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Review Article

Influence of Skin Packaging on Raw Beef Quality: A Review

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A detailed revision of several aspects related to the application of skin packaging to raw beef was considered. Skin packaging, a relatively new technique derived from vacuum packaging, was developed with the aim of retailing small portions of fresh meat, minced meat, or meat preparations. Above all, the influence of this typology of packaging on the microbial population of raw meat was studied, with particular attention to total viable count, aerobic spoilage bacteria, anaerobic bacteria, *Enterobacteriaceae, Brochothrix thermosphacta,* and lactic acid bacteria. Moreover, the effect on acidification by LAB was also deepened. As colour is the main characteristic influencing purchase decisions at the point of sale, the effect of skin packaging on this parameter was evaluated for raw meat but also for cooked meat. Tenderness, juiciness, and the ability to hold liquid of raw meat when packed in skin conditions were also considered. Furthermore, odour and flavour were considered as sensorial parameters possibly affected by skin packaging. Finally, acceptability by consumer was also investigated. In the studies considered, results showed that skin packaging is advantageous in terms of maintenance of meat quality and for prolonging shelf-life, improving the stability of the products.

1. Introduction

The packaging of raw meats provides two main advantages: (i) the protection from physical, chemical, and microbiological contaminations, derived from environment where they are stored, and (ii) the maintenance of the characteristics of quality and safety that allow prolonging significantly their shelf-life: this action is done by protecting meats from surface drying and in many cases from external atmosphere [1, 2].

In the last years, other than these classical functions, a novel need to ensure a high "convenience" to fresh meat was felt; the prepacked meat market grew thanks to its "user friendliness" especially by modern consumers [3]. The same advantage was recognized by large scale retailers, as these products were intended for "self-service." Recently, several aspects have become increasingly important such as the aspect of the packages, traceability, and labelling, which should be usable also by consumers that do not have any specific knowledge about meat quality [4–7]. Currently, the most used typologies of packaging for raw meats are modified atmosphere packaging (MAP), traditional vacuum packaging, and vacuum-skin packaging [8, 9].

2. Main Typologies of Meat Packaging

2.1. MAP Conditioning. Modified or "protective" packaging (MAP) consists of packing the meat portions in trays covered with a vapour and gas-proof plastic film with the aim of reducing surface dryness and maintaining a very different atmosphere composition inside the package if compared to the external one. This mixture usually contains a high percentage of oxygen (70–80%) in order to maintain the brilliant red colour of the meat for a long time, whereas carbon dioxide (at least 20% in concentration) acts as a bacteriostatic agent against the main spoilage microorganisms (*Pseudomonas* spp. in particular) [10].

However, the presence of high partial oxygen pressure inside the package may cause problems with the storage of raw meat, as it could be involved in oxidation phenomena that can affect all the qualitative parameters of the meat, as described in the following sections.

Low O_2 MAP has been also studied, even if not widely used [11]. Low O_2 (essentially no oxygen) MAP may be used as a barrier package with an anoxic atmosphere of N_2 (70–80%) and CO_2 (20–30%) with the addition of a small concentration of carbon monoxide (CO). Anaerobic gas mixtures characterized by low concentration of carbon monoxide (CO) have been largely studied [12–14]. The inclusion of CO provides several advantages, for example, avoiding the undesirable effects of discolouration [13, 15], a better flavour acceptability [16], no bone darkening [17], no premature browning [18], and generally increased beef tenderness (especially with O_2 levels under 40–50% O_2) and acceptability by consumers [19, 20]. Despite this, the application of this packaging is negatively perceived by the consumers [15]. Moreover, as CO could be a potentially hazardous gas, the US Food and Drug Administration (FDA) reported the limit of 0.4% in MAP packaging for raw meat [21, 22] while, in 2001, the EU Scientific Committee on Food established that the use is not admitted as its presence may mask visual evidence of spoilage, even if it is confirmed that the inclusion of 0.3%–0.5% CO in a gas mixture with CO_2 and N_2 in fresh meat determined no health concern (EU, 2001).

2.2. Traditional Vacuum Packaging. Since the presence of oxygen may have a negative impact on beef quality and colour stability, removal of air from packaging has been attested to have favourable advantages. To be effective and to prevent browning episodes that could happen in presence of residual oxygen, air should be removed to anoxic levels (less than 500 ppm) [23, 24]. Traditional vacuum packaging consists of subjecting the meat, inserted in special bags, to the action of a pump that takes out the air inside the bag, leading to the extension of its microbiological and oxidative shelf-life [25].

