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Review

Current research on quantitative trait loci (QTL) in meat quality

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Abstract

Meat quality is one of the most important economic traits in farm animals. Meat quality trait has a multifactorial background and is controlled by an unknown number of quantitative trait loci (QTL). Meat quality is an important trait for genetic selection and breeding. This valuable background knowledge would lead to investigate QTLs and identifying genes of most important traits of aquaculture species in further. Thus, that genomic information could be applied in MAS breeding programs to fulfill the meat and protein demand of market through aquatic species and prevent from the huge loss in aquaculture industry. The objective of this review is to describe meat quality (QTLs), identified in animals. Furthermore, this knowledge will lead the researchers to investigate the QTLs associated with meat quality traits are needed a great attention for genetic development of Aquaculture species.

Keywords: Meat quality traits, Farm animals, Aquaculture species.

INTRODUCTION

Meat quality is one of economic importance in farm animals. From the appearance of the raw material, quality requires analysis and classification of fat content, composition, tenderness, water-holding capacity, color, oxidative stability and uniformity. It is influenced by several factors, such as breed, genotype, feeding, fasting, preslaughter handling, stunning, slaughter methods, chilling and storage conditions (Rosenvold and Andersen, 2003).

Meat quality is of vast importance to the meat trade where the consumer is willing to pay more for better products (Shackelford et al., 2001). Meat quality is an essential trait in meat-producing animals. Meat quality describes the agreeable appearance of meat to consumers, which includes color, tenderness, water holding capacity, marbling and flavor. Due to increased consumer consciousness with respect to eating quality and nutritional aspects of meat, qualitative research on meat is becoming more important (Verbeke et al., 1999).

There is an increasing interest from trade and consumer organizations in high-quality and healthy food and growing concerns about the well-being and health in production systems. Unlike growth traits and reproduction traits, such traits at present have no clear economic value to the farmer. In the case of meat quality there is no general agreement on definitions of good quality, and the awareness of greatest quality varies from country to country and even within a country. Therefore, the dispute of improving meat quality will be the talent to compose a set of principles of different quality traits that would satisfy different markets or groups of consumers.

Meat quality traits have also increasingly concerned more attention in breeding programme. Traits like pH, water-binding capacity (drip loss), protein traits (protein amount in muscle and amount of hydroxyprolin), sensory measurements, fatty acid composition, and color are all investigated for their possible positive effect on meat quality (Cameron, 1990a; Hovenier et al., 1992; Casteels et al., 1995; Meuwissen and Goddard, 1996). Up to date meat consumer taste and nutritional value are important quality attributes of meat (Forrest et al., 1975). Meat quality traits play economically important roles in the value judgment of meat industry (Stone et al., 2005).

Inspiring increases in beef and pork productivity have been achieved by traditional genetic selection methods. However, the next challenge for the industry is to improve fish meat quality, includes various taste-related traits such as tenderness, flavor and juiciness, and also appearance (including colour, fat levels and fat distribution), nutrient content and safety. Consumer choice is influenced by these characteristics as well as by the origin of the product and the system used for its production. Several economically important traits are not recorded systematically in routine genetic development programs, such as carcass characteristics and meat quality.

Meat quality traits

Meat quality

Meat Fibre
Meat pH
Meat Water holding capacity
Meat Drip loss
Meat Protein
Meat Hydroxyprolin
Meat Tenderness
Meat Juiciness
Meat Oxidative stability
Meat Marbling
Meat Firmness

Meat color

Meat fatness

Fat color

Meat quality

Meat quality is one of the most important economic traits in farm animals. Meat quality trait has a multifactorial background and is controlled by an unknown number of quantitative trait loci (QTL). Meat quality is an important trait for genetic selection and breeding. Genome research in farm animals progressed rapidly in recent years, moving from linkage maps to genome sequence. The work on farm animal genome sequencing began in the early 1990s, and assists in the understanding of genomics function in various organisms (Fadiel et al., 2005). Quantitative genetics can be useful for enhancement of meat quality in animal breeding (Kharrati et al., 2009). Meat quality trait loci can be applied in breeding programs by using marker-assisted selection (MAS) (Gao et al., 2007). The goal of genomic technologies is the categorization and mapping of the loci that affected these traits. Generally, meat quality depended on color, water keeping, tenderness and resistance against oxidation. It is prejudiced by several factors, such as breed, genotype, feeding, fasting, pre slaughter handling, stunning, slaughter methods, chilling and storage conditions (Rosenvold and Andersen, 2003).

