TECHNOLOGICAL AND SHELF LIFE CONSIDERATIONS OF BEEF PATTIES CONTAINING PARTIAL FAT SUBSTITUTIONS OF ENCAPSULATED AND UNENCAPSULATED FISH OILS

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Abstract – Technological and shelf life properties of beef patties containing partial substitution of fat with commercial encapsulated and/or unencapsulated fish oils were investigated by combined design of experiment (DOE). Fish oils in encapsulated and unencapsulated forms were included to improve the fatty acid profile and obtain a healthier product. The goal was to develop a formulation without significantly compromising technological and eating quality. A combined mixture design assigned 40 runs with each point representing a different partial-substitution level for fat with encapsulated and unencapsulated fish oils (maximum 15% substitution of fat). The remaining burger formulation comprised 60% beef shin and 0.5% salt. Samples were stored in a retail cabinet over a shelf life period of 15 days. Fatty acid profiles were changed with increasing fish oil inclusion. Linear models for cook loss and TPA-hardness were significant. The substitution of fat with unencapsulated oils increased cook loss but decreased hardness compared to controls and burgers with encapsulated oil. TBARS values showed no significant differences between mixture components, but increased with increasing storage time. The oxidised form of the meat pigments i.e. metmyoglobin, was higher in samples containing unencapsulated fish oil compared to controls and Meg-3 inclusions.

Key Words – Burgers, Fat substitution, Encapsulation, Fish oil, Design of experiments (DOE)

I. INTRODUCTION

Traditionally, comminuted products, e.g. burgers, have been produced with salt and fat. While the reduction or removal of fat and salt in these products is desirable from a health perspective, its substitution or removal represents a significant technological challenge as fats interact with other ingredients to develop texture, mouth feel and assist in the overall sensation of lubricity of foods [1]. Beef has a relatively high saturated fat content compared to other meats and high consumption of saturated fat is one of the primary risk factors associated with the development of cardiovascular disease (CVD). One of the health strategies proposed is the substitution of native fat with healthier fats, such as ω3 oils (unsaturated) that are abundantly present in fish [2]. Fish oils have high contents of *n*-3 fatty acids, such as docosahexaenoic acid (DHA) and eicosapantaeonic acid (EPA). They are recognised by the European Food Safety Authority (EFSA) to have positive effects on human health [3]. While the degree of unsaturation is desirable from a health perspective, it does increase the risk of faster deterioration in shelf life through lipid oxidation [4]. To offset these deleterious effects, the process of microencapsulation has been proposed. By immobilising the fish oil in material, e.g. alginate or whey protein, the fish oil may be protected from the ingress of oxygen that could promote lipid oxidation; fishy odours and flavours may be masked during eating and there may be a protective effect on bioactivity [5]. The aims of this study were to investigate the technological and shelf life consequences of partial substitution of encapsulated and unencapsulated fish oils for native fat in beef patties and to assess the potential of meat products as vehicles for bioactive ingredients

II. MATERIALS AND METHODS

Burger patties were prepared according to previously reported [1] optimised formulations. Fresh shin beef (95% visually lean) and beef fat were obtained from a local supplier (Kepak Group, Ireland). Beef and fat were minced through a 5 mm plate and assigned a treatment according to design of experiments (DOE). A combined

mixture and response surface methodology (RSM) d-optimal experiment was designed using Design Expert (v. 7.6.1, Stat-Ease Inc.). Four ingredient components 1) beef fat, 2) a commercial unencasulated fish oil (Omega-360 Pure 22, Denomega, Norway), 3) a commercial encapsulated fish oil (Meg-3 powder, Ocean Nutrition, Canada), 4) vitamin E (antioxidant); were included with the constraints outlined in Table 1. One processing factor i.e. storage time, representing a typical retail shelf life of burger products, was also considered as part of the overall design.

