Formulation with fava bean (Vicia faba L.) or fava bean + flaxseed delayed lipid oxidation in frankfurter and during its digestion.

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I. INTRODUCTION

The sustainability of meat consumption is the subject of much debate, for reasons of ecological footprint. Plant-based ingredients, especially from legumes or seeds can participate to partial replacement of animal protein especially if it adds value [1]. Rich in proteins, fava beans are a good candidate, provided they are obtained using a process that reduces anti-nutritional factors [2]. Moreover, this crop contains vitamin, mineral, dietary fibre, phenols and flavonoids [3]. Flaxseed, an oil-seeds, is well known for its richness in alpha-linolenic acid and is considered as a great source of ω-3 polyunsaturated fatty acids [4]. But, its alphalinolenic acid content is highly susceptible to oxidation [5]. Therefore, we aimed to evaluate the benefice of partial replacement of meat protein by fava bean and flaxseed flour on the nutritional quality of frankfurter.

II. MATERIALS AND METHODS

Frankfurters were manufactured at the laboratory according to [6] with flour inclusion 10 % FB (Fava bean), and 10 % FBFS (75% fava bean + 25% flaxseed), both processed by extrusion and without any flour for control. Textural properties (TPA) protein, lipid content and composition, nitrogen content and oxidation were assessed on frankfurters. The microstructural characteristics were evaluated by light microscopy. Sections of 10 µm thick collected on glass slides were stained for 3 min with red oil for fat droplets and Sirius red for collagen. Micrographs were acquired at 20x magnification using an Olympus BX 61 microscope equipped with a high-resolution digital camera (Olympus DP 71) and an Olympus Cell Sens software (Olympus France SAS, Rungis, France). *In vitro* adult digestion was performed according to [1] in triplicate, bolus were obtained after being masticated to reproduce the granulometry of *in vivo* bolus. Oxidation was determined using TBARS method and expressed in MDA. The total nitrogen content of in digesta was determined by using a micro-Kjeldahl. Moreover, trichloroacetic acid-soluble nitrogen (accounting for all peptides and free amino acids) and phosphotungstic acid-soluble nitrogen (accounting for small peptides and free amino acids) were also determined.
Data were analysed with the software Jamovi (version 2.3.26) [Computer Software]. Variance analysis (ANOVA) and a Tukey *post-hoc* test, as well as PCA were carried out. The significances were given by p values. Every biochemical analysis has been performed in triplicates, and the results are systematically given as mean ± standard deviation.

III. RESULTS AND DISCUSSION

The textural properties differed between frankfurters: firmness, gumminess and adhesiveness were lower with addition of FB and this effect was even more pronounced for FBFS ($p<0.05$). Protein content was higher with FB addition compared to control and FBFS ($p<0.05$). Lipid content was similar (14%) whatever the frankfurter formulation. But during storage, control samples exhibited more lipid oxidation than those formulated with FB or FBFS, this is still the case during digestion. This result was all the more remarkable as polyunsaturated fatty acids were higher for FBFS frankfurter. The microstructure of the frankfurter (figure 1) showed smaller lipid droplets with FB of FBFS, that could explain the softer

texture for FB and FBFS frankfurter. The nutritional quality of the frankfurter is summarized in table 1, values obtained at the end of digestion 240 min, *i.e.* the ileal digesta.

Table 1: nitrogen content from different fraction and oxidation in digesta.

formulation	Nitrogen g/100g digesta	Big peptides g/100g digesta	Small peptides g/100g digesta	Undigested nitrogen g/100g digesta	MDA µM (lipid oxidation)
control	0.351 +/- 0.018	0.171 +/- 0.01	0.095 +/- 0.005 [a]	0.084 +/- 0.007 [a]	34.3 +/- 2.8 [a]
FB	0.376 +/- 0.009	0.166 +/- 0.012	0.115 +/- 0.016 [b]	0.100 +/- 0.002 [b]	24.4 +/- 1.4 [b]
FB FS	0.361 +/- 0.015	0.160 +/- 0.007	0.092 +/- 0.003 [a]	0.102 +/- 0.008 [b]	28.6 +/- 2.7 [c]
P value	NS	NS	0.003	0.022	0.001

A higher quantity of small peptides was found with FB frankfurter, which indicates greater digestibility. In addition, less oxidation was recorded with frankfurters formulated with FB and FBFS.

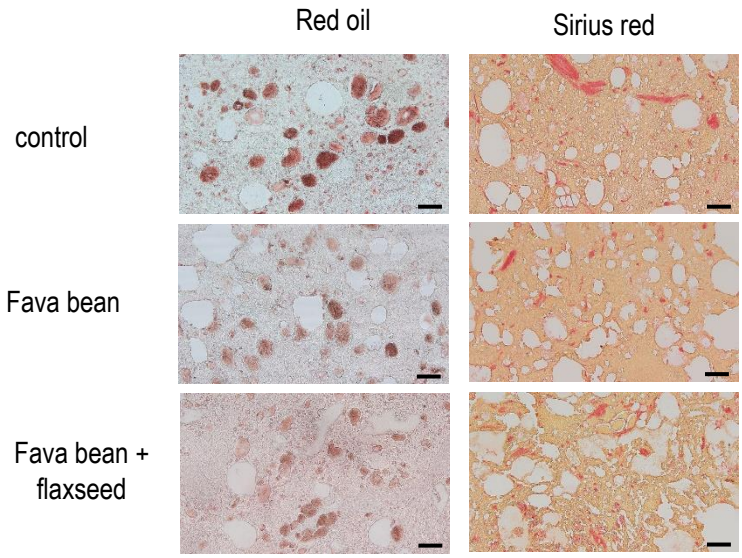

Figure 1: Histological cross-section of frankfurters using red oil (lipid droplets) and Sirius red (collagen) staining. Bar = 100µm

IV CONCLUSION

Reducing our animal protein intake can be achieved by developing mixed animal and vegetable protein products to reduce our carbon footprint. Moreover, the digestibility of frankfurters was not negatively affected by legume flour, which can be explained by the extrusion process, which reduces or even annihilates anti-nutritional factors. The deficiency in sulphur amino acids in pulses is counterbalanced by those provided by meat.

ACKNOWLEDGEMENTS

The Brittany Region in France funds the LEG'ALIM project "Filière régionale durable de légumineuses à graines à haute valeur ajoutée à destination des nouvelles tendances du marché de l'alimentation humaine".

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