However, in view of the general genetics, meat quality traits are usually regarded as quantitative traits. In the last decade, efforts have been put into QTL mapping (Mancini and Hunt, 2005; Ramos et al., 2007). Improving meat quality traits requires more knowledge of modern molecular approaches because of the complex property of meat quality, breeding innovations (Bin, 2007). Recently, meat quality has become an important issue in genetic selection due to the demands of consumers (Grindflek et al., 2001; deKoning et al., 2001; Clop et al., 2003).

Meat quality traits have been studied using crosses between Wild Boar and Large White (Andersson et al., 1994, 1998; Nii et al., 2005), Meishan and Yorkshire (Paszek et al., 2001), Meishan and Large White/Landrace (De et al., 2001; Sato et al., 2003), Duroc and Landrace/Yorkshire (Grindflek et al., 2001), Berkshire and Yorkshire (Malek et al., 2000), Iberian and Landrace (Ovilo et al., 2002), Pietrain and Meishan and Wild Boar (Geldermann et al., 2003), and Duroc and Berlin Miniature pig (Wimmers et al., 2006; Kluas et al., 2005). More than 260 studies on the porcine genome have resulted in the identification of 4,143 meat quality-related quantitative trait loci (QTL) (http://www.animalgenome.org/QTLdb). A number of QTL have been found for meat quality traits on pig chromosome 17 (SSC17) and the alleles from microsatellite markers and candidate genes with advantageous effects on meat quality measures in this region were derived from the Berkshire founders, suggesting that this region is important for meat quality in Berkshire pigs (Malek et al., 2001; Ramos 2006; Romas et al., 2009). Another study on SSC17 also found QTL associated with meat quality traits (Rohrer et al., 2005). Many studies have successfully detected QTL for economically important traits of beef cattle such as growth, carcass, and meat quality traits by using crossbred experimental populations (Keele et al., 1999; Stone et al., 1999; Casas et al., 2000, 2003; MacNeil and Grosz, 2002; Kim et al., 2003). QTL analysis for growth, carcass, and meat quality traits in an F2 population from a cross between Japanese Black and Limousine (Abe et al., 2008). Identification of expression QTL (eQTL) of meat quality traits in porcine M. longissimus dorsi

Table 1. List of meat quality traits used for QTL analyses.

