The partitioning of fat in farm animals

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Summary

This paper discusses aspects of metabolism in adipose tissue of pigs and ruminants. The major homeostatic and homeorhetic endocrine hormones responsible for the regulation of lipogenesis and lipolysis include insulin and the catecholamines. It is argued that a primary action of somatotropin (ST) in reducing body fat and increasing muscle gain is via reducing the actions of insulin. The increased effectiveness of ST in pigs compared to ruminants is related to an inherently lower sensitivity and responsiveness of ruminants to insulin. In contrast, the ß agonists produce a much greater response in ruminants and this is related to an increased sensitivity of adipose tissue to catecholamines. The pathways of fat metabolism are described with the aim of examining the possibility of regulating fat partitioning between depots in ruminants. The importance of acetate versus glucose+lactate differs between depots in the ruminant and it is proposed that this might allow for differential control of lipogenesis. In ruminants, diets promoting starch digestion in the small intestine clearly favour glucose as a lipogenic substrate and this may have an impact on the relative growth of different fat depots via the glucose/insulin axis. Chromium supplementation of ruminants consuming a diet low in chromium alters fat metabolism, probably via the glucose/insulin axis.

Introduction

Consumer preferences and the need to maximise profitability in the rural sector have resulted in an enormous research effort to maximise muscle and minimise fat in meat producing animals such as pigs, sheep and cattle. Leanness at all sites is not always desirable while some markets will pay a premium for beef meat containing extra levels of fat (marbling). In this review we outline the development of fat tissue during growth and how this relates to consumer preferences. The role of the main endocrine hormones which determine the partitioning between fat and protein is described. Endocrine sensitivity and responsiveness to insulin and catecholamines, and pathways of fat biosynthesis are then proposed as major reasons for differences in fat metabolism between the species and between fat depots. Finally the possibility for altering the distribution of fat between depots in ruminants is explored.

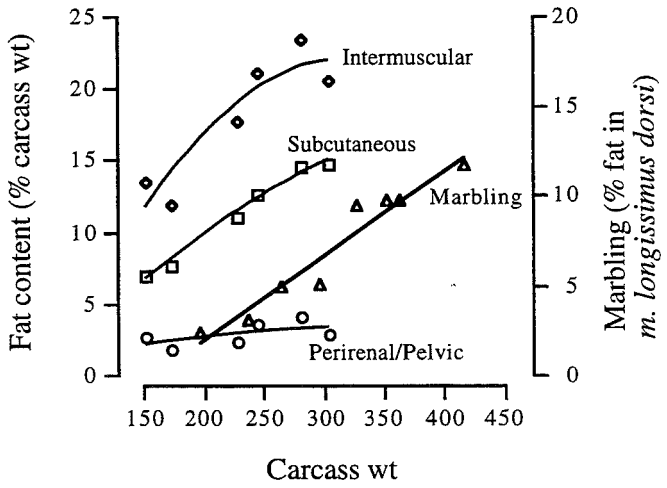
Growth of adipose tissue - practical aspects

Adipose tissue is deposited in specific depots which are similar for all mammals. The primary depots are within the abdominal cavity (perirenal, mesenteric and omental), intermuscular, subcutaneous and intramuscular. However the proportions differ between the species and are influenced by age. Thus the pig has more subcutaneous fat (70% of total body fat) and less abdominal fat then sheep and beef cattle (1).

Adipose tissue depots are thought to develop in the order of abdominal, intermuscular, subcutaneous and finally intramuscular (2). The progressive development of some fat depots in cattle is shown in Figure 1. The data suggest that abdominal fat changes largely in line with carcass (or body) weight while all other depots increase relative to carcass weight. Thompson et al (3) measured chemical fat content at all sites in mature Merino sheep and found intramuscular fat was 7% of total body fat. This compared with subcutaneous at 24%, intermuscular 20%, kidney fat 11%, omental fat 16% and mesenteric at 6%. Therefore the marbling depot is of moderate to small size.

Beef produced for the Australian domestic market originates from cattle yielding a carcass weight of about 200-220 kg and so this results in lean beef (Figure 1, muscle fat content of about 2.5 - 5%) since the subcutaneous and intermuscular fat can be trimmed leaving a low fat product. Alternatively some export markets are forced into producing excessive levels of subcutaneous and intermuscular fat to ensure the maximal development of marbling fat. Marbling is considered as a key factor in determining the organoliptic properties for the consumers in these markets and accordingly there is a pricing structure which pays on marbling score. On the domestic market there is little evidence that marbling plays an important role in palatability. When controlled studies are performed, the influence of marbling is relatively small when compared to the known effects of cold shortening and aging of meat (4,5).

Figure 1. The changes in fat depots during growth in beef steers (data is for Hereford, Angus and Hereford x Angus cross steers) (6,7)



Partitioning between muscle and fat - homeostasis and homeorhesis

The partitioning of nutrients between muscle and fat is regulated by a variety of hormones. Some of these have acute actions (eg insulin, catecholamines, glucagon) whereas others are more involved in the chronic regulation of metabolism (eg somatotropin, oestrogen, placental lactogen, prolactin). In 1929, Cannon (8) proposed the concept of homeostasis to describe the mechanisms which operate on an acute basis to maintain physiological equilibrium. The acute homeostatic regulation of metabolism by insulin, glucagon and the catecholamines is well documented.

However, the concept of homeostatic regulation is insufficient to describe the chronic regulation of partitioning between muscle, fat and other tissues as an animal moves from one physiological state to another. Bauman and Currie (9) introduced the concept of homeorhesis to describe the partitioning of nutrients in favour of a dominant physiological state. They postulated that homeorhetic mechanisms involve alterations in tissue response to homeostatic controls. The proposed mechanisms included: altered release and/or clearance of homeostatic hormones; altered blood flow and hence hormone and substrate supply to an organ; altered tissue sensitivity to a homeostatic hormone via altered receptor numbers and/or binding affinity; and altered tissue responsiveness to a homeostatic hormone through changes in post-receptor signal transduction. Many studies have now demonstrated that the major homeorhetic regulator of the partitioning of nutrients between fat and muscle, somatotropin (ST), exerts its effects through altering sensitivity and/or responsiveness to homeostatic hormones. A discussion of the metabolic actions of ST offers some insight as to how nutrients are partitioned during growth.