Feeding regimens affecting meat quality characteristics

G. Kandeepan[1]*, A.S.R. Anjaneyulu[2], V.K. Rao[3], U.K. Pal[3], P.K. Mondal[3] and C.K. Das[3]

Pregledni rad

Abstract

Consumer oriented demands in meat quality have motivated the meat producers to concentrate on the nutritional aspects of livestock rearing. The meat quality attributes are affected by the amount and type of nutrient intake by the animal. Grass feeding produces a stronger flavored meat. Increased energy density of the diet results in heavier carcass, higher fatness and marbling. Feeding lipids rich in polyunsaturated fatty acids, enhances conjugated linolenic acid in beef, polyunsaturated: saturated fatty acids and n-6: n-3 ratio in pigs. Supplemental feeding of nutrients produces heavier carcass, higher dressing percentage, slight increase in fat deposition and desirable organoleptic traits. Feeding of vitamin E improves colour, tenderness, juiciness, oxidative stability and extends shelf life of meat. Feed supplemented with selenium and zinc fairly improves the acceptability and decreases the oxidative rancidity of the cooked chicken meat product. Probiotic feeding in broilers improves protein, water holding capacity, emulsion stability, emulsifying capacity, organoleptic scores and shelf life of the meat products. The meat obtained from β-adrenergic agonists administered animals showed decrease in tenderness due to a lower percentage of heat soluble collagen and rapid maturation of connective tissues. Organic nutrition did not affect the growth performance and carcass quality of pigs. Thus, animal diet greatly contributes for the quality of meat.

Key words:Nutrition; *meat; quality; grass; concentrates; feed supplements; probiotic; β- adrenergic agonists; organic*

Introduction

Nutrition is a powerful component of livestock production system that controls several aspects of meat quality. Consumer oriented demands in meat quality has motivated the meat producers to concentrate on the nutritional aspects of livestock rearing. The animal feed mostly affects hygienic, sanitary and nutritional characteristics of meat. Particularly, various meat quality attributes that are affected by the amount and type of nutrient intake of the animal shall include dressing yield, meat : bone ratio, protein : fat ratio, fatty acid composition, calorific value, colour, physicochemical and processing properties, shelf life and sensory attributes (Nardone & Valfre, 1999).

The consumers' perception of meat has drastically changed over a period of time. They have become more health conscious. They prefer quality meat at affordable cost with attractive bright colour, leaner with low fat, tender, free from residues and processed under hygienic conditions. More recently, several studies have confirmed meat to be functional food (Kandeepan et al., 2007). It improves the health of the consumers in a more natural way than popping up pills (Fernandez-Gines

[1] National Research Centre on Yak, Dirang, West Kameng District, Arunachal Pradesh 790101, India

[2] National Research Centre on Meat, Chengicherla, Uppal, Hyderabad, Andhra Pradesh 500039, India

[3] Department of Livestock Products Technology, Rajiv Gandhi College of Veterinary and Animal Sciences, Kurumbapet, Puducherry 605009, India

* Corresponding author. Tel.: +91 03780 242259; Fax: +91 03780 242273.
Email address: drkandee@gmail.com (Kandeepan. G)

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Table 1 Carcass and meat quality characteristics of steers (Realini et al., 2004)

Tablica 1. Polovice i obilježja kakvoće mesa junadi (Realini et al., 2004)

Characteristics / Obilježja	Pasture (n=10) / Ispaša (n=10)	Concentrate (n=20) / koncentracija (n=20)
Hot carcass weight, kg / Težina toplog trupa	225.60^{a}	240.10^{b}
Degree of finishing* / Stupanj obrade	1.5^{a}	2.0^{b}
Fat depth, mm / Debljina slanine, mm	3.8^{a}	6.1^{b}
Rib eye area, cm^2 / Površina cm^2	55.20^{a}	62.9^{b}
Total lipid** / Ukupni lipidi	1.68^{a}	3.18^{b}
Total CLA*** / Ukupna linolenska kiselina	0.53^{b}	0.25^{a}
SFA****	49.08^{b}	47.62^{a}
MUFA****	40.96^{a}	46.36^{b}
PUFA****	9.96^{b}	6.02^{a}
PUFA:SFA*****	0.20^{b}	0.13^{a}
n6:n3******	1.44^{a}	3.00^{b}

Mean values with different superscript differ significantly (p<0.05)
Srednje vrijednosti s različitim oznakama signifikantnosti (p<0.05)
* A lower number indicates lack of finishing (0-4) /
Manji broj ukazuje na nedostatak završne obrade (0-4)
** As percentage of total nutrient composition / Kao postotak ukupne hranjive vrijednosti
*** mg Conjugated Linolenic Acid (CLA)/g lipid / Lipid /konjugirana linolenska kiselina
**** As percentage of total fatty acids in the intramuscular fat /
Kao postotak ukupnih masnih kiselina u intramuskularnom masnom tkivu
***** As ratio between the polyunsaturated fatty acids (PUFA) and saturated fatty acids (SFA) / Kao odnos između polinezasićenih masnih kiselina i zasićenih masnih kiselina
****** As ratio between the two group of fatty acids / Kao odnos između 2 skupina masnih kiselina