Trait	Animal	Reference
Meat quality	Pig	Ma J et al., 2010,Ramos A M et al., 2009,Thomsen H et al., 2004,Abe, T. et al., 2008, Rohrer, G et al., 2005,Ponsuksili Siriluck, et al., 2010,KerlRJetal. 2006 ,Li H D et al., 2010 ,Fan Bin, et al., 2007, Soma, Y et al., 2011,Barbara Harlizius and JanMerks, 2004 ,Stratz, P. et al., 2012, Débora M et al., 2008, Ramos, A et al., 2006,Mehmet Ulaş ÇINAR et al., 2012 ,Soma, Y. et al., 2010 ,Stearns, T.M, et al., 2005 ,Andersson et al., 1998,Uemoto, Y et al., 2008 ,Zuo Bo, et al., 2003 ,Romas, A.M et a l., 2009,Choi Igseo et al., 2011,Sanchez et al., 2011,Harmegnies, N. et al., 2006,Sanchez, .P, et al., 2010,Doreen Becker et al., 2013, Li, H.D et al., 2010,Wimmers Klaus, et al., 2005,Cherel Pierre, et al., 2011 ,Zhi-Liang Hu, et al., 2011,Vidal, O et al., 2005,Stratz, P. et al., 2012 ,Lund et al., 2010 ,Koning, D.J. deet al., 2001 , Malek Massoudet al., 2001,Li, Yet al., 2011 ,Eli Grindflek et al., 2001 ,Brinkhauset Große, al. 2010 ,Henri CM Heuven, et al., 2009,Henri CM Heuven, et al., 2009 ,Huang, W. et al., 2012 ,Kim, S.W et al., 2011 ,Ovilo C, et al., 2002,Edwards, D.B et al., 2006 ,Rothschild MF et al., 1995, Moser G et al., 1998, Milan D et al., 1998,Sato, S et al., 2003, Suzuki, K et al., 2006, Débora M et al., 2008, Pierre Cherel1 et al., 2011, Stratz, C et al., 2012,Ramos A et al., 2009, KerL, R.J et al., 2006, Klaus Wimmers et al., 2005, Doreen Becker et al., 2013,Christine Große-Brinkhaus et al., 2010, Huang, W, Z et al., 2012, Harmegnies N, F et al., 2006, Stearns, T.M et al., 2005, Nii, M et al., 2005,Andersson et al., 1994, de Koning et al., 2001, Grindflek, E et al., 2001,
	Cattle	Gutierrez-Gil B, et al., 2007 ,Mingyan Shi et al., 2011,Colin R Cavanagh et al 2011, Casas, E et al., 2000,MacNeil, M et al., 2002, Gutierrez-Gil et al., 2007,
	Bovine	Stone, R.T et al., 1999,
	Turkey	Muhammad L Aslam et al., 2011,
	Sheep	Cavanagh Colin, R. et al., 2010,Karamichou E et al., 2005 ,Johnson, P.L et al., 2005,
	M. longissimus dorsi	Siriluck Ponsuksili et al., 2010,
	Chicken/Bird	Nadaf Javed, et al., 2007 ,Van Kaam, et al., 1999,
Meat color		
	Pig	Taniguchi, M. et al., 2010 ,Fan, B, et al., 2008,
	Chicken	Elisabeth Le Bihan-Duval, et al., 2011,Elisabeth Le et al., 2011,
	Fish	Baranski Matthew et al., 2010,
Meat Fatness		
	pig	Mark Lund Lena et al., 1999 ,Yang, B, et al., 2011 ,Marie-Pierre Sanchez et al., 2007 ,de Koning et al.;, 1999,Annemieke P. Rattink et al., 2000 ,Liu, G et al., 2007 ,Cepica S et al., 2003 ,Kim Jae Hwan et al., 2008 ,Annemieke P et al., 2000, Kim, Y et al., 2006, Nii, M et al., 2006, Jae-Hwan Kim et al., 2008, Juliette Riquet et al., 2007,Marie-Pierre Sanchez et al., 2007, Lena Marklund et al., 1999, Clop, A et al., 2003,
	Chicken	Mignon, G. Le et al., 2008,Behnam Abashat et al., 2006 ,Lei, M et al., 2007 ,Sandrine Lagarrigue et al., 2005,Atzmon, G. et al., 2006,Sandrine L et al., 2006, Abasht B et al., 2006b, Ruy D et al., 2007, Jennen D.G et al., 2004,Ikeobi C.O et al., 2002, Lagarrigue S et al., 2006, Mignon G et al., 2008, Jennen DG et al., 2005, Jennen DG et al., 2004,
	Meishan	Kuehn, L.A. et al., 2007 ,Umeto, Y. et al., 2009 ,
	Cattle	Kim, J.J et al., 2003, Kim, J et al., 2003,
Meat fat color		
	Cattle	Tian R et al., 2009,
Meat fibre		
	Fish	Zhang, et al., 2011,

(Siriluck et al., 2010). QTL mapping for meat quality in commercial pigs (Ker et al., 2006). Several meat qualities QTL with significant effects were discovered on SSC17 (Ramos et al., 2007). Identified QTL pairs involved in the expression of carcass composition and meat quality traits show that the genetic architecture of carcass composition and meat quality is mainly composed of a complex network of interacting genes rather than of the sum of individual QTL effects (Christine et al., 2010).

