LOW-FAT MEAT ANALOGUES MANUFACTURED WITH BIGELS CONTAINING AVOCADO OIL OR WALNUT OIL FOR 3D FOOD PRINTING APPLICATIONS

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I. INTRODUCTION

There is a growing interest for plant-based meat alternatives due to environmental and health concerns. Although the primary focus of these alternatives is given to proteins in terms of macronutrient content, the role of lipids is of great significance from the nutritional and functional standpoints. Fats and oils in meat alternatives contribute to the juiciness, tenderness, mouthfeel, and flavor, however the possible excessive lubrication or stickiness due to these components might need to be circumvented [1]. To enhance nutritional health and wellness of meat alternatives the substitution of saturated fats by healthier fats and oils is a good proposition. Bigels which are two gelled phases attained by mixing oleogels and hydrogels, have emerged as promising semi-solid structured systems to be used as fat substitute in several formulations [2, 3]. The purpose of this study was to investigate various bigels as fat replacers in plant-based meat alternatives. Rheological and hydration properties, as well as colour, of the bigels and the meat alternatives were assessed to evaluate the appropriateness of using bigels as part of the formulation of meat analogues. These products are intended to be used in 3D food printing applications. In other words, this study is focused in the exploration of two trending topics in meat science, the development of plant-based meat alternatives suitable for 3D food printing.

II. MATERIALS AND METHODS

Four bigels were manufactured by mixing an oleogel (either avocado oil or walnut oil) and a hydrogel (either carrageenan or xanthan gum): 1) AVO-CA (avocado oil/carrageenan, 2) AVO-XG (avocado oil/xanthan gum), 3) WAL-CA (walnut oil/carrageenan), and 4) WAL-XG (walnut oil/xanthan gum). Response Surface Methodology was used to determine optimum levels of organogelator (beeswax), oleogel/hydrogel ratio and printing speed based on oil binding stability and dimensional stability (width and height, mm) of the 3D printed elliptic cylinder shaped bigels. Four groups of meat analogues were formulated by mixing water (65 grams) with pea protein isolate (34 g), caramel colorant (0.5 g) and beet powder (0.5 g) with the addition of AVO-CA, AVO-XG, WAL-CA or WAL-XG bigels at 10% level. CIE lightness (L^*), redness (a^*) and yellowness (b^*) values; viscoelastic properties (G': storage modulus; G'': loss modulus); and hydration behavior with Nuclear Magnetic Resonance (NMR) Relaxometry were determined in the bigels and meat analogues. Data from three replications were analyzed using ANOVA and Tukey test ($P<0.05$) with SPSS.

III. RESULTS AND DISCUSSION

In this study, bigels were used to enhance the rheological properties of meat analog formulations to ease processing by 3D printers. G' and G'' values of bigels and meat analogues gradually increased while increasing angular frequency (Fig. 1). G' values of all samples were lower than G'' values, indicating that bigels and meat analogues are more plastic than elastic. Dynamic loss tangent ($\tan \delta = G''/G'$) were less than 1 for all samples. There was no significant difference in colour values for

meat analogues (P>0.05) (Table 1). The lowest *L** value, and the highest *a** and *b** values were observed for the WAL-XS bigels when compared to the others (P<0.05) most likely due to the nonhomogeneous structure generated by mixing xanthan gum and walnut oil. In NMR relaxometry, relaxation time (T_2) for the WAL-CA bigel was significantly higher than for the other bigel groups (P<0.05) which could be attributed to a more homogenous distribution of fat in the continuous phase. In meat analogues, AVO-CA had the greatest T_2 value which was significantly (P<0.05) different from WAL-CA and WAL-XG.

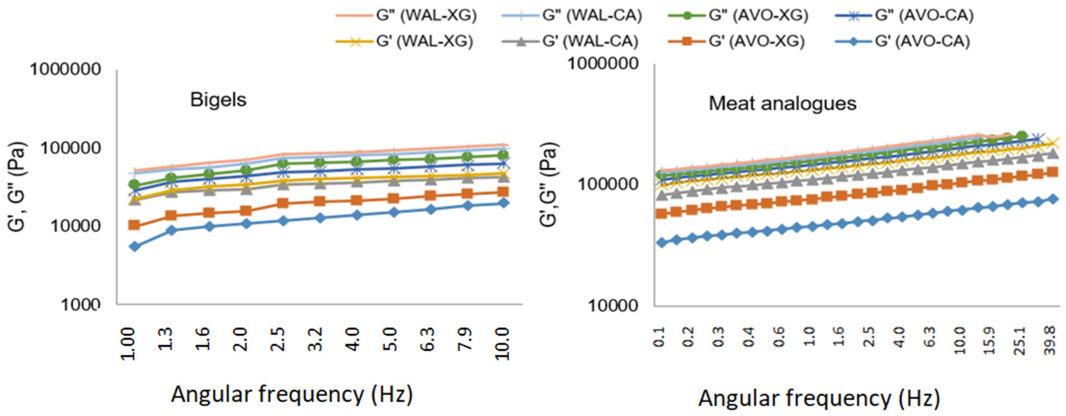

Figure 1. Dynamic rheological properties of bigels and meat analogues

Table 1. CIE colour values (*L*, a*,* and *b**) and relaxation times (T_2, ms) obtained by NMR Relaxometry*

Samples	*L**	*a**	*b**	T_2
BG-AVO-CA	88.7^{b}	-1.80^{b}	22.4^{b}	65.0^{c}
BG-AVO-XG	91.1^{a}	-2.10^{a}	20.9^{cb}	85.2^{b}
BG-WAL-CA	89.4^{ab}	-1.60^{c}	20.6^{c}	129^{a}
BG-WAL-XS	80.8^{c}	-0.70^{d}	27.9^{a}	81.5^{bc}
SEM	1.20	0.20	0.90	9.00
P-value	<0.01	<0.01	<0.01	0.01
MA-AVO-CA	51.6	9.30	21.4	26.3^{a}
MA-AVO-XG	52.1	9.30	21.5	24.5^{ab}
MA-WAL-CA	53.1	9.30	21.2	21.7^{bc}
MA-WAL-XG	52.7	9.60	21.0	21.6^{c}
SEM	0.20	0.10	0.10	0.80
P-value	0.11	0.08	0.50	<0.01

*SEM; standard error of the means. BG: Bigel; MA: Meat analogue. $^{a-d}$: For each attribute, means in a column among BGs or MAs having different superscript letters are significantly different *(P<0.05).

IV. CONCLUSION

Four bigels suitable for 3D printing were successfully manufactured using avocado oil or walnut oil oleogels, mixed with carrageenan or xanthan gum hydrogels. These bigels containing healthy fat alternatives rendered suitable rheological properties for 3D food printing and could be used as novel fat replacers in the formulation of 3D printed plant-based meat analogues.

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