Table 2 Effect of dietary factors on consumer acceptability and TBA values of cooked dark chicken meat (Bou et al., 2005)

Tablica 2. Učinak faktora prehrane na prihvatljivost i TBA vrijednosti kuhane tamne piletine (Bou et al., 2005)

Factors studied / Faktori istraživanja	74 days of storage at -20°C / 74 dana pohrane na -20°C	
	Acceptability score* / Ocjena prihvatljivosti	TBA# (µg MDA•/ kg)
Fat source / Izvor masti		
Fish oil / Riblje ulje	4.9	86
Linseed oil / Laneno ulje	5.0	84
Animal fat / Životinjske masti	5.1	74

*sensory scores based on 9 point scale / senzorna ocjena u skali do 9 bodova
#Thiobarbituric acid (TBA) value / TBA vrijednost
• Malonaldehyde (MDA)

et al., 2005). In this regard, even the American Dietetic Association has endorsed beef and lamb as functional foods.

So it has become imperative to develop nutritional strategies to produce meat more as a functional food than an ordinary source of animal protein. The strategies for quality meat production will include genetic selection and gene manipulation, balanced nutrition and use of approved growth promoting agents. The meat quality can also be improved through utilization of natural antioxidants, mineral supplements and probiotics.

Although there are various approaches in different areas towards quantity and quality of animal production for meat, the World Trade Organization (WTO) agreements have given a prominent and increasing role for law enforcement agencies to focus on improving quality and safety of meat products through adequate nutrition.

Pasture feeding

When animals are fed forages, growth rate is slower, animals attain slaughter weight at later age and the carcass has less fat. The meat is leaner, darker in colour and has more species specific flavors. β-carotene is present in high concentrations in fresh leaf tissue and is responsible for the undesirable yellow colour of fat in pasture fed beef (Daly et al., 1999). An undesirable "grassy" flavor may result from compounds found in forage. Consumption of wild onions and garlic can also give an undesirable meat flavor. This can be decreased or eliminated by feeding high concentrate diets for up to 90 days before slaughter. Lambs and other small ruminants have similar effects. However, feeding high concentrate diets to lambs prior to slaughter is not as common a practice as in beef. The high concentration of tocopherol in green leaf tissues makes the meat little susceptible to lipid oxidation (Aitken & Hankin, 1970).

Grass feeding produces a stronger flavored meat, preferred in the United Kingdom and New Zealand, whereas cereals produce a milder flavored meat that is preferred in Spain and the United States of America. This difference is generally attributed to whether the main dietary fatty acid is α-linolenic, which produces a stronger flavor, or linoleic acid which produces a mild flavor (Melton, 1990; Sanudo et al., 1998).

Feeding grass or concentrates containing linseed (rich in α-linolenic acid, 18:3n- 3) in the diet increases the content of 18:3n-3 and its longer chain derivative eicosapentaenoic acid (EPA, 20:5n-3) in beef muscle and adipose tissue, resulting in a lower n-6: n-3 ratio. Grass feeding also increases docosahexaenoic acid (DHA, 22:6n-3). However, grass feeding not only increases n-3 polyunsaturated fatty acids (PUFA) and conjugated linolenic acid (Table1.) but, due to its high content of vitamin E, color and shelf life is also improved. Conjugated Linolenic Acid (CLA) is formed predominantly in the rumen. The best natural dietary sources of CLA are beef and lamb (Ma et al., 1999). The American Dietetic Association has endorsed beef and lamb as functional foods because of the antitumorigenic properties of the CLA they contain (ADA, 1999). It is evident that opportunities exist to enhance the health promoting fatty acids in beef and beef products offering valuable addition and contribute to market differentiation. However, it is imperative that these approaches that deliver "functional" attributes do not compromise on the health value (lipoperoxidation) or the taste of beef products (Scollen et al., 2006). Frozen meat from semi- extensively reared male buffaloes undergo splitting of fibre and breaking or stretching of connective tissue causing significantly (P<0.05) improved tenderness and juiciness (Kandeepan, Biswas & Porteen, 2006).

Feeding dietary fibre

When diets have a high fibre and low-energy content, carcasses are less fattened, the skeleton is more developed and the lipid content of the carcass is very low, but water and protein content seem to be high. Higher crude fibre feeding leads to lower energy content of the meat.