In several QTL studies, successful discoveries of QTL of body composition and meat quality were reported in pigs (Thomsen et al., 2004; Guo et al., 2008; Liu et al

2007; Liu et al., 2008; Karamichou et al., 2005). There are several reports, in which QTL for growth and meat quality were detected in KNP populations (Lee et al., 2003; Kim et al., 2005a; Kim et al., 2007). QTL analysis for correlations between transcript abundance and meat quality traits, (Siriluck et al., 2010). With approximately 70% of the genome covered by the scan and using a chromosome-wide, identified 37 QTL affecting meat quality and carcase traits, (Ker et al., 2006). Identified total of 14,16,17 and 18 chromosome regions have been selected which cover the major QTL areas affecting carcass and meat quality in Pig, (Barbara and Jan, 2004; Débora et al., 2008). QTL analyzed for meat quality traits several showed pair-wise epistic effects, (Stratz et al., 2012). By QTL analyses founded MYF6 as a potential candidate gene for meat quality traits in pigs, (Mehmet et al., 2012). Identified QTLs affecting growth, body size, carcass, physiological, and meat quality traits in a Duroc purebred population, (Suzuki et al., 2006; Nii et al., 2006; Kim et al., 2006; Uemoto et al., 2008; Soma et al., 2011). First time reported significant QTL for meat quality and carcass traits in the chicken, sheep and Cattle (Van et al., 1999; Nadaf et al., 2007; Gutierrez et al., 2007; Colin et al., 2010). Detected Evidence of quantitative trait loci influencing carcass and meat quality traits in commercial swine lines, (Stearns et al., 2005). Many QTL associated with meat quality traits were found in the Duroc population, (Li et al., 2010). QTL analyses of the growth curve, body weight, breast yield and the meat quality traits on 21 of the 27 turkey chromosomes, (Muhammad et al., 2011). QTL for carcass and meat quality traits on *Sus scrofa* chromosome (SSC7) were detected in Meishan population (Huang et al., 2012). Founded casual genes mutations on chromosome17 in pig (Zhi-Liang et al., 2011; Pierre et al., 2011). Identified 17 epistatic QTL pairs for carcass composition and 39 for meat quality traits in porcine Duroc × Pietrain population, (Brinkhauset et al. 2010). QTL affecting meat and carcass quality were found on SSC2 in this large, commercially produced population, (Henri et al., 2009). Detected 26 estimated breeding values (EBVs) in Swiss Large White Boars for various traits including exterior, meat quality, reproduction, and production. (Doreen et al., 2013).

Meat fibre

In general, muscle fiber density is tightly related to growth of body mass. Fast-growing farm strains tend to have a higher muscle fiber density than slow-growing strains (Dransfield and Sosnicki 1999). Muscle fiber-related traits are major contributors for meat quality (Johnston et al., 2003; Kohn and Kritzinger, 2005). In general, muscle fiber density is tightly related to growth of body mass. Fast-growing farm strains tend to have a higher muscle fiber density than slow-growing strains (Dransfield and Sosnicki, 1999). Fiber diameter trait is related with meat density and toughness. Smaller muscle fiber diameter allows higher muscle-packing density and increases meat hardiness (Johnston et al., 2000). Muscle fiber-related QTLs have been widely studied in poultry and in pig in order to improve meat quality (Ovilo et al., 2002; Jennen et al., 2004, 2005; Nii et al., 2005; Stearns et al., 2005; Abashtet al., 2006; Lei et al., 2007; Estelle et al., 2008). However, to our best knowledge, no studies on meat quality QTLs have been conducted with aquaculture species. Fibre-type composition has been reviewed in relation to meat quality by Klont et al. (1998); Morris et al. (2009).

Muscle fiber-related QTLs have been widely studied in poultry in order to improve meat quality (Ovilo et al., 2002; Jennen et al., 2004; 2005; Nii et al., 2005; Stearns et al., 2005; Abashtet al., 2006; Lei et al., 2007). However, to our best knowledge, no studies on meat quality QTLs have been conducted with aquaculture species. QTL analysis of muscle fiber-related traits, including muscle fiber cross-section area and muscle fiber density in common carp (Zhang et al., 2011).

