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EVALUATION OF RHEOLOGICAL PROPERTIES OF PORK MYOFIBRILLAR PROTEIN GELS AND LOW-FAT MODEL SUASGAES WITH CHICKPEA POWDER

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I. INTRODUCTION

Myofibrillar protein (MP) plays a crucial role in determining the quality of meat products by influencing water-holding capacity (WHC), gel strength, and texture. The incorporation of plant proteins into meat formulations has been shown to enhance these properties by modifying protein-protein interactions. Chickpeas (CPs) are a rich source of protein, dietary fiber, and bioactive compounds such as polyphenols and carotenoids, which contribute to their functionality in food systems [1]. Drying methods, such as oven-drying and freeze-drying, significantly impact the physicochemical properties and nutritional quality of plant-based ingredients [2]. The incorporation of plant-based proteins in low-fat meat products has gained increasing attention due to increasing consumer interest in health-conscious diets and the potential to improve product quality [3]. In this study, chickpea powder (CPP) processed via freeze-drying (FCP) or oven-drying (OCP), was incorporated to MP gels and low-fat model sausages (LFMSs) to evaluate its effect on physicochemical and textural properties. Thus, the objectives were to assess the quality of MP gels in terms of cooking yield, gel strength, protein surface hydrophobicity, sulfhydryl (-SH) and disulfide (S-S) group levels, and SDS-PAGE results. In addition, the quality of LFMS was also assessed based on pH, color, proximate composition, cooking loss, expressible moisture, textural properties, and SDS-PAGE analysis.

II. MATERIALS AND METHODS

Pork MP (40 mg/mL) was extracted from the loin and mixed with various concentrations (0-1.5%) of FCP or OCP. MP gels were prepared, heated to 80°C, and analyzed for cooking yield (CY, %), gel strength (GS, gf), protein surface hydrophobicity, and -SH/S-S group levels. Protein profiles of raw pork MP were performed by SDS-PAGE. LFMSs were formulated with CPP (1.0% or 1.5%) and evaluated for pH, color, cooking loss (CL, %), and expressible moisture (EM, %). Texture profile analysis (TPA) was conducted to assess hardness, springiness, cohesiveness, and chewiness. Statistical analysis was performed using one-way ANOVA, followed by Duncan's multiple range test to determine differences at the significant level of $P<0.05$.

III. RESULTS AND DISCUSSION

<Analyses of MP>

As shown in Figure 1A, the viscosity increased with the addition of CPP with dose-dependent manners. As the CPP level increased, CY (%) and GS (gf) also increased (Figure 1B and 1C), indicating enhanced protein cross-linking and gel stability due to the interaction between CP proteins and MP. Especially, freeze-dried CPP groups showed a more pronounced effect on CY compared to oven-dried CPP groups, at higher concentrations. This indicates that freeze-drying might be better functional properties of CPP relevant to gelation and water retention, which might be due to less protein denaturation or structural damage during the drying process. SDS-PAGE profile revealed a reduction of myosin heavy chain and the formation of high-molecular-weight polymers at the top of the gel in CPP-treated groups (Figure 1D), confirming improved gelation.