Feeding high concentrate diet

In general, as the energy density of the diet increases, either through the use of high quantity grains that replace forages or by adding fat, the growth rate of the animals increase, animals reach slaughter weight at younger age, the resultant carcass is heavier and higher in overall fatness and marbling (May, 1992). The percentage of muscular tissue is lower and that of fat higher, in animals of high plane of nutrition than those on a lower plane. When the proteins: energy ratio is increased, the fastest growing animals may become leaner. The meat is juicier and the fat flavor masks the meat flavor of the species (Campbell & King, 1982).

Beef carcasses from grain fed cattle are not as susceptible to cold shortening as these fatter, heavier, more muscular carcasses chill slower. Rapid rates of growth have been shown to have higher amounts of collagen solubility in young cattle fed with high concentrate diet (Wu et al., 1981). Therefore, feeding high concentrate diets to cattle prior to slaughter has a positive effect on structural components of the muscle (Table1.) and results in improved meat palatability. Concentrate diets improve beef flavour and juiciness. The meat is brighter and cherry red in color and the fat is whiter. Beef obtained from cattle fed on corn based diets is more desirable in terms of flavour than pasture-fed beef. Flavour difference is due to fatness variation in beef (Melton, 1983).

On high plane of nutrition, a greater proportion of fat is synthesized from carbohydrate; and such fat has consequently a lower iodine number. High plane of nutrition increases the percentage of intramuscular fat and decreases the percentage of moisture in sheep. There is a progressive diminution in the percentage of myoglobin from 0.08 to 0.05% in the longissimus dorsi as the plane of nutrition is increased in pigs. Low concentration of tocopherol in grain-based diets makes the beef susceptible to auto-oxidation of oxymyoglobin (bright red) to metmyoglobin (brown) and decrease colour stability (Faustman et al., 1989). Intensive feeding of high concentrate diets prior to slaughter improves marbling scores and palatability ratings in beef (May et al., 1992). The meat from intensively reared young male buffaloes showed a significantly (P<0.05) higher moisture, collagen solubility, sarcomere length, myofibrillar fragmentation index, tenderness and connective tissue residue scores but lower collagen, insoluble collagen and shear force value compared to meat from semi- extensively reared spent male and female buffaloes (Kandeepan et al., 2009).

Feeding sub maintenance diets

In sub maintenance diets, fat is mobilized rather than deposited from muscles. Undernutrition causes a marked increase in the water content of the muscle (83% compared to 74% in well- nourished animals). This is also associated with the increase in percentage of intramuscular collagen and a decrease in its salt soluble proteins, a factor conducive to toughness (Bailey & Light, 1989). Sub maintenance feeding to growing broilers from 4-8 weeks of age reduced yield of breast and thigh muscle weights by 30-35% than those fed ad libitum (Asghar et al., 1986).

Feeding inadequate protein diet

Although inadequacy of many nutrients is bound to have repercussion on the meat quality, only a few are of

Table 3 Effect of Vitamin E on Taste Characteristics of Cooked Roast Beef (Robbins et al., 2003)

Tablica 3. Utjecaj vitamina E na senzorna svojstva goveđeg pečenja (Robbins et al., 2003)

Characteristics Svojstvo	Vitamin Treatment / Tretman vitaminom		
	Vit E(E+)	Control/Kontrola (E-)	SEM
Tenderness / Nježnost	10.25	10.53	0.20
Saltiness /Slanost	1.23	1.50	0.13
Juiciness /Sočnost	6.45^{b}	7.15^{a}	0.19
Beef flavour / Miris i okus	8.11	8.50	0.26

15 cm semi-structured line scale where 0=none and 15=intense / skala 15 cm 0=nema, 15=intenzivno

consistent concern in practice. Protein inadequacies affect the amount of meat more than its quality. A failure to provide sufficient amounts of essential amino acids also impairs meat formation. Lysine is of particular concern because of its very high proportions in muscle protein and its usual marginal levels in most feeds. Such inadequacies are likely to occur prior to marketing and result in additional carcass fat and decreased breast meat yield (Moran & Bilgili, 1990).

With a diet low in digestible protein that decreases growth rate, the meat quality is enhanced because of low muscle glycogen reserve. The development of glycolytic metabolism is limited and the fall of the pH during the processing of the muscle into meat is restricted and this meat has a better water-holding capacity.

Feed restriction on carcass composition

The carcasses of feed restricted rabbits are less fatty, have a lesser meat to bone ratio and a lower slaughter yield (Ouhayoun et al., 1998). Body composition is rich in water and ash and has less fat and protein. Feed restriction could be detrimental for the juiciness and flavour of the meat but not on other sensory traits even though muscular fat content was largely decreased (Larzul et al., 2004). Feed restriction in the grain fed group resulted in significantly slower weight gain, reduced carcass weight, and reduced subcutaneous and intramuscular fat (Daly et al., 1999).