Meat pH

Reported in many studies the ultimate pH is the most important indices of meat quality. They should be used in a standard evaluation of meat and especially in choosing meat for ageing process. The same quality parameters are taken into account in the evaluation of carcasses and meat intended for export (Wulf et al., 1997; Wulf and Wise, 1999; Page et al., 2001; Gońi et al., 2007). High pH is improper for sorting, confectioning and blankness covering of meat. Moreover, meat of a high ultimate pH can be characterized by sticky structure, increased water-holding capacity and decreased specific taste (Pipek et al., 2003; Villarroel et al., 2003).

Meat water holding capacity

Water represents between 70% and 80 % of the weight of raw meat, and so influences the sensorial quality and organoleptic aspects juiciness, tenderness, texture, smell and color and the technological quality (Arango and Restrepo, 2003), traits that meat processing, such as capacity for water retention (CWR), the pH and the conductivity (Eguinoa et al., 2006). The ability of meat to retain inherent water, defined as water-holding capacity (WHC), is a fundamental quality parameter for both the industry and the consumer. Water-holding capacity (WHC) appear to be associated, their specific biochemical properties vary separately (Warriss and Brown, 1987; van Laack et al., 1994; Joo et al., 1995). Meat with excessive drip loss is not expectable (Kauffman et al., 1992; Warner et al., 1993; Warner and Kauffman, 1996).

Drip-Loss

Drip loss is an economic problem first for the raw meat producers due to the loss of weight caused in the butchering, with accumulation of fluid around the meat at the point of sale, reducing acceptance and causing negative response by consumers (Roseiro et al., 1994). Drip loss depends on the limitation of sarcomeres which is regulated by the interaction of muscle temperature and rigour development. All factors influencing the rate of quality deviations like PSE, DFD, Acid meat, RSE, PFN will inevitably affect the degree of drip loss (Fischer, 2007).

Meat protein

The changeability in protein quality is one of the most important concerns, and often drawback, in its use in poultry and livestock rations. However, because of the nature of the raw materials and processing methods, the quality of animal protein meals can vary noticeably (Wilder, 1973; Skurray, 1974; Johnston and Coon, 1979a).

Meat hydroxyprolin

The determination of Hydroxyprolin in meat products is an often used parameter for the evaluation of meat quality. Hydroxyprolin in meat science as a connective tissue marker (John 1988; Smith and Judge 1991).

Meat tenderness

Meat tenderness is an important issue in meat production because it has a major impact on consumer satisfaction. Consumers consider tenderness to be the single most important component of meat quality (Miller et al., 1995). Meat flavor, tenderness and juiciness appear to be the three most important determinants of sensory satisfaction for the consumer (McIlveen and Buchanan (2001). A current concern in production of meat is tenderness of the end product, which has a major impact on consumer liking. Meat tenderness can be dominated by a number of environmental influences, although it seems that genetics of the animal can play a significant role (Shackelford et al., 1994). QTL were found influencing meat quality tenderness on SSC4 and SSC14, colour on SSC5, SSC6 and SSCX; and conductivity on SSC16 (Harmegnies, N., et al., 2006). QTL analyses detected (CAPN1) as a potential candidate gene on BTA29 affecting meat tenderness, (Smith et al., 2000).

Meat juiciness

Only a few studies have been made to obtain a more basic knowledge of factors of importance to juiciness, even though juiciness facilitates the chewing process as well as brings the flavor component in contact with the taste buds. Juiciness is therefore of great importance for the overall eating understanding and should certainly not be overlooked as an important eating quality. Juiciness is slightly correlated to IMF (r=0.33) but even more correlated to pH_u (r=0.68). (Dransfield et al., 1985).

