QUALITIES OF BEEF PACKAGED IN HIGH-OXYGEN MODIFIED ATMOSPHERE USING VARIOUS GAS COMPOSITIONS AND HEASPACES

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Abstract – In order to maximize benefits of packaging beef in high-oxygen modified atmosphere, the reductions of O_2 concentration in gas mixture and/or packaging headspace were investigated. Five kinds of packaging were evaluated during retail display up to 14 days. Experimental gas atmospheres included 70%, 55% or 40% O_2, with all packages containing 30% CO_2 and the make-up gas N_2. These three gas mixtures were used with the same usual headspace (V1). Two of them were also studied with a smaller headspace (V2: 60% of V1).

The 5 kinds of packages were assessed for microbial quality, weight loss, colour and commercial acceptability, and for consumers' preferences at purchase and consumption levels.

On the whole, none of the five packaging was found much more effective than the others. Thus a headspace reduction appeared possible and moreover well accepted by consumers at the retail level. However consumer satisfaction during consumption was higher when beef was vacuum packaged.

Key Words – Consumer acceptability, MAP (modified atmosphere packaging), Shelf-life

I. INTRODUCTION

Packaging of fresh beef in high-oxygen MA has been increasingly used in many countries including France. It provides an extension of shelf-life of fresh meat by postponing microbial growth [1] and ensures the desirable bright-red colour expected by the consumer [2]. The drawbacks of high-oxygen atmospheres are lipid oxidation and rancidity with possible development of off-flavours [3], protein oxidation and reduced tenderness and juiciness [4-6]. Moreover myoglobin oxidation occurs quite quickly [7] thereby limiting beef shelf-life to about 10-12 days.

Recent research in MAP has focused on finding the correct blend of gases that maximizes advantages while minimizing disadvantages, including eating qualities [4, 8]. Jakobsen *et al.* [9] reported that, while oxygen levels higher than 20% were necessary to promote meat colour, package oxygen contents higher than 55% may not provide additional colour stabilizing benefits.

Furthermore, improving environmental performance of the packaging is of serious concern to suppliers. Reducing the height of the tray and optimizing the headspace is a possible answer. According to Jackobsen *et al.* [10], a headspace to meat volume ratio of 2-3 to 1 is recommended, but this is nowadays rarely applied. Package collapse due to CO_2 dissolution in meat during storage is generally thought to be limited if gas volume is more than 1.5-2 times higher than meat volume. The phenomenon disappears when it is 2-3 times higher [11]. Different studies indicate that the relevant ratio could probably be lowered to the ratio of 1 to 1 [12]. In this respect, the French research has raised two questions about beef packaged in high-O_2 MA (i) which level of O_2 concentration does allow the best compromise between microbial, commercial, and eating qualities? (ii) would it be possible to lower the most commonly used headspace to limit economic and environmental impacts of beef packaging in France?

The objective of this study was to investigate the effect of different gas compositions and headspaces (three compositions, two headspaces) on microbial and commercial shelf-lives and on consumers' perception of fresh beef packaging.

II. MATERIALS AND METHODS

Fifteen animals were slaughtered on the same day (Friday) in the same abattoir (partner of the study) according to the same process. Following the usual practice of the abattoir for case-ready packaging

production, various kinds of animal were selected: cows and young bulls, animals mainly from dairy cattle (but not only), with a carcass weight ranging from 260 to 390 kg.

Three days later (on Monday), ultimate pH measurements were done in order to check that none of the carcasses had a pH value over 5.8. M. *longissimus dorsi* (LD) were removed from both sides of the 15 carcasses and transported to the laboratory under refrigerated conditions. The following day (day 0), those muscles were trimmed of external fat and cut into steaks, leading to 54 steaks by carcass. These steaks were randomly assigned to different objectives: pre-packaging controls, high-O_2 packages according to the five kinds tested for each day of analysis, and a control packaging under vacuum. Thus the different kinds of packaging were compared for each animal, in order to avoid concerns linked to beef quality variability. This comparison was replicated for the 15 animals.

MAP used three gas compositions (Table 1): (i) 70% O_2 + 30% CO_2 (70/30), (ii) 55% O_2 + 30% CO_2 + 15% N_2 (55/30), (iii) 40% CO_2 + 30% O_2 + 30% N_2 (40/30) and two kinds of tray sealer (Guelt, OPS1000, France).

