PS1.03 Possible methods for changing the glycolytic potential 247.00

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***Abstract*— Muscle glycogen content at slaughter plays a major role in the postmortem metabolism during which muscle converts to meat. Number of meat quality traits are related to post mortem glycolysis characteristics. Glycolytic potential is a measure of glycogen store that takes into account products of the postmortem glycogen breakdown trough glycolysis. Effect of breeding, feeding, preslaughter treatment and genetic on glycolytic potential are reviewed, focusing on pigs with some insight in beef and poultry meat.**

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***Index Terms*—glycolytic potential, meat quality**

I. INTRODUCTION

Meat quality is often described by a very large number of traits. In pig, meat quality is usually described by muscle pH, colour, water holding capacity or tenderness. The pH has been implicated as a major factor influencing pork quality. The rate and extent of pH decline can affect the protein denaturation and fresh pork quality such as color and water-holding capacity.

The anaerobic metabolism of glycogen results in formation of lactate and a simultaneous decline in pH. In order to better understand post mortem pH fall rate, [9] studied the evolution of principal substrates involved in anaerobic glycolysis. From these observations, it was showed that it was possible to estimate initial (pre-slaughter) muscle glycogen content in a post-mortem muscle sample. The definition of glycolytic potential (GP) was fixed as the sum of main muscle glucidic compounds susceptible to transformation into lactate (see [26] for details).

In pigs, a decreased glycogen content would be desirable [37] severe antemortem glycogen depletion would negatively affect pork quality. On contrary, in beef, increasing glycolytic potential, focusing on preslaughter treatment, should be developed because beef palatability would probably be improved [55]. Research has shown that breeding system, feeding, fasting, transport, lairage and genetic variation, may influence muscle glycolytic potential and/or stress level and, ultimately, pork quality.

Recent studies focused on the two glycogen forms known as macroglycogen and proglycogen. Details can be found in [1]. The macroglycogen fraction in humans and rats is found to increase with high muscle glycogen concentrations and is mainly being metabolized during aerobic exercise, proglycogen mainly being metabolized during anaerobic conditions.

II. REARING CONDITIONS

Physical activity, long and repeated, during growth, is supposed to increas muscle glycogen stores. The increase depends on muscle type, degree of involvement in activity and intensity [12].

Outdoor reared pigs have a higher GP then indoor reared pigs ([13][3]) but the difference might depend on muscle ([29][52]). Part of the differences might be attributed to physical activity and ambient temperature. When temperature decreases, glycogen content increases in Longissimus dorsi muscle and elevated growing-finishing temperatures have been shown to decrease GP [30]. A lower glycogen store in outdoor pigs has been observed [23], but slaughtering occurred in autumn and outdoor pigs were fed ad libitum and feed withdrawal might have been more stressful than for indoor pigs restricted fed.

Mild negative handling during breeding (systematic refusal of physical contact), associated with the presence of the negative handler at slaughter, resulted in lower glycogen levels immediately before slaughter [49]. These observations suggest that negative experience with humans may enhance reactivity to the slaughter procedure, possibly due to increased fear of humans.

Calves which have been submitted to gentled contacts during breeding had a high GP at slaughter [32]. Gentled calves were less agitated or stressed during transport to the slaughterhouse compared with control calves.

III. FEEDING

The feed-induced manipulation of muscle energy levels was reviewed by [1]. Supplementation of high levels of sucrose or other digestible carbohydrate sources, a few days prior to slaughter or during overnight lairage has been known to increase muscle glycogen stores but this is a short term effect. In contrast, other diet-induced regulations of the glycogen pools require changes in metabolic pathways and the glycogen synthesis apparatus. The combination of low digestible carbohydrate and high fat content in the diet causes a muscle glycogen-reducing effect. Results of several studies have shown that muscle glycogen stores