The atmosphere present inside the package allows controlling the growth of the main aerobic spoilage microflora while, thanks to the absence of oxygen, it favours the growth of lactic acid bacteria (mainly composed of nonspoilage organisms), thus promoting a clear extension of the shelf-life of raw meat [26, 27]. The anaerobic environment is not optimal for the maintenance of meat colour, making this packaging not applicable for self-service marketing, while it is suitable for the wholesale market of primal cuts [28, 29]. Another issue associated with this kind of packaging is the nonperfect adhesion of the packaging to the surface of meat, which could lead to the possible permanence of small air pockets that could be occupied during the shelf-life by the exudate produced from the muscular tissue. Anyway, in vacuum-packaged meats, the exudate that can accumulate in the small residual fissures can reduce the microbiological shelf-life [30].

2.3. Skin Packaging. The most recent packaging technique used for meat storage is skin packaging, from traditional vacuum packaging. In this case, raw meats are placed on a plastic tray, and then they are covered by a plastic film that is thermoformed at the same time of the meat apposition, thus acquiring exactly the shape of the meat piece [31]. The exclusive shrinking of the upper skin by heating in vacuum-skin packaging avoids the formation of air, reducing the eventual visible formation of exudate and prolonging the microbiological shelf-life [30, 31].

This technique has been developed with the intention of commercializing small portions of raw meat, minced meat, or meat preparations, which could be purchased in retail shops [32, 33]. The tight adherence of the plastic film to the product has also the finality to improve all sensorial aspects perceptible by the consumer, as this technique is mostly intended to be used in self-service purchases.

The aim of the present review is to revise the effects of the application of skin packaging to raw meat on different parameters that could influence the final quality, including the possible perception of consumers. All these characteristics will be compared with vacuum and MAP packaging, based on the scientific literature available.

3. Quality Characteristics of Packaged Fresh Meat

3.1. Microbial Population of Raw Meat. The type of packaging used may have an impact, more or less evident, on the microbial population present on the surface of raw meat; in particular, the application of vacuum implies a selection towards psychrotrophic anaerobic bacteria, preventing the replication of microorganisms that are strictly aerobic, such as many Gram-negative bacteria [34]. The effects of the packaging, reported by different studies, differ according to the type of microorganisms considered. In particular, consider the following.

(i) Total Aerobic Bacterial Count. This parameter is not usually substantially modified, as similar loads are reported in the presence and absence of oxygen [35, 36]. The comparison between traditional vacuum packaging and skin packaging resulted in slower microbial growth by applying skin technique (with a difference of 1.65–2.1 log CFU/g). The positive effect of skin packaging is likely due to the direct contact with the high temperature of the plastic film with the surface of meat, which leads to the partial inactivation of the microflora. Moreover, skin packaging ensures the absence of spaces that could be occupied by small amounts of air or liquid accumulated, which can provide an optimal substrate for microbial growth [26, 31].

(ii) Aerobic Spoilage Bacteria. The main spoilage aerobic psychrotrophic microorganisms (*Pseudomonas* spp., *Acinetobacter* spp., etc.) are strongly inhibited by oxygen-free packaging, reaching differences higher than 2 log CFU/g in bacterial load if compared to modified atmosphere packaging. Some authors highlight the higher inhibition of skin packaging due to the absence of spaces with residual oxygen in the packages [26, 35].

(iii) Anaerobic Bacteria. These microorganisms, though well adapted to the absence of oxygen, showed a lower growth ability when skin packaging was applied, if compared to the conventional vacuum, with an average difference in loads of 1.20–1.65 log CFU/g [26].

(iv) Enterobacteriaceae. The bacteria belonging to this family, due to their distinctive facultative anaerobic characteristics, in some cases also psychrotrophic, represent an important part of the specific spoilage of raw meat stored in anaerobic conditions. The use of modified atmosphere packaging exerts

an effective inhibitory action, thanks to the addition of active concentrations of carbon dioxide (at least 20%), which results in an acidification of the substrate (with formation of carbonic acid), to which enteric bacteria are particularly sensitive. Better performance of the skin packaging if compared to the conventional vacuum is reported, with difference in Coliforms counts around 1.5 log CFU/g [26, 35].