The trays used were PS EVOH PE 11000 (Form' Plast) of 50 or 30 mm depth (for V1 or V2). The film reference was LINTOP PE HB A40 (Linpaq).

Case-ready packaging were stored at 3°C for 8 days (⅔ of their 12-day expected shelf-life) and then at 8°C in order to simulate a cold chain failure at the consumer level. The trays were held under light during the day and kept in the dark during the night as for display conditions. Analyses were carried out on 6th, 8th, 10th and 14th days of storage (expected deadline + 2 days).

After several storage durations, microbiological evolution was studied through 5 microbial flora: total aerobic plate count (30°C, NF V08-011), *lactic acid bacteria* (NF V08-03), *Pseudomonas* spp. (NF V04-504), *enterobacteriacae* (NF V 08-504) and *Brochothrix thermosphacta* (NF V08-505).

Commercial appreciation of the high-O_2 case-ready meat products was also done through 4 ways: (i) by calculation of the drip loss during packaged storage based on steaks weights, (ii) through a sensory trained panel (3 or 4 members) assessment of the trays before and after opening, (iii) through instrumental colour measurements performed with a Minolta CR 400 colorimeter (CIE L*a*b* system) and with a spectrophotometer (iv) by 12 consumers' evaluations of steak commercial attractiveness without opening the trays.

Table 1 Gas composition and volume of the 5 kinds of MAP tested

		Compared MAP samples				
		M1 (control)	M2	M3	M4	M5
Gas mix composition	O_2	70%	70%	55%	55%	40%
	CO_2	30%	30%	30%	30%	30%
	N_2	-	-	15%	15%	30%
Headspace (volume) (D : tray's depth)		V1 (D=50 mm)	V2 (D=30 mm)	V1	V2	V1

For the last point dealing with packaging attractiveness, consumers were asked to compare the 5 kinds of steak packages for each of the 15 animals. They classified these 5 packages by order of preference and expressed their willingness to pay for each of them.

Furthermore, meat eating qualities were assessed through sensory analyses by a panel of 164 French naïve consumers. Steaks coming from the 5 kinds of high-O_2 MAP and from the vacuum packaging were grilled to ensure a "rare" degree of doneness and distributed according to a sequential monadic procedure. Consumers were asked to evaluate tenderness, juiciness, flavour liking and overall liking, and to rank each sample as "unsatisfactory", "everyday quality", "better than everyday quality" or "premium quality".

Both consumers' controls took place after 8 days of display, whereas the other analyses were done after several display durations (6 to 14 days).

Statistical analysis was performed with 9.2 SAS software version (SAS Institute, USA) using analysis of variance techniques (MIXED and GLIMMIX procedures) with correction of the multiplicity of tests by Turkey-Kramer method.

III. RESULTS AND DISCUSSION

Gas compositions were in line with expectations and changed little during the storage time.

Microbial load

Data on the microbiological characteristics of steaks stored in high-O_2 MAP indicated that the microbial loads were not a problem to reach the shelf-live of 12 days.

The steak initial mean contamination (day 0) reached 1,9 log and increased up to nearly 4 log after 14 days of packaged storage. According to the European rules, a 14-day microbial shelf-live allows an official retail shelf-life up to 12 days (- 2 days), depending on the commercial quality of the

meat. This relatively low microbial evolution is likely linked to the presence of 30% CO_2 in the gas mix, which inhibits microbial growth [1]. Changes mainly occurred in the last third of the expected shelf-life after the cold chain failure, both quantitatively and qualitatively: thus *Brochothrix thermosphacta* and *Pseudomonas spp.* became dominant species on the steaks while remaining at reasonable levels.

These results confirm those regarding the sensory commercial assessment of the steaks: after packaging opening, the trained panel didn't notice any odour problem, suggesting a good management of microbial loads during the expected shelf-live. Meat and fat colour degradations actually limit the shelf-life under high-O_2 MAP. This is a quite standard outcome for deboned beef cuts [13].

Compared to storage time and temperature, the kind of MAP had little effect on the microbial load. The total aerobic plate count and *Pseudomonas* spp. were the only flora to react to the kind of MAP, with M2 (70/30 V2) having the best evolution for microbial quality.