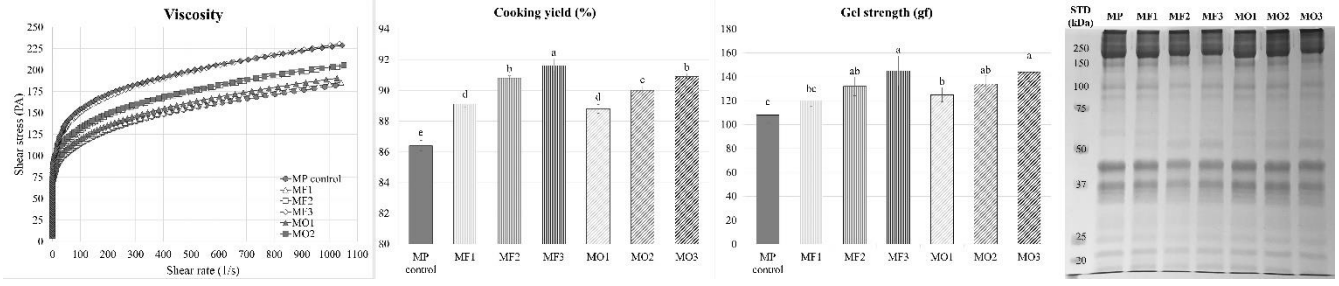


Figure 1. (A) Viscosity, (B) CY (%), (C) GS (gf), and (D) SDS-PAGE of MP gels as affected by different drying methods and various concentrations of CPP. Treatment: MP control, MP gels without CPP; MF1, MP gels with 0.5% freeze-dried CPP; MF2, MP gels with 1.0% freeze-dried CPP; MF3, MP gels with 1.5% freeze-dried CPP; MO1, MP gels with 0.5% oven-dried CPP; MO2, MP gels with 1.0% oven-dried CPP; MO3, MP gels with 1.5% oven-dried CPP. [a-e]Means having same superscripts in a same column are not different ($P<0.05$).

As CPP level increased, protein surface hydrophobicity decreased, while S-S group levels increased, suggesting the formation of stronger protein network (Table 1). This trend indicates that dietary fibers and proteins in CPP likely facilitated protein aggregation and disulfide bond formation, thereby reinforcing the gel matrix through enhanced intermolecular cross-linking.

Table 1. Hydrophobicity, -SH and S-S group levels of MP paste added with different drying methods and various concentrations of CPP

	Treatment[1)]						
	MP control	MF1	MF2	MF3	MO1	MO2	MO3
Hydrophobicity (Bound BPB, μg)	6.06±0.35^{a}	4.62±0.46^{bc}	3.91±0.39^{c}	2.54±0.34^{d}	4.82±0.86^{b}	3.86±0.09^{c}	2.88±0.13^{d}
-SH group level (μmol/g protein)	95.2±0.11^{a}	84.0±3.65^{bc}	77.5±1.25^{d}	69.9±5.62^{e}	87.2±2.63^{b}	80.1±0.42^{cd}	71.5±0.59^{e}
S-S group level (μmol/g protein)	5.14±0.51^{c}	6.68±0.29^{c}	21.7±1.79^{b}	36.3±2.36^{a}	6.04±1.03^{c}	20.9±2.78^{b}	34.1±0.85^{a}

[1)]Treatment: as shown in Figure 1. [a-e]Means having same superscripts in a same column are not different (P<0.05).

<Analyses of low-fat model sausages>

CL (%) and EM (%) of LFMS decreased with increasing CPP concentration, with oven-dried CPP (especially 1.5%) showing the most significant reduction, indicating improved water retention. After cooking, CPP-treated groups showed increased high-molecular-weight biopolymer bands and reduced MHC intensity, especially at higher concentrations, suggesting enhanced protein polymerization and gel network formation.

