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EFFECT OF DIFFERENT PACKAGING METHODS ON CONSUMERS EATING QUALITY OF BEEF

Review

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Abstract: *Protecting meat and meat products during the distribution process, including storage and transport, from contamination by dirt, bacteria, moulds, yeasts, parasites, toxins and weight loss are very prominent. The aim of this review was to summarize the effect of packaging on consumers eating quality of beef. If meat is packaged in different packaging methods there may be a change in some beef quality parameters. Three types of packagesl are in general used today i.e. vacuum, atmospheric and active one. If meat is packaged in modified atmosphere with high oxygen content the colour stability of beef increases, but other quality parameters are negatively affected. Vacuum packaging has considerable advantage on all meat eating quality except of colour and purge problem. It has been observed that active packaging systems maintain as well as extend meat eating quality and shelf-life beef.*

Keywords: *Packaging, Beef; eating quality*

1. Introduction

Raising cattle to produce safe, high quality protein for the human diet is an important element in the nutritional well-being of the world. Therefore, production practices that optimize the wholesomeness, nutritional quality and palatability of beef are all critical to consumer satisfaction [1].
Beef is defined as the flesh of cattle used as food. Fresh meat includes meat from recently processed animals as well as vacuum-packed meat or meat packed in controlled-atmospheric gases, which has not undergone any treatment other than chilling to ensure preservation. The diverse nutrient composition of meat makes it an ideal environment for the growth and propagation of meat spoilage micro-organisms and common food-borne pathogens. It is therefore essential that adequate preservation technologies are applied to maintain its safety and quality [2].
The processes used in meat preservation are principally concerned with inhibiting microbial spoilage, although other methods of preservation are sought to minimize other deteriorative changes such as colour and oxidative changes.
Beef quality can be affected by many factors. The following three are the main factor determine beef quality: palatability, nutritional quality and safety (wholesomeness). There are numerous pre- and post-harvest management practices and technologies that positively affect all three of these factors. Palatability refers to the overall beef-eating experience which is determined by the tenderness, juiciness and flavor of the beef. While tenderness, juiciness and flavor are all important in

creating the best overall eating experience, there is some controversy among meat scientists as to which factor is the most important and detectable by the consumer [1]. The purpose of packaging is primarily to protect foodstuffs during the distribution process, including storage and transport, from contamination by dirt, bacterias, moulds, yeasts, parasites, toxic substances or those influences affecting smell and taste or causing loss of moisture. Packaging should help to prevent spoilage, weight losses and enhance customer acceptability. Simple packaging without further treatments is less effective in prolonging the shelf-life of meat and meat products. Frequently full advantage of packaging can only be achieved in combination with preservation methods. Though meat handling, storage and consumption may differ from one place to another, the factors limiting the shelf-life of these products are the same. There are *endogenous* factors, such as: pH-value or the degree of acidity of the product, the amount of moisture available in the product and *exogenous* factors, such as: oxygen (from the air), micro-organisms, temperature, light; and evaporation and desiccation [3].

Primary Functions of Packaging are: protect against physical change, Protect against chemical change, Protect against microbes and Present the product to the consumer in an attractive manner. Advantages of Packaging to Industry and the Consumer are: Economy of scale (cutting and packaging carried out at a limited number of centralized locations), Transportation costs reduced, Better sanitation is achieved (increased shelf life), Better inventory and product control for retailer, Trim losses minimized: weight losses due to evaporation also minimized and Enhances palatability due to controlled aging [4].

Consumers base their purchasing choices on perceived quality and a bright red colour of beef is to many a sign of freshness and good meat quality, making colour the most important quality attribute for retailers. Meat colour depends on both the degree of pigment and the muscle structure. Retailers have reported an increasing problem with colour stability in beef [5]. If meat is packaged in different packaging methods there may be a change for some beef quality parameters. Therefore, the aim of this review was to summarize the effect of different packaging methods on consumers eating quality of beef.

2. Effect of different packaging methods on consumer eating quality

For all meats the two main costs for production is animal husbandry and storage [6]. The high investment in production and storage makes it even more important to have the right type of packaging, also considering environmental damage and recycling of packaging material [5]. The role of meat packages is to protect the meat and increase the shelf life but it should also help to sell the product. Many interrelated factors influence the shelf life and freshness of meat such as temperature, oxygen, endogenous enzymes, moisture, light and most important microorganisms [7]. Consumers have become increasingly concerned about food-borne risks and personal health [8].