Meat oxidative stability

All meat and fish products are prone to oxidation. Along with meat products, poultry meat is considered to be more prone to the development of oxidative rancidity compared to red meat. Oxidation reduces meat quality by a number of ways, including off-flavor formation, drip loss, colour changes etc. The formation of unstable lipid oxidation products strongly reduces the consumer's acceptability of the product. Oxidative processes can also affect the ability of the membranes to hold water and may contribute to drip loss (Jensen, 1998; Weber, 2001). An enhancement in oxidative stability can be achieved by modifications in the lipid composition of muscle cells membranes (Barroeta and Cortinas, 2002). Higher levels of PUFA in the diet increase the PUFA/saturated fatty acid (SFA) balance in the carcass (Grau et al., 2001). The PUFA are healthier than SFA, but also are more prone to oxidation and can act further as pro-oxidants.

Meat marbling

Marbling (intramuscular fat) is the fat within the actual muscle of the animal. It is different to subcutaneous fat, this is external fat is deposited more slowly and continuously throughout the life of an animal Marbling. Marbling, intramuscular fat is an importantly intrinsic factor contributing to meat deliciousness and thus used as an indicator for meat quality grading (USDA, 1997; CMA, 2003).

Meat firmness

Meat should appear firm rather than soft. When handling the retail package, it should be firm, but not tough. It should give under pressure, but not actually be soft. Firmness of fish meat is one of the indicators of freshness of fish. Fish meat after death, has strong flexibility and firmness (Masashi et al., 2007).

Meat color

Color is an important quality attributes that influences consumer acceptance of many food products. Meat purchasing decisions are influenced by color more than any other quality factor because consumers use discoloration as an indicator of freshness and integrity. As a result, nearly 15% of retail is discounted in price due to surface discoloration, which corresponds to annual revenue losses of $1 billion (Smith et al., 2000). Along with external appearance traits of meat, color is generally the first visual feeling that consumers have and has some influence on their buying decisions. It has been determined that over 40% of consumers judged the freshness of meat by its color, and thus color can be easily utilized as an indicator for the visual evaluation of meat quality. Meat color has a heritability value of approximately 30%, which is higher than those of other meat quality traits such as pH, water-holding capacity and drip loss. Color also has genetic correlations with these traits. Meat color can be integrated in breeding schemes as an objective trait (Sellier, 1998; Brewer et al., 2002). QTL relevant to meat color measures, juiciness score and glycolytic potential traits (Malek et al., 2001). QTL analysis and gene expression QTL (eQTL) were combined to identify the causal gene (or QTG) underlying a highly significant QTL controlling the variation of breast meat color in a F2 cross in chicken lines (Elisabeth et al., 2011). Investigated positional gene on chromosome SSC6 by QTL analysis in pig (Taniguchi et al., 2009). Detected QTL region on chromosome 17 genes related to meat color in pig (Fan et al., 2008).

Red-orange meat color is an essential quality of farmed salmonid fish, which determines its market acceptance and price (Sigurgisladottir et al., 1997). However, meat color is a good applicant trait to be improved more efficiently with marker assisted selection (MAS). As the Atlantic salmon industry has expanded, meat quality traits have become of increased interest to producers. Meat color is well thought-out to be an indicator of salmon freshness and quality and processors and retailers will downgrade or even reject product with insufficient color (Nickell and Springate, 2001). Recently, reported QTL analysis for meat color in Tilapia and Atlantic salmon, Coho salmon (Lee et al., 2005; Derayat, 2009; Matthew et al., 2010).

Meat fatness

The tendency is to focus on the production of edible lean with a minimum of excess visible fat (Forrest et al., 1975), but the fact remains that fat in meat contributes to the eating quality of meat (Webb, 2003; Wood, 1990). It is also widely accepted that the amount of fat in meat influence is major components of meat quality (Wood et al., 1999). Fat and long-chain fatty acids, contribute to important aspects of meat quality and are central to the nutritional and sensory values of meat (Webb and Neill 2008; Guo et al., 2009).