(v) Brochothrix thermosphacta. This psychrotrophic facultative anaerobic microorganism is one of the main specific spoilage agents of raw meat [37]; its ability to replicate was proved in MAP-preserved and vacuum-packed meats, as well as in skin packed meats. However, skin packaging was recognized, in some studies, to determine slightly lower loads of this microorganism if compared to the conventional vacuum, probably due to the absence of air pockets, which are fundamental for the metabolism of *Brochothrix thermosphacta* [35].

Apart from the ability of replication, the presence of atmosphere inside the package affects the metabolism of *B. thermosphacta*. Under fairly close anaerobic conditions, *B. thermosphacta* acts as an homofermentative microorganism, producing exclusively lactic acid without alteration of the meat, while, in presence of low oxygen concentrations, like those occasionally present in conventional vacuum packages, it is able to produce compounds (e.g., acetone-diacetyl and short-chain fatty acids) that strongly affect the sensorial properties of meat, in particular the odour [38].

(vi) Lactic Acid Bacteria (LAB). These microorganisms represent, in optimal conditions, the main microflora of raw meat maintained in anaerobic conditions. The restriction of oxygen due to the application of vacuum atmosphere considerably selects meat microflora towards CO_2-tolerant microorganisms like lactic acid bacteria (mainly *Lactobacillus* spp., *Leuconostoc* spp., and *Carnobacterium* spp.) [39–41] (Fontana et al. 2006). In some cases, however, if present in very high loads, they can also act as spoilage agents, producing gas and acid odour [37]. Kamenik et al. [35] reported in vacuum-packaged meats higher values of LAB if compared to the same beef samples maintained in MAP (5.14 log CFU/g versus 2 log CFU/g). In some cases, the comparison between traditional vacuum packaging and skin packaging has yielded variable results; some authors did not detect differences, while others found lower growth by LAB with skin packaging [26, 31, 35].

In particular, Barros-Velázquez et al. [26] reported significantly slower rates of LAB in beef maintained in vacuum-skin packaging system if compared to those processed with traditional vacuum packaging, with average differences during shelf-life at 4°C of 1.25 log CFU/g. In this case, however, the lower growth of LAB was relatively less important than that of other microbial groups [26]. Concerning the specific composition of the lactic microflora present on raw meat, no differences were revealed between the two types of packaging, with the exception of a higher frequency in traditional vacuum of *Leuconostoc* spp., one of the most important spoilage anaerobic microorganisms [42].

3.2. pH of Raw Meat. Meat pH is determined by various factors, acting in the different production phases. The pH of meat at the end of slaughtering/sectioning process, at the beginning of shelf-life (the so-called "ultimate pH"), depends mainly on the accumulation of lactic acid coming from glycogen present in the muscular tissue at the time of slaughtering.

Glycogen content, in turn, is influenced by several factors affecting live animals in the last preslaughter phases, the intrinsic characteristics of the animals and the muscle considered [43]. During the storage of MAP or vacuum-packaged meat, the internal pH is quite stable [44–46], while the surface pH can be influenced by the microflora, in particular when meat is packaged under anaerobic conditions [47, 48]. Organic acid production by LAB determines the decrease of pH and it constitutes one of the main mechanisms of biopreservation in foods [49]. As already stated, packaged meats with absence of oxygen are subjected to a gradual acidification during storage, thanks to the lactic acid produced by the LAB representing the predominant microbial population.

The presence of low pH values in meat may result in both negative and positive repercussions such as the following:

(i) Higher possibility of protein and lipid oxidation; however, this phenomenon needs the presence of oxygen (present in low concentration or absent in vacuum and skin packaging)

(ii) A decrease in the ability to hold liquids by the meat, which, if very marked, could be appreciable as a decrease in juiciness

(iii) Effective protection against the development of the main spoilage microorganisms [26, 50].

A comparison between vacuum and skin packaging has shown a stronger acidifying action of the latter, reaching in some cases pH values just over 5. This result is presumably related to the growth of LAB that, though slower if compared to their growth in traditional vacuum packaging, is relatively more intense than the growth of other microorganisms, thus conditioning the environment and acting as antagonist of alkalinizing microflora [26]. In the study of Barros-Velázquez et al. [26], in the final part of the commercial life (40 days) a marked alteration due to the decomposition of proteins by LAB was observed; that alteration was followed by the decarboxylation of amino acids with carbon dioxide production and the increase of pH (with values > 6.5); this phenomenon has never been detected in raw meat packaged with skin packing and stored under the same environmental conditions.

3.3. Meat Colour. Meat colour is directly associated with its freshness and is the main factor determining the purchase choice of consumer [51, 52].