Packaging protects products against deteriorative effects, which may include discolouration, off-flavour and off-odour development, nutrient loss, texture changes, pathogenicity and other measurable factors. Variables that influence shelf life properties of packaged fresh meat are product type, gas mixture, package and headspace, packaging equipment, storage temperature and additives [7]. Three types of packaging in general are used today i.e. vacuum, atmospheric and active packaging [4].

Modified atmosphere packaging (MAP)

Modified atmosphere packaging can be defined as; "the removal and/or replacement of the atmosphere surrounding [meat] before sealing in with vapour-barrier materials" [9], [10].

The most common consumer packaging method of beef in Sweden and most of the Western World is high-oxygen modified atmosphere packaging (MAP), with the gas composition 80% O_2 and 20% CO_2 [5]. Packaging of fresh beef in high-oxygen MAP is predominantly used for retail display of steaks and minced meat. By using modified atmosphere packaging the shelf life of fresh red meat can be extended [11], compared with meat wrapped in air-permeable overwrap. The amount of meat that is packaged in high-oxygen MAP is increasing due to the increased colour stability and better hygienic quality of the meat compared with meat wrapped in airpermeable plastic [12].

The high-oxygen content gives the beef a stable bright red oxymyoglobin colour that is desirable to consumers at the moment of purchase [13]. The report of [14] showed high oxygen MAP systems resulted in less palatable juiciness, flavour and overall acceptability of beef. The first research to show a detrimental effect of oxygen in MAP on sensory tenderness was [15], who showed that storage of beef steaks in 10 – 20% gas flushed MAP packs reduced the sensory tenderness scores, relative to vacuum packaged beef steaks. Successively, [16] demonstrated that high oxygen MAP packaging systems increased toughness. More recently, [17] investigated various packaging treatments on sensory scores for lamb longissimus thoracic lumborum and semimembranosus muscles. Using a similar consumer testing protocol to that used in the current experiment, packaging longissimus thoracics lumborum and semimembranosus muscles in high oxygen MAP decreased tenderness scores by 10 to 14 sensory units compared with VSP packs when tested after 5 or 10 days in the packaging treatments. However not all experiments have reported a toughening effect of high oxygen MAP. Similarly, [18] showed a trend for higher shear force in the MAP treatment, although it failed to achieve significance.

Previous studies have proposed several mechanisms by which the high oxygen MAP penalty could occur. [19] Reported that high oxygen MAP increased cross-linking of myosin heavy chain through disulfide bonding, and the content of protein thiols decreased indicating increased protein oxidation. Their study also suggested that the high oxygen MAP pack promoted oxidation and inhibition of calpains. [20] Reported a lower myofibrillar fragmentation index suggesting lower proteolysis in high oxygen MAP. [21] concluded that packaging in modified atmosphere containing a high level of oxygen resulted in protein cross-linking and reduced tenderness and juiciness of the meat. More recently [17] and [22] failed to show any effect of high oxygen MAP packaging on desmin degradation, suggesting that the toughening effect of high - oxygen MAP was not due to inhibition of post-mortem proteolysis.

The high oxygen MAP effect was independent of aging rate and from the literature would most likely have been due to myosin cross linking, but further verification would be needed [14].

The magnitude of the MAP effect tended to vary according to muscle [23].

Their study showed a higher response in the semimembransous muscle compared to a low response in the rectus femoris and vastus lateralis muscles. Also a recent report by [24] showed a much higher MAP effect in shear force for the biceps femoris compared with the longissimus lumborum muscles. They concluded that the difference was likely due to differences between muscles in proteolysis rates.

The addition of 20-30% CO_2 prolongs the shelf life by inhibiting bacterial growth [5]. However, high-oxygen MAP will allow growth of aerobic bacteria and therefore has a reduced shelf life compared to vacuum packaging [25]. Most of the shelf life properties of meat are extended by use of MAP, but anoxic forms of MAP without carbon monoxide (CO) do not provide bloomed red meat color and MAP with oxygen (O_2) may promote oxidation of lipids and pigments [5].

The use of CO for meat packaging is not allowed in most countries due to the potential toxic effect, and its use is controversial in some countries [26]. [27] Concluded that the major disadvantages of CO-MAP of red meat were the negative image of CO held by consumers because of its potential toxicity. However, [28] and [29] showed that addition of 0.4% CO to modified atmospheres for chilled beef did not mask spoilage, even when the color stability was increased. Currently, consumers are not informed by the package itself regarding use of CO or elevated O_2 levels in the headspace of MAP meats. Due to the lack of consumer understanding of the science and being misinformed about this technology, consequently, to improve consumer attitudes about CO packaging of fresh meat, communications should be designed to not only inform consumers about the use of CO, but also familiarize consumers with the science of this technology. An increase in personal knowledge and media exposure influenced acceptance of CO-MAP negatively [26].