in finishing pigs can be decreased through strategic feeding of diets low in digestible carbohydrates ([42][4]). High protein feeding (low starch) would also decrease GP [44]. [46] failed to find a significant effect of adding fat (and lower crude protein content) on GP and [31] found no difference in GP of the muscle among pigs fed either a control diet or a high protein/low carbohydrate diet. The addition of rapeseed oil to the diet lowered the content of glycogen in the LD and PM, indicating a shift from glycogen toward lipid metabolism[27]. It seems that a decrease in muscle glycogen synthesis may be inhibited by elevated content of FFA in plasma, in that study induced by adding rapeseed oil in the diet. [1] concluded that feed-induced reduction in muscle glycogen seems to claim a critical ratio between fat and digestible carbohydrate.

In the study presented by [43], the large reduction in total glycogen during the 3-wk strategic feeding period [42] was caused by a reduction in the macroglycogen content. In contrast to macroglycogen, the proglycogen content did not change during the strategic feeding period.

IV. PRE-SLAUGHTER TREATMENT

Muscle glycogen content is influenced by pre-slaughter treatment, i.e. fasting duration, transportation, lairage and handling at slaughterhouse. Stress and physical activities, inducing adrenaline release, result in a glycogen depletion. But time between stress and slaughter time is of importance also considering that muscle glycogen stores may be impacted by other factors such as the time of the last meal. Animals with a decreased glycogen level due to a stress period are able to partially build up muscle glycogen content from hepatic glycogen stores during a resting period. Additionally, interaction between rearing conditions and preslaughter treatments have been suggested.

Feed withdrawal before slaughter has been shown to have a variable effect on muscle glycogen reserves. Fasting may have low influence on muscle glycogen content in pigs [8] [21] as well as in cattle [19]. Only [54] reported a reduction of muscle glycogen with 24 h to 48 h of fasting, For [43], an overnight fasting, transport, and preharvest handling induced no significant changes in total muscle glycogen.

The effect of transport, depends on duration and condition [16]. A 2-hour transportation has no effect on glycolic potential [17] whereas a 6-hour transportation decreases glycogen content in Longissimus dorsi. A 3-hour transportation had no effect on GP for [4] and decreased GP for [2]. For [21], a short transport decreases muscle glycogen content. No differences in the GP was observed when pigs were transported 30 min or 2.5 h before slaughter, but the GP was markedly decreased in pigs transported for 8 h [31]. In young cattle, a 11-hour transportation decreases glycolytic potential ([19]). There were no effects of transport floor space on longissimus muscle glycolytic potential ([41]).

Resting at slaughterhouse is recommended to restore muscle glycogen content, but studies reported contradictory results ([16]). Longer resting time seems to decrease muscle glycogen content due to stressful event occurring during that period. [17] showed that the muscle glycogen content decrease was similar with a 2-hour and 24-hour resting time. [22] found no difference in GP for a 30-min or 3h lairage time. [47] showed that a resting period of 16h tented to decrease glycogen stores. Pigs that were mixed and lairaged had lower glycolytic potential than non mixed and non lairaged pigs [52]

[7] found there was a decrease in glycolytic potential in the samples taken after handling. For [22], a high stressor treatment (forced, by yells and electric goads, to move back and forth four times in the corridor leading to the stunning area) clearly decreased glycolytic potential. For [22], the effects of preslaughter stress on GP superseded the effects of any preceding treatment, such as transport and lairage. In chicken, a stressful handling (heat stress and shacking) was associated with a high GP compared with a gently handling [6] but only in thigh meat, not in breast meat.

Interactions between preslaughter treatments and prior experience has been reviewed by [49]. The effects of behavioural and physiological stress responses on muscle metabolism depend on the energy status of the pig. For example, [18] showed an interaction between fasting and mixing of pigs; 4 h after mixing with unfamiliar pigs, muscle glycogen was decreased in fasted but not in fed animals. The greater decrease in glycolytic potential in fasted pigs is a result of higher depletion during handling and a lower replenishment during the recovery period. When energy status is low, skeletal muscle depends more on its endogenous glycogen stores, while aggression during mixing may be higher, presumably further increasing muscle glycogen breakdown. Consequently, slaughter procedures are likely to have a larger effect on ante- and post-mortem metabolism in fasted than fed pigs [49].