3.3.1. Raw Meat Colour. The colour of raw meat depends strictly on the state of its pigments and in particular of myoglobin. In recently slaughtered animals, in an oxygen-rich environment, myoglobin is mainly present in oxygenated form (oxymyoglobin), with typical red colour. Meat packaging in anaerobic (vacuum or skin) condition, instead, results in the detachment of O_2 from the myoglobin molecule (purple deoxymyoglobin) or in its subsequent oxidation (brown metmyoglobin), depending on the residual oxygen rate within the pack [53, 54]. This type of colouration is less attractive for the consumer, even if this transformation is reversible, and it is well known that, after the opening of the packages, meat experiences a "blooming" phenomenon, which consists in reacquiring the original red colour. Both of these molecules are in a reduced form (with Fe^{++} in the heme group) [55, 56]. However, during storage the ability of the substrate to maintain the reduced form of myoglobin decreases, due to the depletion of reducing compounds (e.g., glucose, antioxidant substances such as α-tocopherol), and is strongly influenced by the packaging method. The use of an oxygen-rich modified atmosphere, in fact, favours the depletion of redox potential of the meat substrate, leading to the formation of metmyoglobin, the oxidized form of the pigment (heme Iron as Fe^{+++}), with typical brown colour, characteristic of the meat exposed to air for a certain period of time and perceived as "not fresh" by the consumer [16, 54, 57].

Some studies have identified "thresholds" in the content of metmyoglobin, which significantly influence the consumers' purchasing choices. Meat is considered bright red when the content of this molecule does not exceed 20% of the total myoglobin, while when the percentage reaches 40%, it is clearly perceived as a brown colour; finally, with values greater than 60%, the colour perceived is grey-greenish. The no-purchase decision occurs when the metmyoglobin content is around 30–40% [4, 58].

It should also be noted that metmyoglobin formation can occur through various oxidative reactions, which may involve both oxymyoglobin and deoxymyoglobin, and that such oxidative reactions may also occur in presence of a reduced oxygen concentration within the package [59, 60].

Several studies compared the colourimetric parameters of meats packaged in a modified atmosphere rich in oxygen with traditional vacuum or skin packaging.

Meats packaged in modified atmosphere are universally known to be redder at the beginning of shelf-life and with a higher brightness (L) index [5, 61, 62]. During storage, nevertheless, a gradual modification of the parameters is constantly noticed, with a decrease in brightness, intensity of red colour (a^* index), and colour saturation (Chroma). Vacuum- or skin-packaged meats, on the other hand, resulted as more stable. It should be obviously considered that the purple colour, related to the anaerobic atmosphere, is immediately perceived by the consumer in prepackaged meats, but, after the opening of the packages, blooming allows recovering red intensity [35].

The measurement of the relative concentration of metmyoglobin in meats during their shelf-life also confirmed the clear difference between rich oxygen-modified atmosphere (with values reaching 20–25% in 12 days) and skin packaging (stable values around 5%). Some authors compared traditional vacuum packaging with skin packaging, revealing better performance in skin especially in case of prolonged shelf-life. Probably this difference is due to the different vacuum conditions between the two typologies of packaging. In vacuum, in fact, the presence of small air spaces determines the persistence of low residual oxygen concentrations, sufficient to cause rapid oxidation of deoxymyoglobin to metmyoglobin, thanks to the penetration of oxygen into the superficial layers of meat. This phenomenon does not occur in the skin packaging, thanks to the tighter adhesion of the plastic film to the surface of meat [5, 25, 36, 50, 62].

Finally, some studies have found the presence, at the end of shelf-life of traditional vacuum-packaged meats (about 40 days), of colour alterations that would no longer allow their commercialization, in particular the appearance of a grey-greenish colouration. This phenomenon has not been found, considering the same storage time, in meats stored in skin packaging [26].

3.3.2. Cooked Meat Colour. Another important aspect related to meat colour is the effect of cooking on its "core" colour. This factor is particularly important because the consumer subjectively decides whether meat is "well cooked" or "rare," although its colour, at the same cooking temperature, is different depending on the packaging conditions of the meat purchased [63].