Dietary fat content

Fat is the main component of meat that is most affected by nutrition. When fat is present in the diet of rabbits at high levels (more than 9%), the dressing percentage is increased, carcasses are fatter, the carcass length to circumference ratio is reduced, and the fat content of hind leg meat is increased, while water and protein content is reduced (Pla & Cervera, 1997). However, in some studies different feeding plans and fat enriched diets do not show variation in chemical composition of the longissimus dorsi muscle of rabbits (Castellini & Battaglini, 1992).

Feeding high levels of unsaturated fats have resulted in problems of carcass fat softness and oxidative instability of meat (Alhus & Dugan, 2001). Fish oil supplementation increased the proportions of n-3 fatty acids, which may increase acceptability of the beef by the consumers (Wistuba et al., 2006). Feeding high n-3 fatty acid enriched diet to pigs caused an improvement of these fatty acids and increased the susceptibility of pork to peroxidation (Nurnberg et al., 1999).

Feeding PUFA rich lipids which are protected from ruminal biohydrogenation result in further enhancement of the PUFA in meat with concomitant beneficial improvements in the ratio of polyunsaturated: saturated fatty acids (P:S ratio) and n-6:n-3 ratio (Scollen et al., 2006). Feeding PUFA-rich diets increases the content of CLA cis-9, trans-11 in beef. CLA isomer in beef is mainly associated with the triacylglycerol lipid fraction and therefore is positively correlated with level of fatness.

Increasing the content of n- 3 PUFA improves "greasy" and "fishy" flavour in beef, whereas, color and shelf life are reduced. Under these situations, high levels of vitamin E are necessary to help stabilize the effects of incorporating high levels of long chain PUFA into meat.

Vegetable or animal source of added fat affect the lipid composition, flavour and juiciness of rabbit meat (Oliver et al., 1997). Enriching the diets with soy, sunflower oils or soy beans increases the proportion of unsaturated fatty acids. The fatty acid profile of the meat and fat deposits of rabbits do not exactly reflect the fatty acid profile of the dietary source of fat (Cobos et al., 1993). Meat juiciness was increased and the meat from rabbits fed with animal fat diets was considered to have more "liver" taste, while vegetable fat provided an "aniseed" or "grass" flavour. The addition of vegetable and animal fat to the diet affected fat color significantly. Water holding capacity and pH of longissimus dorsi muscle were higher in rabbits fed with fat-enriched diets (Pla & Cervera, 1997).

If a 5% of copra oil (coconut) rich in lauric acid is added, the carcass has a pleasant appearance but the meat has a soapy taste, which makes it unfit for consumption. Conversely, when olive oil is incorporated into the diet, the carcasses are unappealing but the meat is acceptable. Adding linseed oil and soybean oil, both give an unpleasant flavour to meat because of the high content of polyunsaturated fatty acids, especially linoleic acid which easily peroxidises. If the fat added is cocoa butter (rich in stearic acid), the meat has a high organoleptic quality.

The dietary fat has significant effect on meat flavour and stability. Fats and oils are commonly used in poultry and pork diets. Poultry and pork normally have high levels of linoleic acid in their tissue and this partly contributes to their mild flavour. Altering the fatty acid composition of the diet in non ruminants influences the final fatty acid composition of the fat. Increasing the unsaturated fatty acids in diet improves the rate of oxidation, which makes a significantly lower deposition of highly unsaturated fatty acids in the meat. As a result, the carcass content of linoleic acid and α-linolenic acid were 0.6 to 0.8 and 0.35 respectively in pigs (Enser et al., 1996).

Feeding of fats and oils in pigs

Higher oleate diet fed growing pigs was found with higher muscle and adipose tissue oleate levels. The longissimus muscle chops were juicier and more tender (St. John et al., 1987). Attempts to reduce the fat content of porcine carcasses by nutritional manipulation can cause in increased softness and loss of cohesiveness in fatty tissue, leading to separation of subcutaneous fat into layers. This undesirable effect is due to a decrease in the size of the fat cells and an increase in the ratio of linoleic to stearic acids in the fat (Wood, 1984).

The more unsaturated the fatty acid, the greater its propensity to undergo peroxidation and it is well established that feeding high levels of fish oils containing EPA and DHA results in a fishy taint in meat (Opstvedt, 1984). High oleic sunflower containing diet was softer, oilier and considered visual quality defect. In pigs fed canola oil, the subsequent meat had more off flavour and lower overall palatability ratings than normal ration fed pigs (Miller, 2002).