A handling intensity × distance moved interactions for GP and glycogen has been described by [41]. When pigs were previously handled aggressively, pigs moved 125 m had lower longissimus muscle glycolytic potential values than pigs moved 25 m. Additionally, stressor number tended to affect longissimus muscle glycolytic potential, with a non additive response to stressors.

V. AGE/WEIGHT- SEX

At birth piglet muscle glycogen content is very high whatever the muscle. The glycogen content decreases rapidly after birth, the evolution being different depending on the muscle. An increase can be observed between 4 and 8 weeks of age, due to feeding and activity at weaning. After weaning, the glycogen content seems to slightly decrease. [25] found no difference for glycolytic potential between pigs of 100 or 125kg liveweight. In cattle, glycogen content increases with age. Boars tend to have a higher muscle glycogen content compared with castrates and females though this difference has not always been found significant as there is an interaction between sex and preslaughter treatment. Boars are expected to be more active before slaughtering leading to a decrease in muscle glycogen store. For glycolytic potential, castrates and females are considered to have the same level [13][44].

VI. GENETIC DETERMINISM

Glycolytic potential can be durably modified by selection, crossbreeding or introgression considering already known breeds, genes, markers or polygenic variability. Most studies comparing breeds (see [26]for references) concluded that muscle glycogen content was similar in Large White, Landrace and Piétrain breeds. In Duroc, GP has been found to be generally higher than in Large White or Yorkshire [26][48][51]. The highest muscle glycogen content was found in the Hampshire breed. Differences between breeds may depend on the muscle [26]. Significant differences between breeds are mainly observed in white glycolytic muscles.

Halothane gene has no effect on GP ([26] for review). RN gene has a major effect on muscle glycogen content. The dominant RN- allele increases dramatically glycogen content in white muscles and in a lesser extent in red muscles ([10] [14][24]). The causative mutation (R200Q) in the PRKAG3 gene underlies the high glycogen level [36]. The excess of glycogen found in RN– carriers is presented mainly as macro-glycogen [15], or macro and pro-glycogen [56]. In the later study, they observed that pro-glycogen was preferentially metabolized postmortem, but they were unable to conclude for macro-glycogen breakdown. The V199I mutation, also called rn* allele [10], was associated with a lower GP than the normal rn+ allele but this result has not been confirmed by later studies ([20][24]). The T30N substitution is associated with GP, the N allele being associated to a lower GP.

Few QTL have been reported in literature. Five QTL for glycolytic potential have been described including one on SSC7 in a Meishan × Pietrain population [40], and three on SSC11, 15, and 17 in a Berkshire × Yorkshire intercross [35]. Seven additional QTL were mapped on SSC1, 3, 4, 5 6, 7 and 16 in a White Duroc × Erhualian [11].

Heritability values for GP are moderate and vary from 0.14 to 0.38 ([26][39]), and muscle glycogen content can be hold as a selection criterion. In chicken, heritability value for GP was high (0.43; [28]).

In pigs, considering genetic correlations [26][39], a decreased GP would lead to a decrease in lean proportion, but in Duroc selection on lean growth efficiency had no significant consequences on GP [34] though GP tended to increase in the lean line. In Danish Landrace, a comparison between 1976- and 1995-pigs showed no significant difference for muscle glycogen content [38]. In French Large White, GP increased between 1977 and 1998, in accordance with increased lean meat content [53]. On contrary, in chicken, selection for a low abdominal fatness (lean line) induced a decreased GP [45], and genotypes with greater muscle mass showed a decreased level of glycogen stores [5].

New genetic knowledge on GP regulation should be available trough genomics studies. The major stake will be to disentangle the interaction between glycogen metabolism and animal reactivity, especially at slaughter.

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