The disadvantage of high-oxygen content when packaging beef in modified atmosphere (MAP) is the increased level of lipid oxidation [12]. It has also been shown that high-oxygen content in MAP can negatively affect the tenderness in beef [30-32] and increase cross-linking of proteins in pork [19] and beef [33]. High-oxygen MAP has been shown to increase the breaking strength of individual beef muscle fibers [33]. Moreover, sensory attributes such as juiciness and meat flavour are negatively affected and the amount of off-flavour increases in high-oxygen MAP [30], [32]. In other studies storage of beef in high oxygen MAP generated high off-flavour or warmed over flavour (WOF) or both [21], [30] and [31]. Beef packaged in high-oxygen MAP resulted in a large increase in WOF and TBARS as well as a decrease in juiciness and tenderness compared with packages without oxygen [31]. The correlation between sensory analysis and TBARS (2-ThioBarbituric Acid Reactive Substances) has been found to be high; consequently TBARS is a good predictor of the perception of rancidity [34]. After storage in high-oxygen MAP, several volatile compounds, mainly carbonyls such as ketones and aldehydes from the lipid oxidation, were identified to be responsible for the rancid flavour in beef, using gas chromatography-olfactometry [35]. The lower tenderness and juiciness scores found in beef steaks packed in high-oxygen MAP may be due to protein oxidation leading to cross-linking/aggregation of myosin, and hence a deterioration in sensory quality [21].

The shelf life of high-oxygen MAP is not as long as that in vacuum packages but it is still about twice that obtained in air [36].

Nonetheless, the high-oxygen content may promote oxidation of lipids, proteins and pigments in the meat, which leads to inferior beef quality. Generally, If meat is packaged in modified atmosphere with high oxygen content the colour stability of beef increases, but other quality parameters such as shear force, tenderness, juiciness and meat flavour are negatively affected due to oxidation of proteins and fat [5].

Low O_2 MAP may be used as a barrier package with an anoxic atmosphere of N_2 and CO_2. N_2 is an inert gas that is not reactive with meat pigments or absorbed by the meat; therefore, it maintains integrity of the package by its presence in the headspace. However, CO_2 reacts with meat, changing the properties [37].

Vacuum packaging (VP)

Vacuum packages are commonly used for packaging whole muscles for the initial ageing period before they are cut and packaged in consumer packages. The considerable advantage of meat packaged in vacuum is that the tenderization process continues in the package leading to more tender meat. The vacuum packages are easy to handle and store, and the long shelf life may prevent the need for short-time frozen storage [37]. Vacuum packaging materials for primal cuts are usually three layered co-extrusions of ethyl vinyl acetate/polyvinylidene chloride/ethyl vinyl acetate, which generally have an O_2 permeability of less than 15.5 ml/m^2 /24 h at 1 atmosphere as a result of the polyvinylidene chloride layer [37].

Vacuum packaging extends the shelf life of beef even further than high-oxygen MAP and the tenderization continues throughout the storage time. Vacuum packing eliminates the air surrounding the meat and consequently the meat colour changes from a red oxymyoglobin colour to a purple deoxymyoglobin colour [36].

Vacuum packed steaks were perceived as more tender than high oxygen MAP steaks after both 5 and 15 days of storage [5], but the two main problems with selling meat to consumers in vacuum packages are i) the colour, since the meat has a purple Deoxy-myoglobin colour and ii) the amount of purge in the vacuum packages, which does not look appealing to consumers. The lack of the bright red colour of skin packed beef was regarded as a possible disadvantage in marketing [39].

Vacuum and skin packed steaks had higher scores for meat flavour and juiciness compared with MAP steaks. The decreased juiciness for MAP steaks was also combined with a higher total water loss. In contrast to this, reduced juiciness scores for steaks in high-oxygen MAP could not be explained by weight loss in the study by [31]. The lower WHC might be influenced by an increased level of protein oxidation causing limited degradation of cytoskeletal proteins and hence increased shrinkage of the overall muscle cell [40], even though this was not verified by the result of [5] protein oxidation analysis.