Over the past few years, several experimental crosses have been used to detect QTLs for fatness in pigs (Rothschild et al., 1995; Milan et al., 1998; Moser et al., 1998; Lena et al., 1999; De Koning et al., 1999; Annemieke et al., 2000; Jean-Pierre et al., 2001; Marie-Pierre et al., 2007; Jae-Hwan et al., 2008; Yang et al., 2011). Studies have shown that intramuscular fat (IMF) content is one of the most important traits influencing eating quality uniqueness (Verbeke et el., 1999). Therefore, research on IMF deposition in the muscles of pigs and other meat-producing animals is currently one of the most important fields of study in meat quality science. Researchers investigating genetic variation related to IMF deposition in pigs have identified certain quantitative trait loci (QTL), and the locations of these on porcine chromosomes have been posited (Sanchez et al., 2007, 2011; Janss et al., 1997). In pig breeding, fat reduction is surveyed by a selection for decreased backfat thickness (BFT), which also creates a reduction in intramuscular fat (IMF) content. The reduction in IMF is unwanted because of positive correlations with meat tenderness, juiciness, and taste (DeVol et al., 1988; Cameron, 1990a). It has been reported that marbling and backfat thickness are positively correlated (Huff-Lonergan et al., 2002) and that a low percentage of intramuscular fat reduces tenderness and juiciness of the meat (DeVol et al., 1988). QTL influencing the weight of abdominal fat (AF) was detected on chicken chromosome 5 (GGA5) using two successive F2crosses between two divergently selected Fat and Lean INRA broiler lines (Mignon et al., 2008) Many QTLs detected affecting fatness in chicken (Lagarrigue et al., 2006; Ikeobi et al., 2002; Jennen et al., 2004; Ruy et al., 2007; Abasht et al., 2006b; Sandrine et al., 2006; Atzmon et al., 2006).

Meat fat color

Yellow fat colour in beef cattle is of economic importance as many carcasses with high fat colour scores are down-graded for export markets. Yellow fat in cattle is caused by the deposition of *β-carotene* in adipose tissues. *β-Carotene* is the pioneer of vitamin A and, as such, is a fundamental nutrient in the diet of animals (Von Lintig and Vogt, 2004). On the other hand, there is proof that the inheritance of yellow fat color in animal is more complex than being a simple Mendelian recessive trait (Kruk, 2001; Tian et al., 2010). Moreover, in addition to the quantitative trait nucleotide (QTN) in theBCO2gene, several other QTL of sensibly large effect have been identified for yellow fat color in cattle (Tian et al., 2009).

CONCLUSION

Several QTL studies have been studied on meat quality traits in some animals but very few QTL studies are reported in fish. All over about 05 traits have been analyzed in 07 types of animals and 03 aquaculture species. These traits include, such as meat quality, meat color, meat fibre, meat fatness and fat color (Table1). Meat fibre Quality traits are reported only in the common carp and pig (Estelle et al., 2008; Nii et al., 2005; Zhang et al., 2011). Recently, reported QTL analysis for meat color in Tilapia and Atlantic salmon, Coho salmon (Lee et al., 2005; Boulding et al., 2008; Derayat 2009; Matthew et al., 2010). Safe, nutritious, an enjoyable and pleasant eating fish is a basic requirement of consumer. It is therefore, qualitative traits such as meat quality have a basic importance to improve aquatic production. Therefore, carcass trait (meat quality, meat fatness, meat fibre and meat color etc), need great attention to be investigated in aquaculture species. Importantly, muscle fiber related trait are considered major contributor to meat quality and fiber density is directly related with the body mass growth. It requires further investigation in other commercial aquaculture species to increase the product and profit of aquaculture. Different types of molecular markers and various approaches have been applied to detect the QTLs effecting meat quality traits in animals. Likewise, body colour and carcass trait need much more attention from the researcher and scientists, to investigate the gene controlling such important trait, for increasing yield of aquaculture. Present review contains the necessary information about the QTLs detected important traits of animals. This valuable background knowledge would lead to investigate QTLs and identifying genes of most important traits of aquaculture species in further. Thus, that genomic information could be applied in MAS breeding programs to fulfill the meat and protein demand of market through aquatic species and prevent from the huge loss in aquaculture industry.

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