Table 1. Factors and levels for the d-optimal response surface experimental design

Level	Fat	Meg-3	Oil	Vit. E
low	34.00	0	0	0
high	40.00	6.00	6.00	0.015

Levels expressed in % of total burger weight (100g per patty)

This assigned 40 runs with each run representing a different substitution level for fat with meg-3 powder/oil/vitamin E over the storage period. Minced beef and fat, Meg-3 powder/fish oil/vitamin E were formed into 100g patties containing 0.5% salt using a burger former. Samples were packed in black PET trays (containing an absorbent strip) heat sealed (low oxygen permeable film <2 mL/24 h/38 °C) and gas flushed using a modified atmosphere of 80% O_2: 20% CO_2 (BOC Ltd., Ireland) using an Ilpra Foodpack Basic V/G (Ilpra, Italy). All treatments were placed in a random order in an open-front retail display cabinet (Cronos fan-assisted cabinet, Criosbanc, Italy; lighting: lux ≈ 600, 58 W deluxe cool white bulbs) for up to 15 days at 4 °C. After the storage period had elapsed, samples were blast frozen (air speed 3.75 m/sec) and stored (-20 °C) for subsequent analyses. Data presented in this study include technological parameters of cook loss and texture (TPA – hardness) and shelf life parameters of oxidation (thiobarbituric acid reactive substances, (TBARS), free fatty acids, (FFA)) and meat colour pigments, using previously reported methodologies [6, 7, 8].

III. RESULTS AND DISCUSSION

The fatty acid composition of the burger patties was obtained through gas chromatography mass spectrometry (GCMS). Representative chromatograms of selected extremes (control, and maximum partial-substitution with Meg-3 powder) on day 0 are presented in Figure 1a-b respectively. The inclusion of encapsulated fish oil altered the fatty acid profile of the burger patties, with the fatty acids known to have a positive health effect on humans i.e. DHA, docosapentaenoic acid (DPA) and EPA shown to be present. A similar profile was obtained for the unencapsulated oil (data not shown).

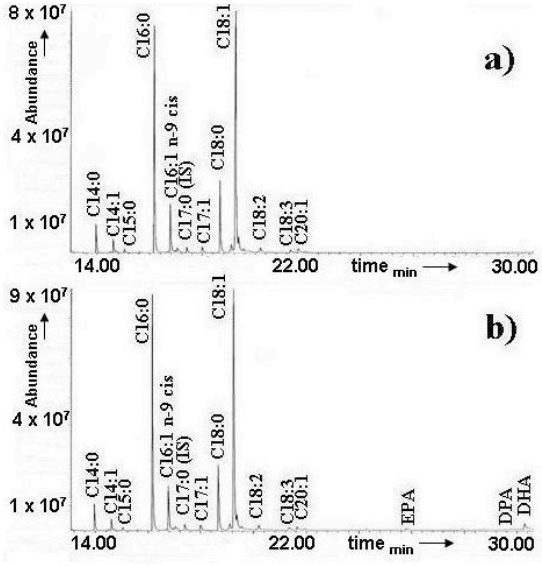

Figure 1a-b. Representative GC-MS chromatograms of free fatty acid profiles of raw beef patties containing a) beef fat (control) and b) Meg-3 powder (15%/max substitution) on day 0.

Technological parameters

The response surfaces of the technological parameters, cook loss and TPA-hardness, are presented in Figure 1a-b. The data for cook loss was fitted with a combined linear/mean model to assess the mixture and processing components respectively. The data for cook loss was fitted with a combined linear/mean model to assess the mixture and processing components respectively. The predicted model for cook loss was found to be significant ($p<0.0001$) but showed a fit of R^2 = 0.50 with the experimental data. Figure 2a shows cook loss increased in sausages containing unencapsulated oil compared to fat- or Meg-3-substituted counterparts. This is in agreement with other authors on fat substitution with oil in other meat products (lower processing yield) [9].

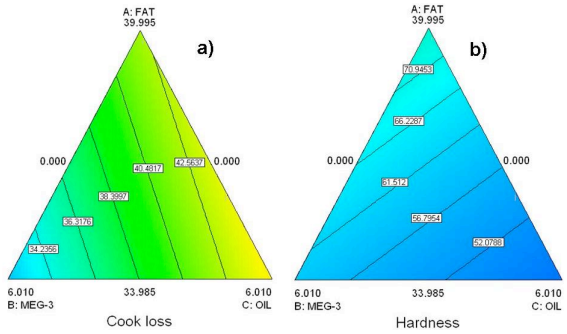

Figure 1a-b. 2D response surface of a) cook loss and b) TPA-hardness for burger patties

Furthermore, the observation in the present study was consistent across the 15 day storage life and had no significant effect on the model. Texture data for hardness (TPA) was fitted with a linear/mean, which was transformed using an inverse function as recommended by the Box-Cox method. This minimised the residual sum of squares in the model, thus improving fit. The predicted model for hardness was significant ($p<0.021$) with the linear mixture terms (A: fat; B: Meg-3; C: Oil; D: Vitamin E) also being significant. However, only a low experimental fit to the data was achieved ($R^2 = 0.18$). This could be attributed to the heterogeneous nature of the burger. Hardness values were lowest in burgers containing more oil compared to their fat and Meg-3 containing counterparts (Figure 2b). No significant change was observed over the storage period as was the case for the cook loss data. Lower hardness values in burger patties have been previously reported [10] when substituting fat with avocado oil.