The lack of O_2 in packages may minimise the oxidative deteriorative reactions, and reduce aerobic bacteria growth, which usually causes pigments to be in the deoxymyoglobin state. Low O_2 vacuum packages for retail meat cuts are usually vacuum skin packaging (VSP) systems for placing the retail cut in a barrier styrene or polypropylene tray and vacuum sealing barrier films that are heat shrunk to conform to the shape of the product [41]. VSP packaging equipment removes atmospheric air or flushes the air from the package with gaseous mixtures such as N_2, CO_2 or mixtures of N_2 and CO_2 before heat sealing the film layers [37]. N_2 is inert, i.e. it does not react with meat product components such as fat or myoglobin.

Its function is to replace the atmospheric oxygen (O_2) and thus prevents O_2 induced negative impacts. CO_2, has a protective function, as it inhibits to some extend the growth of bacteria and moulds [42]. The common construction for the top and bottom package webs is nylon barrier polymer of polyvinylidene chloride or ethylene vinyl alcohol, tie layer and ionomer. Nylon provides bulk, toughness and low melting point, while the barrier layer prevents vapour permeation and the ionomer gives necessary seal characteristics [37]. A variation of VSP is for the lidding film to have outer barrier and inner air-permeable layers so that before retail display, the outer barrier film layer is peeled away from the permeable layer so that air can then contact the meat product and result in a bloomed colour [41], [43]. In [13], it investigated whether consumer preferences for beef colors (red, purple, and brown) or for beef packaging systems (modified atmosphere, MAP; vacuum skin pack, VSP; or overwrap with polyvinyl chloride, PVC) influenced taste scores of beef steaks and patties. To test beef color effects, boneless beef top loin steaks (choice) and ground beef patties (20% fat) were packaged in different atmospheres to promote development of red, purple, and brown color. To test effects of package type, steaks and patties were pretreated with carbon monoxide in MAP to promote development of red color, and some meat was repackaged using VSP or PVC overwrap. Finally they conclude that, Appearance scores and likelihood to purchase were correlated (r=0.9). However, color or packaging did not affect (P>0.5) taste scores. Thus, consumer preferences for beef color and packaging influenced likelihood to purchase, but did not bias eating satisfaction.

Vacuum packaged meats have been marketed successfully for years in many countries. However, the darkpurplish color of deoxymyoglobin in vacuum packaged retail beef has not been accepted by consumers [5], [44].

Active packaging

Active packaging systems are developed with the goal of extending shelf life for foods and increasing the period of time that the food is high quality [45]. Is the incorporation of specific compounds into packaging systems that interact with the contents or environment to maintain or extend product quality and shelf life, while intelligent or smart packaging provides for sensing of the food properties or package environment to inform the processor, retailer and/or consumer of the status of the environment or food [46]. Active packaging technologies include some physical, chemical, or biological action which changes interactions between a package, product, and/or headspace of the package in order to get a desired outcome. Active packaging is typically found in two types of systems; sachets and pads which are placed inside of packages, and active ingredients that are incorporated directly into packaging materials [45].

Active Packaging functions and technologies include moisture control, O_2-permeable films, O_2 scavengers or absorbers, O_2 generators, CO_2 controllers, odour controllers, flavour enhancement, ethylene removal, antimicrobial agents and microwave susceptors [47] in addition to indicators of specific compounds [48] and temperature control packaging. The most important active packaging systems applied to meat and meat products are oxygen scavengers, antimicrobial, antioxidant, and carbon dioxide emitting/generating packaging [47], [49].

I. Oxygen scavengers

An oxygen scavenger is a substance that scavenges oxygen chemically or enzymatically and therefore, protects the packaged food completely against deterioration and quality changes due to oxygen [50]. Often the oxygen absorber or scavenger is enclosed in a porous sachet or packet but it can also be part of packaging films and structures. Steaks packaged without oxygen scavengers had more discoloration and significantly higher proportions of metmyoglobin when compared to steaks packaged with oxygen scavengers. Prevention of metmyoglobin formation was influenced by the number but not the type of oxygen scavenger employed [42]. Oxygen scavengers effectively prevent oxidative damage in a wide range of food constituents such as (i) oils and fats to prevent rancidity, (ii) muscle pigments and flavours to prevent discolouration of meat and loss of taste and (iii) nutritive elements, e.g., vitamins to prevent loss of the nutritional value [50].

II. Antimicrobial active packaging

The aims of using antimicrobial active packaging are to extend shelf life and to ensure food safety of meat and meat products. There are four basic categories of antimicrobial packaging [51]:

1) Incorporation of antimicrobial substances into a sachet/pad inside the package. The antimicrobial sachet/pad can be produced by generating antimicrobial compounds in situ with subsequent release, or by using sachets to carry and then release the antimicrobials [52].