Feeding of fats and oils in Poultry

A significant increase in TBA number and rancid flavour scores (Table 2) for broilers fed 150 g/kg full fat linseed compared with birds fed animal diet were recorded (Ajuyah et al., 1993). Raised α-linolenic concentration was contributing to the oxidative instability. Nutritional effects on flavour of poultry meat are mainly negative and stem from feeding excessive quantities of n-3 PUFA derived from fish or linseed. This high susceptibility to peroxidation results in a rapid production of off-odors and flavors that reduce shelf life of both raw and cooked meat (Enser, 1999). Fish meal and fish oil in broiler diets should not exceed 12% and 1% by weight, respectively, if fishy taints are to be avoided. Other factors that "taint" the meat are the use of certain ingredients in rations. For example the use of fish meal in rations for slaughter animals can leave a "fishy" taste and it is well known that Ostrich are sensitive to iron, so use of ingredients with high iron content can taint the meat to give a livery taste.

Feeding dietary supplements

Supplemental feeding of nutrients produces heavier carcass, higher dressing percentage, first quality cuts, enhanced muscle proportion, slight increase in fat deposition and desirable organoleptic traits (Volpelli et al., 2002). Niacin supplementation improved ultimate pH and color score but decreased carcass shrink and drip loss percentage (Real et al., 2002). Dietary chromium methionine chelate supplementation is an alternative regimen to produce novel

Table 4 Quality of Buffalo Meat Pre-blended with Natural Antioxidants (Sahoo & Anjaneyulu, 1997)
Tablica 4. Kakvoća bivolskog mesa prethodno pomiješanog s prirodnim antioksidansima (Sahoo & Anjaneyulu, 1997)

Treatment	Day / Dan 0	Day / Dan 4	Day / Dan 8	Mean / Srednja vrijednost
Colour scores (5 points) / Ocjena boje (5 bodova)				
Control/Kontrola	4.60	2.67	1.0	2.74ª
SA*	4.77	4.70	4.33	4.60ᵇ
TA**	4.67	2.97	1.13	2.87ª
SA+TA***	4.70	4.60	3.90	4.39ᶜ
Met myoglobin (%) / Metmioglobin (%)				
Control/Kontrola	57.67	59.80	74.27	63.87ª
SA*	52.07	53.97	60.0	55.25ᵇ
TA**	55.77	58.80	68.87	60.73ªᶜ
SA+TA***	54.33	55.17	60.20	50.05ᵇᶜ
TBARS Number (mg malonaldehyde/ kg meat)				
Control/Kontrola	0.355	0.663	1.313	0.733ª
SA*	0.276	0.313	0.551	0.367ᵇ
TA**	0.310	0.440	0.709	0.469ᵇ
SA+TA***	0.291	0.318	0.705	0.420ᵇ

*Sodium ascorbate
**α-Tocopherol acetate
***Combination of Sodium ascorbate and α-Tocopherol acetate

Table 5 Effect of dietary factors on consumer acceptability and TBA values of cooked dark chicken meat (Bou et al., 2005)
Tablica 5. Učinak faktora prehrane na prihvatljivost kupaca i TBA vrijednost kuhane tamne piletine (Bou et al., 2005)

Factors studied / Faktori istraživanja	74 days of storage at -20oC / 74 dana pohrane na -20oC: Acceptability score* / Ocjena prihvatljivosti	TBA# (µg MDA•/ kg)
Zn supplementation / Dodatak Zn		
0 mg/kg	4.9	93
600 mg/kg	5.1	71
Se supplementation / Dodatak Se		
0 mg/kg	5.0	91
Selenite, 1.2 mg/kg	5.2	73
Se yeast 0.20 mg/kg	4.8	83

*sensory scores based on 9 point scale / senzorna ocjena u skali do 9 bodova
#Thiobarbituric acid (TBA) value •Malonaldehyde (MDA)

animal products such as low cholesterol, high lean and low fat meat (Ohh & Lee, 2005).

Feeding vitamin supplements in the diet

Feeding of vitamin E improves color stability/ freshness, tenderness, juiciness (Table.3), oxidative stability and extends shelf life of meat (Dirinck et al., 1996; Enser, 1999; Aalhus & Dugan, 2001). Vitamin E is not synthesized in animal cells and must be obtained from plants through diet. Green plant tissues have high concentration of Vitamin E than mature senescent tissue. Grains have low concentration of vitamin E. Supplementation of Vitamin E @0.5 g/day for 126 days doubly increases the display life of meat from grain finished animals (Liu et al., 1996).

Vitamin E helps to prevent lipid oxidation and retards metmyoglobin formation in meat exposed to air, so improving quality (Table.4). Retardation of browning by Vitamin E is linked to an inhibition of lipid oxidation. Auto oxidation produces metmyoglobin and super oxide radical from oxymyoglobin. Super oxide generates lipid free radicals that oxidize another oxymyoglobin as free radical scavenger. Vitamin E is an alternative substrate to oxymyoglobin and slows metmyoglobin accumulation (Lamari et al., 1996).Addition of Vitamin E is much more effective in stabilizing meat colour when it is incorporated through a dietary pathway than when it is added post-mortem to ground meat (Mistumoto et al., 1991).