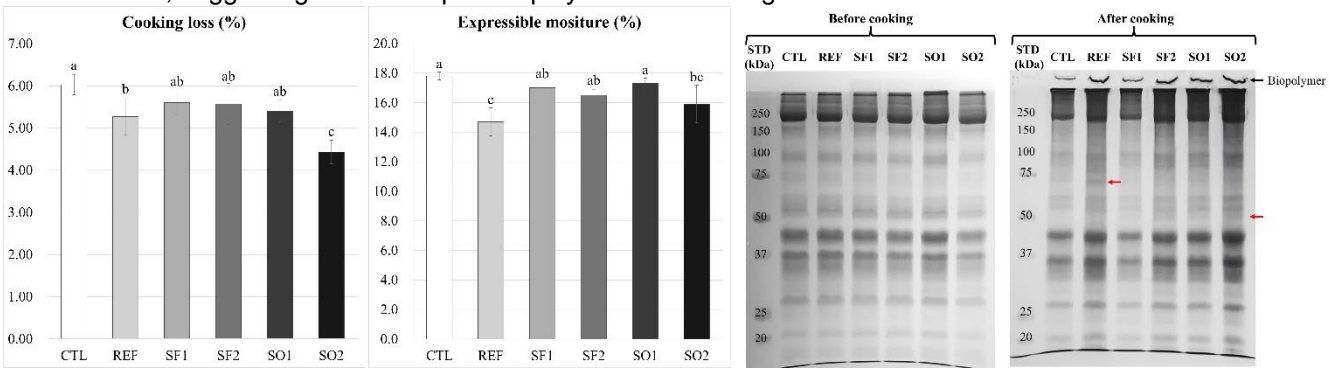


Figure 2. Cooking loss (%), expressible moisture (%), viscosity, and SDS-PAGE of LFMS added with different drying methods and various concentrations of CPP. Treatment: CTL, LFMS without CPP; REF, LFMS with 1.5% SPI; SF1, LFMS with 1.0% freeze-dried CPP; SF2, LFMS with 1.5% freeze-dried CPP; SO1, LFMS with 1.0% oven-dried CPP; SO2, LFMS with 1.5% oven-dried CPP. [a-c]Means having same superscripts in a same column are not different (P<0.05).

pH values increased with CPP addition depending on the concentration and drying method (Table 2). *L** remained relatively stable, however, *a** decreased and *b** increased with the addition of CPP. Textural analysis showed increased hardness and chewiness with CPP addition. The addition of legume protein in the meat products increased with dose-dependent manners as supported in the gel strength of MP due to the cross-linking.

Table 2. pH and color values, textural properties of LFMS added with different drying methods and various concentrations of CPP

Treatment	pH	Color (*L**)	Color (*a**)	Color (*b**)	Hardness (gf)	Springiness (mm)	Gumminess	Chewiness	Cohesiveness
CTL	6.08±0.01^{d}	69.7±0.34^{a}	10.0±0.26^{a}	6.55±0.42^{c}	2733±112^{c}	4.94±0.20^{a}	23.6±1.09^{b}	117±7.47^{d}	0.87±0.02^{a}
REF	6.15±0.01^{a}	69.3±0.23^{a}	9.66±0.08^{b}	7.31±0.31^{ab}	4005±68.7^{a}	4.92±0.27^{a}	34.7±0.44^{a}	170±8.70^{a}	0.87±0.03^{a}
SF1	6.11±0.01^{c}	69.5±0.24^{a}	9.47±0.02^{b}	7.39±0.23^{ab}	3339±172^{b}	4.59±0.18^{a}	30.8±2.21^{a}	141±5.10^{bc}	0.93±0.07^{a}
SF2	6.13±0.02^{b}	69.8±0.23^{a}	8.86±0.26^{c}	7.64±0.19^{a}	3738±214^{a}	4.47±0.37^{a}	33.8±5.78^{a}	150±15.6^{abc}	0.90±0.11^{a}
SO1	6.12±0.01^{bc}	69.5±0.27^{a}	9.32±0.16^{b}	7.12±0.07^{b}	3349±175^{b}	4.69±0.47^{a}	29.9±4.89^{a}	138±9.06^{c}	0.89±0.12^{a}
SO2	6.12±0.00^{bc}	69.8±0.06^{a}	8.87±0.23^{c}	7.39±0.21^{ab}	3745±280^{a}	4.73±0.06^{a}	34.1±2.49^{a}	159±15.5^{ab}	0.92±0.04^{a}

Treatment: as shown in Figure 2. [a-d] Means having same superscripts in a same column are not different (P<0.05).

IV. CONCLUSION

The incorporation of CPP improved the functional properties of MP gels and LFMSs with dose-dependent manner by enhancing gel strength, water retention, and texture due to the cross-linking of CPP and meat proteins. These findings suggest that CPP is a promising functional ingredient for improving the quality of processed meat products.

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