartfiel, 1967) whereas, at a low level of PUFA, an essential fatty acid deficiency may occur. In comparison with diets containing greater or lesser amounts of PUFA the highest weight gain and food conversion efficiency occurred with calves given a diet containing 4·8 g C18:2 acid and 40 mg vitamin E/kg powder (Molnar & Abel, 1971) or 5·5 g C18:2 and C18:3 acids and 20 mg vitamin E/kg dry matter (Roy, Stobo, Gaston, Shotton & Ganderton, 1973*a*, *b*).

Essential fatty acids (*EFA*). Although weakness of the legs, dull haircoat and partial alopecia at 5–6 weeks of age were considered as evidence of a need for fat (Cunningham & Loosli, 1954) or of EFA deficiency in calves given fat-free diets (Lambert, Jacobson, Allen & Zalatel, 1954), calves can be reared on a skim-milk diet supplemented with minerals and vitamins to gain 0·70 kg/d to 16 weeks (Roy, Stobo & Gaston, 1970), even though the diet contained only 0·11% of its energy as EFA, compared to a minimum requirement of 1% as EFA suggested for pigs (Leat, 1962). However, it is well known that increasing the fat content of the diet increases the EFA requirement of the rat, whilst in the calf, substitution of a proportion of tallow by coconut oil, although increasing fat digestibility, reduced the percentage of energy from EFA from 0·98 to 0·51% and increased the susceptibility of calves particularly to respiratory infection (Roy *et al.* 1973*b*).

Quantity of fat. Young calves given skim milk containing only 10 g fat/kg dry matter tend to have diarrhoea, but gastric proteolysis and acid secretion appear to be somewhat greater than, and over-all protein digestibility similar to, that obtained with a diet containing 200 g fat/kg (Roy, Stobo, Gaston & Greatorex, 1970). The diarrhoea may be associated with the reduction in pancreatic enzyme secretion that occurs, possibly as a result of a lack of a stimulatory effect of fat or of bile salts, or alternatively with the high lactose content of skim milk (Roy & Ternouth, 1972; Ternouth & Roy, 1973; Ternouth, Roy & Siddons, 1974).

At *ad lib.* levels of feeding, increasing the concentration of fat from 10 to 300 g/kg dietary dry matter increases the fat deposition in the carcass but has no effect on nitrogen and Ca retention. This suggests that dietary fat is not a readily available source of energy under optimum environmental conditions (Roy, Stobo & Gaston, 1970; Roy, Stobo, Gaston & Greatorex, 1970).

The inclusion in diets of medium-chain triglycerides (MCT; C8:0, C10:0 acids), although suggested as a readily available source of energy (Veen, 1972), had no effect in increasing N retention and reducing fat deposition but did increase apparent digestibility of fat. When MCT was the sole source of fat, 100% mortality occurred at 8–15 weeks of age, possibly associated with a deficiency of EFA (J. H. B. Roy, I. J. F. Stobo & J. E. Storry, unpublished results).

Conclusion

Although the degree of passive immunity received by the neonatal calf from colostrum is of overriding importance, the composition of the milk-substitute diet, both qualitatively and quantitatively in terms of protein, carbohydrate and fat plays a significant role in the maintenance of health and in the level of production that can be obtained.

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