Retail case-life assessments

Steaks under MAP had few drip loss over the first 10 days of storage: it reached around 2% for each of the 5 kinds of packages.

However, despite a relatively good microbial level, discolouration gradually impacted meat acceptability, thus the steaks were still acceptable after 10 days of display but unacceptable after 14 days. Little differences were noticed between the 5 kinds of packages. Nevertheless M2 pack (70/30 V2) allowed a better meat appearance preservation than M5 (40/30 V1). This was true for several parameters assessed by the trained panel. Similar trend was found for objective colour measurements. R630/R580 index fell faster for M5 package (40/30 V1), showing a greater myoglobin oxidation into metmyoglobin than for M2 package (70/30 V2). No other differences were found for the instrumental colour measurements.

Consumers' perception of the trays

The consumers' sensory assessments indicated that M2 and M4 packages using smaller trays (V2) were the most accepted. By contrast, M5 (40/30 V1) and M1 (70/30 V1) packages were often poorly positionned. Thus consumers seemed sensitive to the volume reduction of the trays which can lower the environmental impact without degrading the sanitary quality of the meat. This result aligns with Bozec *et al.* [14], who worked on pork chops in high-O_2 MAP.

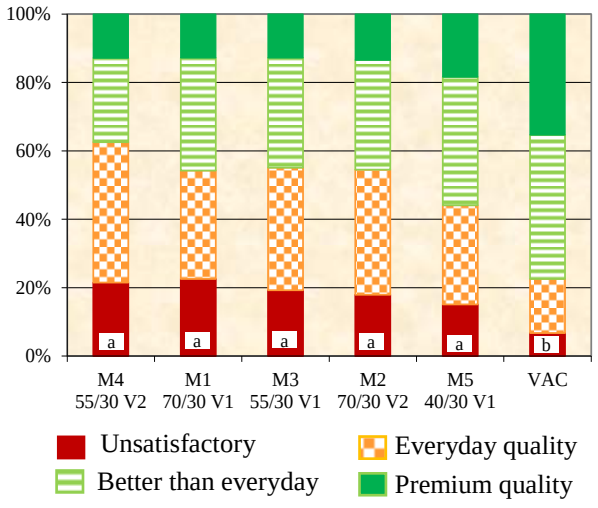
Consumers' sensory evaluation of eating quality

After 8 days of storage, the 164 consumers involved didn't perceive substantial differences between the 5 compared MAP (Fig. 1). This result was quite inexpected since high-O_2 concentration is presumed to impact negatively eating qualities [3-6]. The 5th kind of MAP (M5) containing only 40% O_2 had systematically the best raw mean results, even if it was statistically non-significant. The same trend was observed by Zakrys *et al.* [4] working with 134 Irish consumers who found beef steaks packaged under MAP containing 40% O_2 more acceptable than those under MAP with 50%, 60% or 70% O_2. In the present study, the package storage time may have been too short to generate more sensitive differences between the 5 MAP and the steaks were perhaps too lean (LD lipid content at about 2%) regarding a possible detrimental effet on flavour liking.

However, one of the main results of this work is the superiority of steaks from vacuum packages (VAC) over those from high-O_2 MAP according to consumers' point of view (all the meats derived from the same animals and were stored during the same time).

These findings are similar to those noticed in previous studies. Aaslyng *et al.* [15] reported a Scandinavian consumer preference for beef steaks packed without oxygen. Lagerstedt *et al.* [6] found that high-O_2 MAP negatively influenced beef shear force, thawing loss, colour stability, tenderness, juiciness and to some extent meat flavour, compared to vacuum packaging.

Figure 1. Frequency distributions of eating quality grades allocated by 164 French consumers to each of the 6 kinds of packaging. Different small letters indicate significant differences ($p < 0.05$)



Nevertheless such results involving consumers have been rarely reported and quantified before in France within a public-funded study.