2) Direct incorporation of the antimicrobial agents into the packaging film. This can be achieved by the conventional heat treatment method such as co-extrusion of packaging films with the antimicrobials although high loss of bioactive compounds will occur. Alternatively, non-heating methods such as solvent compounding, electrospinning, and casting can be used to maintain the maximum antimicrobial activity of the packaging films [53].

3) Coating of packaging with a matrix that acts as a carrier for antimicrobial agents so that the agents can be released onto the surface of food through evaporation into the headspace (volatile substances) or migration into the food (non-volatile substances) through diffusion. This matrix can be a plastic film or any food safe materials such as wax or polysaccharides incorporating antimicrobials and directly coated on the food. 4) Use of polymers that are inherently antimicrobial. Two examples of these polymers used in food packaging and coatings are chitosan and poly-L-lysine. The charged amines of the polymers interact with negative charges on the microorganism cell membrane which cause leakage of intracellular constituents and then cell death [54].

III. Antioxidant active packaging

High levels of oxygen in meat packaging can facilitate microbial growth, lipid oxidation, development of off-flavours and off-odors, colour changes and nutritional losses. Lipid oxidation not only results in the development of rancidity, but also the potential formation of toxic aldehydes and the loss of nutritional quality because of polyunsaturated fatty acid (PUFA) degradation [55]. Therefore, control of oxygen levels in meat packaging is important to limit the rate of such deteriorative and spoilage reactions [49].

The effects of an alginate-based edible coating containing natural antioxidants (rosemary and oregano essential oils) on lipid oxidation, color preservation, water losses, texture and pH of beef steaks during 14 days of display were studied. The coatings significantly decreased color losses, water losses and shear force compared to the control. The coatings had a significant effect on consumer perception of odor, flavor and overall acceptance of the beef. Generally, they conclude that

coated meat was redder, had a more intense chroma and was more tender [56].
The addition of essential oils (EO) from oregano (OR, Oreganum heracleoticum L.) or thyme (TH, Thymus vulgaris L.) into soy-based edible films (EF) as an antioxidant activepackaging is effective in retarding oxidative changes in meats [57].

IV. Carbon dioxide emitting/scavenger

Carbon dioxide emitters can be used either alone or with oxygen scavengers to extend the shelf life of meat. Co_2 acts as an antimicrobial agent and it also prevent the collapse of the pack, which is caused by the development of a partial vacuum as the residual oxygen is utilized. Use of Co_2 emitter in conjunction with an oxygen scavengers to replace the oxygen removed with an equivalent volume of Co_2, has proven to be successful in the prevention of pack collapse. Carbone dioxide scavengers do not have application in the packaging of meat [42]. The action of CO_2 has differential effects on microorganisms; for instance aerobic bacteria such as Pseudomonas can be inhibited by moderate to high levels of CO_2 (10-20%) whereas lactic acid bacterial proliferation can be stimulated by CO_2. Furthermore, proliferation of pathogens such as C. perfringens, C. botulinum and L. monocytogenes is only minimally inhibited by CO_2 levels lower than 50%. There is concern that by inhibiting spoilage microorganisms, a food product may appear edible while in fact containing a high quantity of pathogens that have multiplied due to a lack of indigenous competition [58].

3. Conclusion

The high-oxygen content of MAP may promote oxidation of lipids, proteins and pigments in the meat, which leads to inferior beef quality. Generally, if meat is packaged in modified atmosphere with high oxygen content the colour stability of beef increases, but other quality parameters such as shear force, tenderness, juiciness and meat flavour are negatively affected due to oxidation of proteins and fat. Vacuum packaging extends the shelf life of beef even further than high-oxygen MAP and the tenderization continues throughout the storage time. Vacuum packing eliminates the air surrounding the meat and consequently the meat colour changes from a red oxymyoglobin colour to a purple deoxymyoglobin colour., but the two main problems with selling meat to consumers in vacuum packages are i) the colour, since the meat has a purple Deoxy-myoglobin colour and ii) the amount of purge in the vacuum packages, which does not look appealing to consumers. The lack of the bright red colour of skin packed beef was regarded as a possible disadvantage in marketing. Active packaging refers to the incorporation of additives into packaging systems with the aim of maintaining or extending meat product quality and shelf-life. Active packaging systems include 1) oxygen scavengers, 2) carbon dioxide scavengers and emitters, 3) antioxidant and 4) antimicrobial packaging technologies.

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