It is recognized that meat packaged in oxygen-rich atmospheres appear "well cooked" at lower temperatures (55°C) than that stored in the absence of oxygen (65–75°C) [3, 64]. This is due to the so-called "premature browning," which is the denaturing of proteins that occurs at temperatures lower than expected. Meat stored in the absence of oxygen is richer in deoxymyoglobin, a molecule that is more resistant to thermal denaturation than other forms (oxymyoglobin and metmyoglobin) [5]. This factor could have an impact on consumer protection, as, under strong oxygenation/oxidation conditions, meat may appear well cooked after a thermal treatment insufficient to inactivate the main potential pathogenic microorganisms. In some studies, the comparison between traditional vacuum packaging and skin packaging showed the need for skin packaging to reach higher temperatures to obtain the "well-cooked" appearance of meat [65].

3.4. Raw Meat Tenderness. Meat tenderization during the aging and storage is a key factor for the consumers perceptions [66–68]. In fact, if colour is the main aspect that determines if a consumer would purchase or not a meat, tenderness is one of the most important factors that affect the satisfaction at the time of consumption and, consequently, the repurchase of the product.

In meats packed in oxygen-rich atmospheres, many studies have shown scarce tenderness [3, 65, 69, 70]. This phenomenon is linked to the oxidation of muscle proteins [71]; several authors reported the possible mechanisms of the negative effect of oxidation on meat tenderization, which are mainly due to the following:

(i) Inactivation of endogenous proteases, especially calpains (the most important being μ-calpain): these enzymes need a reducing substrate to carry out their action, given the presence of functional groups -SH (thiols) which are subject to oxidation; however, the role of this mechanism is debated, as some authors highlighted the marginal role of calpains in meat tenderization [35, 72].

(ii) The aggregation of muscle proteins: the mechanism involves also in this case the thiol groups, which form di-sulphide links among myosin molecules. Some authors found a decrease in thiol concentration contextually with meat oxidation [5, 35, 63, 72].

A greater tenderness perceived by consumers in meat maintained without oxygen has been reported [64] (Lagerstend et al., 2011); the difference if compared to the meats packaged in modified atmosphere becomes increasingly evident during shelf-life.

Skin-packaged meats are sometimes reported for a slower tenderization, becoming harder than those maintained under traditional vacuum packaging [26, 31]. This may be related to a lower proteolysis due to the reduced development of proteolytic bacteria, or to a more pronounced acidification of the substrate, thus decreasing the calpains action (which mainly acts in a neutral environment) [73]. However, contrasting results are reported by different studies, with some authors describing a higher tenderness of meat stored in skin packaging, especially in the final stages of shelf-life [35, 63].

3.5. Raw Meat Juiciness and Water Holding Capacity. Juiciness, coupled with tenderness, is one of the main factors considered by the consumer at the moment of consumption of meat [74]. Its evaluation is carried out with different methods, both subjective (consumption tests) and instrumental, by measuring the ability to retain water by the meat. As with other organoleptic characters, the preservation of raw meat in the presence of oxygen generally results in lower quality compared to anaerobic packaging, with an increase in the difference with the evolution of the shelf-life [65].

Some authors found a greater drip loss in meat maintained in aerobic conditions (3–5%, if compared to 1% detected in skin-packaged meat), probably due to protein oxidation and further structural modifications; however, this effect was not constantly observed [72].

Comparison between traditional vacuum packaging and skin packaging showed slightly higher drip loss values in the latter case: this phenomenon was explained by the greater acidification of the meat, with values close to the isoelectric point of muscle proteins (4.8–5.2), making them less polar and therefore less available for binding the water molecules. Considering cooking loss, values below 1.5–2% were found in skin-packaged meats if compared with those maintained in modified atmosphere, while no differences were observed if compared to traditional vacuum packaging [3, 5, 36].

A particular aspect related to the ability of the meat to retain the liquids is represented by the loss of exudate during storage. This phenomenon has a dual value for the consumer: firstly, the presence of visible liquid through the packaging makes the meat less attractive and therefore decreases the likelihood of purchase; secondly, the liquid present can act as a substrate for microbial growth and may therefore decrease the shelf-life [5, 35]. The influence of the different packaging methods on this phenomenon is very evident. When meat is conserved in oxygen-rich modified atmosphere, the liquid is usually present in a fairly small amount, and various solutions (drilled pans, adsorbent cloths) are adopted for its rapid absorption. In the case of traditional vacuum packaging, accumulation is very evident, as the technique employs a negative pressure that tends to allow the spillage of liquids out of the meat, and the presence of small "pockets" on the surface permits accumulation. In the case of skin packaging, instead, the adhesion of the plastic film to the surface of the meat eliminates the possibility of formation of empty spaces that can be occupied by the liquid [75]. Different studies showed constant differences between traditional vacuum and skin packaging throughout the shelf-life of the meats, with a loss of liquid equal to about 2–4% (vacuum) and 1% (skin), respectively [5, 35].