IV. CONCLUSION

For each of the 5 kinds of packaging tested, the spoilage flora development remained satisfactory throughout the storage period. However, beef steaks packaged in high-O_2 MAP discoloured quite rapidly so that the meat was unacceptable after 14 days of display whereas it was still acceptable after 10 days. According to the results of this experiment, case-ready packages with 70% O_2/small headspace (M2) or 55% O_2/control headspace (M3) appeared to be a little more efficient to preserve meat quality traits during display. Packages with 55% O_2/small headspace (M4) were slightly less efficient. The position of the current packages used by French meat industrials (70% O_2/control headspace: M1) didn't seem to be just as good. The worse performances were obtained with 40% O_2/control headspace (M5) despite its small eating quality advantages. But on the whole, none of the five tested packages was found much more effective than the others. Vacuum packaging used as control sample for consumer testing was the most preferred packaging for all the evaluated eating qualities. This suggests that high-O_2 MAP is probably not the best way to reach consumers' satisfaction and to create customers' loyalty. These findings may be useful to beef processors and retailers, especially regarding headspace reduction and vacuum performances.

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REFERENCES

1. McMillin, K. W. (2008). Where is MAP going? A review and future potential of modified atmosphere packaging for meat. Meat Science 80: 43-65.
2. Mancini, R. A., Hunt, M.C. (2005). Current research in meat colour. Meat Science 71:100-121.
3. Jayasingh, P., Cornforth, D. P., Brennand, C. P., Carpenter, C. E., Whittier, D. R. (2002). Sensory evaluation of ground beef stored in high-oxygen modified atmosphere packaging. Journal of Food Science 67(9): 3493-3496.
4. Zakrys, P I., O'Sullivan, M. G., Allen P., Kerry, J. P. (2009). Consumer acceptability and physiochemical characteristics of modified atmosphere packed beef steaks. Meat Science 81(4): 720-725.
5. Kim, Y. H., Huff-Lonergan, E., Sebranek, J.G., Lonergan, S.M. (2010). High-oxygen modified atmosphere packaging system induces lipid and myoglobin oxidation and protein polymerization. Meat Science 85(4): 759-767.
6. Lagerstedt, A., Lundström, K., Lindahl, G. (2011). Influence of vacuum or high-oxygen modified atmosphere packaging on quality of beef M. *longissimus dorsi* steaks after different ageing times. Meat Science 87(2): 101-106.
7. Grobbel, J. P., Dikeman, M. E., Hunt, M. C., Milliken, G. A. (2008). Effects of packaging atmospheres on beef instrumental tenderness, fresh color stability, and internal cooked color. Journal of Animal Science, 86:1191-1199.
8. Resconi, V. C., Escudero, A., Beltrán, J. A., Olleta, J. L., Sañudo, C., Campo M. M. (2012). Colour, lipid oxidation, sensory quality, and aroma compounds of beef steaks displayed under different levels of oxygen in a modified atmosphere package. Journal of Food Science 77(1): S.10-S18.
9. Jakobsen, M., Bertelsen, G. (2000). Colour stability and lipid oxidation of fresh beef. Development of a response surface model for predicting the effects of temperature, storage time, and modified atmosphere composition. Meat Science 54: 49-57.
10. Jakobsen, M., Bertelsen, G. (2002). The use of CO_2 in packaging of fresh red meats and its effect on chemical quality changes in the meats: A review. Journal of Muscle Foods, 13: 143-168.
11. Picgirard, L. (2008). Producing stock-keeping units: technological and sanitary aspects. Sciences des Aliments, 18: 379-387.
12. Murphy, K. M., O'Grady, M. N, Kerry, J. P. (2013). Effect of varying the gas headspace to meat ratio on the quality and shelf-life of beef steaks packaged in high oxygen modified atmosphere packs. Meat Science, 94(4): 447-454.
13. Parafita, E., Frencia, J. P., Picgirard, L. (2011). Early alteration of beef colour packaged in a modified atmosphere: investigation of indicators involved in the phenomenon appearance. In Proceedings 57th International Congress of Meat Science and Technology (P332), 7-12 August 2011, Ghent, Belgium.
14. Bozec, A., Vautier, A., L'Hommeau, T., Leroux, A. (2014). Optimizing the shelf-life of pork chops with new gas compositions and reduced headspace. In Proceedings 44th International Congress of Meat Science and Technology (136-A), 17-22 August 2014, Punta Del Este, Uruguay.
15. Aaslyng, M.D., Torngren, M.A., Madsen, N.T. (2010). Scandinavian consumer preference for beef steaks packed with or without oxygen. Meat Science 85(3): 519-524.