Vitamin C and E are the natural antioxidants in meat that are derived from diet and may contribute to colour stability (Anjaneyulu, Kandeepan & Kondaiah, 2006). Vitamin C and E were individually effective at slowing metmyoglobin formation, whereas, when applied simultaneously, they completely inhibited metmyoglobin formation over 7 days. An excess of dietary vitamin A increases proteolytic activity of the muscle, perhaps by increasing the permeability of the membrane within which catheptic enzymes are contained. Increased vitamin D may increase tenderization via increased calcium levels in muscle tissue at harvest. This increased muscle pool then activates proteolytic enzymes that degrade certain muscle proteins (Swanek et al., 1999).

Feeding mineral supplements in the diet

Feed supplemented with Selenium and Zinc fairly improved the acceptability and decreased the oxidative rancidity of the cooked chicken meat product (Table.5). When the diet is high in iron, the meat will be a very dark red and cause the metallic taste when the meat is cooked. Poor nutritional diet with inadequate levels of calcium, phosphorus and the major vitamins A, and D causes multi-colored muscle meat in rabbits. Some muscles are dark red and some are nearly pink in color. This causes a problem with ground meat (Pla et al., 1995).

Probiotics feeding

Probiotic is a live microbial feed supplement which improves the intestinal microbial balance in favor of the host animal (Fuller, 1989). Public disapproval and banning of antibiotics and growth hormones as feed additives (due to their residual effects in meat) in certain parts of the world has renewed commercial interest in probiotics production and its use in poultry feeding. These are neither absorbed in the gut nor do they reach the general circulation i.e. without residual effect in meat.

A most widely used probiotic bacterium is *Lactobacillus acidophilus.* Lactobacilli colonize in the crop having effect on nutritional and performance parameters. They act as natural substitutes for feed antibiotics. Lactobacillus spore powder supplemented diets resulted in superior carcass characteristics of broilers such as reduced shrinkage, higher dressing percentage, giblets and edible meat yield. Lactosac feeding in broilers improved protein, water holding capacity, emulsion stability, emulsifying capacity, organoleptic scores and shelf life of the meat products. Also, probiotic fed group showed better carcass grade with higher dressing percentage, meaty cut up parts and meat: bone ratio (Mahajan & Sahoo, 1998).

Dietary yeast (*Saccharomyces cerevisiae*) components, such as whole yeast and cell wall supplementation improved tenderness and reduced oxidation of meat. Lowest supplementation of *Saccharomyces cerevisiae* significantly improves the liver weight in broilers.

Feeding β-adrenergic agonists

The commonly used β-adrenergic agonists include clenbuterol, cimaterol and ractopamine. β -adrenergic agonists have shown enormous potential to alter the muscularity and ratio of lean to fat in meat animals. The order of efficacy of these drugs in livestock is Cattle > Sheep > Turkey > Pig > Poultry. Unlike anabolic steroid hormones, β -adrenergic agonists are effective in all sexes to the same extent. The mechanism of action and the potential value lies in repartitioning effects. They reduce the amount of fat in the body and increase protein accretion, so promoting muscular development (Das et al., 2004). Fat reduction is done by both reducing the fat production (lipogenesis) and increasing fat breakdown (lipolysis). Protein accretion is through reducing breakdown and favoring normal protein turnover. Particularly, high proportions of type II, glycolytic, fast contracting fibres are more affected.

They are orally active and so can be administered in the feed, usually at levels of 1-10 ppm. The carcass yield is improved by around 1-2% in pigs and poultry and by up to 5-6% in cattle and sheep (Table.6). This is due to both an increase in carcass weight and a decrease in the size of the viscera. The carcasses have better conformation. The increase in muscle development is accompanied by reduction in subcutaneous, inter muscular and intramuscular fat (Warris, 2000).

Some β-adrenergic agonists may produce meat that is darker in color and tougher after cooking. Darker color is caused by reduced glycogen levels in the muscles at slaughter

Table 6 Effect of Oral Administration of β-adrenergic Agonists (Moloney et al., 1991)

Tablica 6. Učlinak oralne primjene β-adrenergilnih agonista (Moloney et al., 1991)

Animal Životinja	Weight gain (%) Prirast	Feed consumption (%) Potrošnja hrane	Feed/gain (%) Dodatak hrane	Muscle (%) Mišićni	Fat (%) Mast
Cattle / Goveda	+10	-5	+15	+10	-30
Chicken / Pilići	+2	-	+2	+2	-7
Pigs / Svinje	+4	-5	-5	+4	-8
Sheep / Ovce	+15	+2	+15	+25	-25

Table 7 Effect of Cimaterol on Meat Quality of LD Muscle (Vestergaard et al., 1994)