Shelf life parameters

Oxidative status of the burger patties are presented in Figures 2 and 3. The determination of TBARS was determined by spectrophotometer. Data was fitted with a mean/quadratic model which was transformed using a log function as recommended by the Box-Cox method. The predicted model for TARS was significant with the both the linear ($p<0.0001$) and quadratic ($p<0.01$) processing term (E: storage & E^2) being significant. This gave a reasonable fit to the experimental data ($R^2 = 0.60$). Figure 2 shows increased oxidation over the storage life of the burger patties. This was consistent across products containing encapsulated shown below), unencapsulated oils and saturated fat (control). The expectation was to observe increased oxidation, particularly in burger patties formulated with the unencapsulated oil. However, the lack of any consistent trend between mixture components may relate to the relative brevity of the shelf life period investigated.

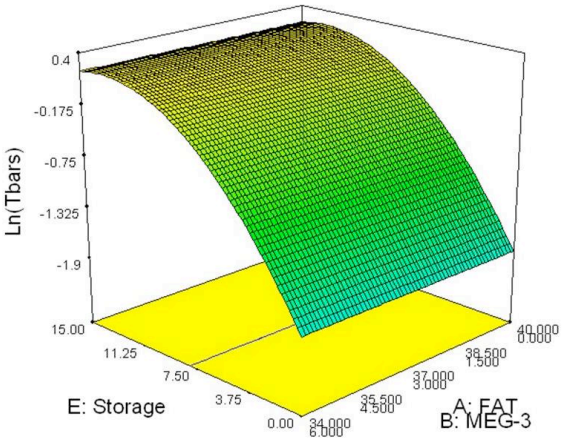

Figure 2. 3D response surface of (transformed) TBARS data of burger patties over storage (15 days)

Investigating the colour stability of products developed from these substitution strategies is an important consideration for their shelf life capabilities. The relative proportions of myoglobin redox forms by extraction from meat using spectrophotometry are shown in Figure 4a-c.

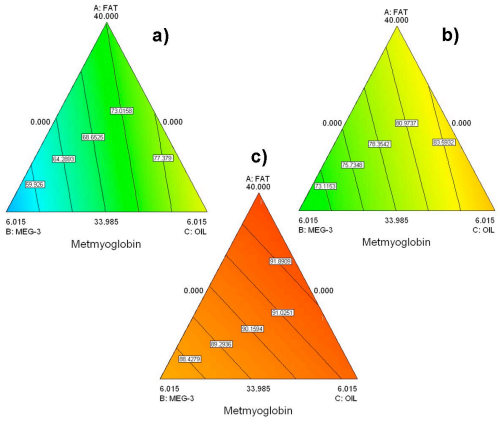

Figure 4a-b. 2D response surface of relative proportion of metmyoglobin in burger patties on days a) 0; b) 7; and c) 15; of the storage period

In the present study, the oxidized form of myoglobin, metmyoglobin will be discussed. Data was fitted with a linear/linear model. The

predicted model was significant ($p<0.0001$) with significant linear components of the mixture ($p<0.01$) and significant interactions between fat:storage ($p<0.05$) and Meg-3:storage ($p<0.001$). This gave a reasonable fit to the experimental data ($R^2 = 0.62$). Response surfaces show that metmyoglobin was more predominant in samples containing the unencapsulated oil compared to the encapsulated oil or beef fat controls over storage (Figure 4a-c). The oxidation of the unencapsulated oil could have increased free-radical generation and promoted the formation of metmyoglobin [6].

IV. CONCLUSION

Fish oil substitution resulted in burger patties with a healthier profile compared to commercially available alternatives. However, partial substitution of fat with fish oil changed technological and shelf life aspects of the burger patties. This was more obvious with unencapsulated fish oil inclusions, that appeared to have a more detrimental effect on the cook loss and the hardness of the products, while encapsulated fish oils were closer to the trends observed in controls. While no negative oxidative effects were observed for any of the substituted ingredients, some indirect destabilisation of colour may have manifested with the use of the unencapsulated oil. Overall, less negative effects on product quality were associated with encapsulated fish oil than with their unencapsulated counterparts.

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