3.6. Raw Meat Odour and Flavour. Odour and flavour of raw meat are related to the presence of various volatile compounds (odour) and not volatile compounds (flavour), and they are among the main requirements considered by consumers [76–78].

During the shelf-life, meat packaged in oxygen-modified atmosphere is affected by oxidative phenomena that affect both the protein component (with amino acid destruction and carbonyl compound formation) and lipid (rancidity with the presence of "Warmed Over flavour") [3, 5, 65]. These phenomena do not occur in the case of packing in absence of oxygen; oxidative stability was demonstrated by measuring TBARS (reactive substances to thiobarbituric acid), detecting the presence of very low concentrations of these compounds (derived from oxidation of lipid substrates) in vacuum- or skin-packaged meat (0.8 mg malondialdehyde/kg), while an increase was detected during the shelf-life of MAP stored meat (2.4 mg/kg) [3, 35, 36].

Comparing the two types of vacuum packaging (traditional and skin packaging), consumers generally do not show any particular preference. However, the frequent presence, in the case of traditional vacuum packaging, of a typical smell at the time of opening should be noted: this odour is defined as acidic or "dairy" or sometimes as a "stuffy" odour, and it is due to the action of microbial anaerobic microflora, with the formation of aldehydes, ketones, and sulphur dioxide [30, 79]. This phenomenon, even if not persistent, is obviously unpleasant for the consumer as it is considered as sign of alteration. In this case, skin packaging is advantageous, as it inhibits more efficiently the microbial growth on the surface of the meat, which usually does not have any particular odour at the time of opening [80].

Finally, concerning the compounds that determine meat flavour, a study performed on swine meats did not reveal any particular difference between traditional vacuum packaging and skin packaging. However, a higher concentration of succinic acid was found in skin-packed meats: this compound, derived from the metabolism of lactic acid bacteria, is known to be crucial for the appearance of the typical flavour of cooked meat [81, 82].

3.7. Acceptability by the Consumers. Studies performed with the aim of assessing consumers' preferences when buying raw meat indicate that they privileged the colour and appearance of the meat, including the appearance of the packaging, as the main factors of choice at the time of purchase. At the time of consumption, however, tenderness, juiciness, odour, and flavour prevailed [4, 83].

At the time of purchase, the purple colour typical of meat packaged in vacuum or in skin is generally perceived by consumers in a nonpositive way; this factor becomes less important if consumers have to test the colour after opening the packages. In these cases, the higher colour stability during the evolution of shelf-life is preferred [4]. In several studies, consumers demonstrated preferring packaged meats in absence of oxygen for tenderness, juiciness, and flavour. A lower inclination to spend money was revealed in case of meat packaged in the presence of oxygen. The difference between vacuum-packaged meat or skin packaging varied: in some cases the two typologies of packaging were not even distinct by consumers, while, in other tests, 30% of consumers declared being willing to buy meat maintained in skin packaging at a higher price [20, 65].

4. Conclusions

The studies considered in the present review on the effect of raw meat packaging on the microbiological, chemical, and physical characteristics and consumer acceptability of fresh meat revealed the role of skin packaging as an important factor for the maintenance of meat quality and the extension of the shelf-life.

Apart from the remarkable differences if compared to the modified atmosphere packaging, which are beneficial in terms of inhibition of microbial growth and protein and lipid oxidation prevention, also the comparison with traditional vacuum packaging indicated the presence of positive aspects mainly related to the remarkable stability of the product. This feature is mainly ensured by the thermal adhesion of the plastic film to the meat surface, which determines the absence of spaces where air or purge can be left; this fact determined the substrate as less favourable to microbial growth and less exposed to oxidative reactions.

Many of the parameters analyzed showed performances equal to or better than conventional vacuum packaging. In any case, the appearance of meat is anyway closely linked, as in the vacuum packaging, to the perception of brown colour due to the presence of metmyoglobin (as a low O_2 partial pressure still remains, especially with traditional vacuum packaging). It should be remembered that, in the case of packaging intended mainly for self-service marketing at the large scale retailers, the consumer's choice is not guided directly by experienced staff, as would be in a butcher's shop. Considering the potential better stability and shelf-life of meats maintained in skin packaging, it is therefore necessary to invest in consumer education, especially with the information about the natural recovery of the optimal colour at the time of opening of the packages.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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