Tablica 7. Učinak ciamterola na kakvoću mesa (Vestergaard et al., 1994)

Treatments	Control	Cimaterol
Glycogen / Glikogen (μmol/g)	93	75.5
Protein / Bjelančevine(%)	22.5	23.3
Intramuscular fat / Međumišićno mason tkivo(%)	0.86	0.58
Soluble collagen / Topivi kolagen(%)	23.9	24.2
Shear force /Poprečna sila (kg)	5.8	17.7
Meat colour / Boja mesa(CIE Lab)		
Lightness /Svjetloća	40.6	42.4
Hue /Opažanje boje	31	33.2
Saturation /Saturacija	21.2	19.9

leading to a higher ultimate pH in the muscles. Toughness may result from a lower activity of proteolytic enzyme systems postmortem. By reducing intramuscular fat, β-adrenergic agonists may also reduce other eating quality parameters. Ractopamine feeding in finishing pigs decrease carcass fatness, increase lean, shear force and decrease in tenderness (Xiao et al., 1999; Alhus & Dugan, 2001).

pH and Water Holding Capacity(WHC)

Carcasses from β-adrenergic Agonists administered animals showed increased glycolysis that resulted in decreased muscle glycogen which ultimately increased the pH (Simmons et al., 1997). The less fat cover resulted in faster cooling of carcass. The increase in the rate of pH fall resulted in decreased WHC causing increased drip loss in veal.

Meat colour

Cimaterol resulted in a lighter meat due to decreased WHC caused by increased reflectance by moist surface (Table.7). A significant decrease in Heam pigment was observed due to increased percentage of white muscle fibers (Wheeler & Koohmaraie, 1992).

Meat tenderness

The meat obtained from these animals showed decrease in tenderness or increase in shear force due to decrease in percentage of heat soluble collagen (22-40%) and rapid maturation of connective tissues (Dawson et al., 1990). There was an increase in size and /or percentage of white muscle fibers with larger diameter. A decreased calpain activity in the carcasses of young bulls resulted in decreased proteolysis, which combined with changes in muscle fibre size decreases the tenderness (Vestergaard et al., 1994).

Calpain and calpastatin activity

A decrease in μ-calpain and/ or increase in calpastatin level results in decreased myofibrillar protein degradation. Consequently there is a decrease in 30kDa fragment and an increase in titin concentration (Koohmaraie & Shackelford, 1991).

Organic nutrition

Organic nutrition did not affect the growth performance and carcass quality of pigs (Millet et al., 2005).

Conclusion

Nutritional technology is a mechanism to improve meat quality. An adequate nutrition enables fast weight gains and strong muscling; the determining factor for high quality meat and consumer acceptance. Nutrition has direct effect on appearance, flavor, odor, tenderness and consumer acceptance. It has positive effect on fat content, fatty acids, cholesterol levels, vitamins and trace minerals, targeting products for specific category of consumers. Thus, animal diet greatly contributes for enhancing the meat production and quality.

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Režimi prehrane koji utječu na kvalitetu mesa

Sažetak

Zahtjevi u kvaliteti mesa s obzirom na potrošače su motivirali proizvođače mesa da se koncentriraju na nutritivne aspekte uzgoja stoke. Na karakteristike kvalitete mesa utječe količina i vrsta nutrijenata koje životinja unosi. Pasenjem trave nastaje meso intenzivnijeg okusa. Energetski jača prehrana rezultira težim polovicama, većom količinom masnoće i meso je više prošarano masnim tkivom. Prehrana polinezasićenim masnim kiselinama bogatim lipidima pojačava konjugiranu linolnu kiselinu u junetini, polinezasićene: zasićene masne kiseline i n-6: n-3 omjer kod svinja. Nadomjesna prehrana nutrijentima rezultira težim polovicama, većim postotkom gnoja, laganim povećanjem u taloženju masti i poželjne organoleptičke karakteristike. Prehrana vitaminom E poboljšava boju, mekoću, sočnost, oksidativnu stabilnost i produžava vijek trajanja mesa. Prehrana s dodatcima selena i cinka znatno poboljšava prihvatljivost i smanjuje oksidativnu užeglost proizvoda od kuhanog pilećeg mesa. Probiotska ishrana brojlerskih pilića povećava bjelančevine, sposobnost vezanja vode, emulzijsku stabilnost, emulzijski kapacitet, organoleptičke rezultate i vijek trajanja mesnih proizvoda. Meso dobiveno od životinja kojima su davani β-adrenergični receptori je pokazalo smanjenu mekoću zbog nižeg postotka toplinski topivog kolagena i brzog sazrijevanja vezivnih tkiva. Organska prehrana nije utjecala na rast i kvalitetu svinjskih polovica. Prema tome, prehrana životinja uvelike doprinosi kvaliteti mesa.

Ključne riječi: *prehrana, meso, kvaliteta, trava, koncentrati, prehrambeni nadomjesci, probiotik, β-adrenergični receptori, organski*

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Ernährungsregimearten, die auf die Fleischqualität einen Einfluss haben

Zusammenfassung

Forderungen hinsichtlich der Fleischqualität in Bezug auf die Verbraucher motivierten die Fleischhersteller, sich auf nutritive Aspekte der Fleischherstellung bei Viezucht zu konzentrieren. Auf die Charakteristiken der Fleischqualität haben einen Einfluss Nutrimentenmenge und –sorte, die das Tier einnimmt. Durch das Grasen bekommt das Fleisch einen intensiveren Geschmack. Die energetisch stärkere Ernährung resulitiert mit schwereren Hälften, einem größeren Fettgehalt und das Fleisch wird mit Fettgewebe gesprenkelt. Die Ernährung mir polyungesättigten Fettsäuren reich an Lipoiden verstärkt die konjugierte Linolsäure im Rindfleisch, polyungesättigt: gesättigte Fettsäuren und n-6: n-3 Verhältnis bei Schweinen. Die Zusätzliche Ernährung mit Nutrimenten resultiert mit schwereren Hälften, einer größeren Düngermenge, einer leichten Vergrößerung der Fettablagerung und den erwünschten organoleptischen Charakteristiken. Die Ernährung mit Vitamin E verbessert Farbe, Zartheit, Schmackhaftigkeit, oxidative Stabilität und verlängert die Fleischdauerzeit. Die Ernährung mit Zusatz von Selen und Zink verbessert bedeutend die Annehmbarkeit und vermindert die oxidative Ranzigkeit der Erzeugnisse aus dem gekochen Hühnerfleisch. Probiotische Ernährung der Broiler vergrößert die Eiweißstoffe und die Fähigkeit der Wasserbindung, Emulsionsstabilität, Emulsionskapazität, organoleptische Resultate und die Dauerzeit von Fleischerzeugnissen. Das Fleisch von Tieren, denen ß-adrenergische Rezeptoren gegeben wurden, hat eine verminderte Zartheit, dies wegen einen niedrigeren Prozent des wärmeauflösbaren Kollagens und einer schnellen Reife des Bindegewebes. Die organische Ernährung hatte keinen Einfluss auf den Wuchs und die Qualität von Schweinehälften. Demzufolge kann man feststellen, dass die Ernährung der Tiere wesentlich die Fleischqualität beeinflusst.

Schlüsselwörter: *Ernährung, Fleisch, Qualität, Gras, Konzentrate, Ernährungsersatze, Probiotika, ß-adrenergische Rezeptoren*

Regimi alimentari che influiscono alla qualità di carne

Sommario

La qualità di carne rischiesta dai consumatori ha motivato i produttori di concentrarsi agli aspetti nutritivi dell'allevamento di bestiame. Alle caratteristiche qualitative della carne influisce la quantità e la specie di nutrienti consumati dall'animale. Il sapore di carne diventa più intenso pascolando. L'alimentazione rinforzata energeticamente risulta con gli animali più pesanti e più grassi, e la loro carne è più attraversata con il tessuto grasso. Alimentazione con gli acidi grassi poli-insaturi, ricchi di lipidi, rinforza un coniugato acido linoleico nel manzo, la reciprocità acidi grassi insaturi : acidi grassi saturi e quella n-6 : n-3 dai maiali. L'alimentazione supplementare con i nutrienti risulta con gli animali più pesanti, che danno una quantità più grande di concime, una leggera crescita nella sedimentazione dei grassi e anche con le volute caratteristiche organolettiche. L'alimentazione con la vitamina E migliora il colore, morbidità, quantità di acqua nella carne, stabilità ossidativa, e anche prolunga la durata di conservazione di carne. L'alimentazione che contiene il selenio e il zinco migliora notevolmente l'accettabilità e diminuisce il danno ossidativo dei prodotti di carne di pollo cotta. La nutrizione probiotica dei polli broiler aumenta le proteine, abilità idrofila, stabilità di emulsione, capacità di emulsione, risultati organolettici e la durata di conservazione dei prodotti di carne. La carne ottenuta degli animali i quali non sono stati sottoposti ai recettori β-adrenergici dimostra una morbidità diminuita grazie alla minore percentuale del collagene termicamente solubile e alla maturazione rapida dei tessuti connettivi. L'alimentazione organica non ha avuto influsso alla crescita e alla qualità di maiali. Si è venuto alla conclusione che l'alimentazione di animali ha un ruolo importante nella qualità della loro carne.

Parole chiave: *alimentazione, carne, erba, concentrati, supplementi nutritivi, probiotico, recettori β-adrenergici, organici*

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