QUALITY CHARACTERISTICS OF HARBIN DRY SAUSAGES BY INOCULATION WITH LACTIC ACID BACTERIA AND *STAPHYLOCOCCUS XYLOSUS*

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I. INTRODUCTION

Harbin dry sausage is a naturally fermented sausage and it is famous in the northeast of China for its distinctive properties, such as flavor, color, and texture. Lactic acid bacteria (LAB), together with coagulase-negative staphylococci, are the primary bacteria found in fermented sausages, contributing to the final organoleptic and hygienic properties of the products. To better illustrate the effect of bacterial fermentation on the quality characteristics in Harbin dry sausages, the moisture content, water activity and distribution, and texture profile were analyzed in the present study.

II. MATERIALS AND METHODS

1. Bacterial cultures Three LAB strains (*P. pentosaceus*, *L. curvatus*, and *L. sakei*) and one *Staphylococcus* strain (*S. xylosus*) were used in this study.
2. Harbin dry sausage preparation A total of seven batches of dry sausages were prepared. A control batch was not inoculated with starter culture, and the other batches were inoculated with various single strains or mixed strains. Single strains included *P. pentosaceus* R1 (Pp), *L. curvatus* (Lc), *L. sake* (Ls) and *S. xylosus* (Sx), respectively. One batch of mixed strains was composed of *P. pentosaceus*, *S. xylosus* and *L. curvatus* (Pp+Sx+Lc), and another was composed of *P. pentosaceus*, *S. xylosus* and *L. sake* (Pp+Sx+Ls). Sausages were prepared according to the method of Chen et al. [1].
3. Moisture content, water activity and water distribution Moisture content was measured using the procedures in AOAC. Water activity (Aw) was measured using a water activity analyzer (Decagon Devices, USA). Nuclear magnetic resonance (NMR) relaxation was measured according to the methods of Zhang et al. [2] using an LF-NMR minispecmq 20 (BrukerOptik GmbH, Ettlingen, Germany) to analyze the water distribution.
4. Texture profile analysis Texture profile analysis (TPA) was conducted employing a TA-XT plus Texture Analyzer (Stable Micro System, UK) with an aluminum cylindrical probe P-50 (50 mm diameter). The sausages were cut into cylinders (20 mm diameter × 30 mm height) and subjected to a two-cycle compression test. The sausages were compressed to 50% of their original height with a 25 kg load cell at a speed of 2.0 mm/s. Hardness, springiness, adhesiveness, compression, and cohesiveness were determined.

III. RESULTS AND DISCUSSION

1. Moisture content and water activity

As shown in Figure. 1A and B, the moisture content and Aw declined in all sausages over the fermentation period. Compared to the control, there was a lower moisture content and Aw in the inoculated sausages at the end of the fermentation period ($P < 0.05$). This was attributed to the favoring of carbohydrate metabolism to organic acids by bacterial fermentation, which causes muscle protein denaturation, muscle bundle shrinkage, and the loss of water from the intra- and inter myofibrillar protein network.

The water distribution and mobility within meat can be evaluated by LF-NMR. In our experiments, three peaks were observed and directly assigned to three distinct water classes (Figure. 1C). After a nine-day fermentation, the T_{2b} relaxation time of the sausages was slightly longer than for the initial, fresh sausage, and the T_{2b} of the control sausage was longer than for the inoculated sausages ($P < 0.05$). These results indicated that inoculation with bacteria caused shorter T_{2b} relaxation times. The change of the bonding capacity of protein for water can be attributed to the oxidation of myofibrillar proteins.

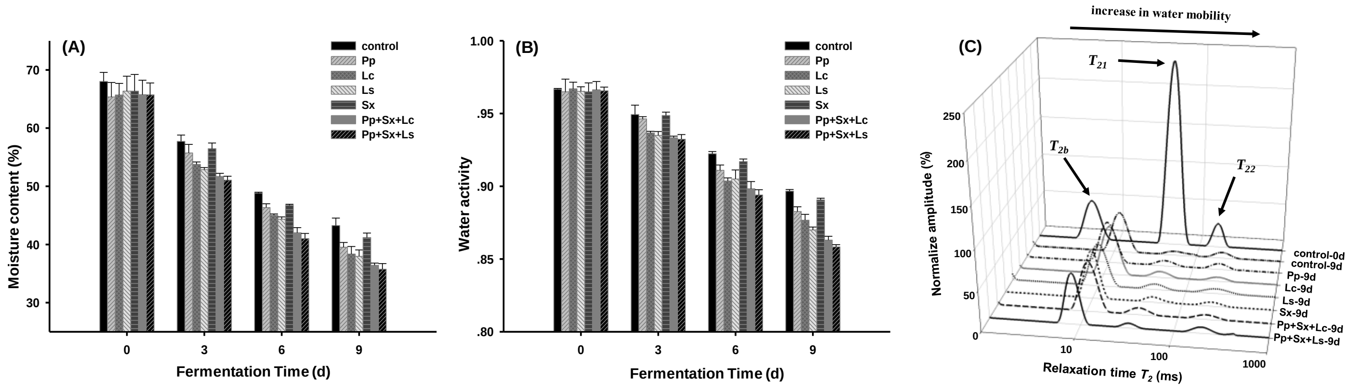

Figure 1. Moisture content (%), water activity and water distribution of Harbin dry sausages during a nine-day fermentation: control and inoculated with bacterial strains

2. Texture analysis

The texture profiles of all sausages were analyzed after the nine-day fermentation, including hardness, springiness, cohesiveness, gumminess and chewiness (Table 1). Inoculation with LAB strains resulted in a greater hardness, springiness, gumminess and chewiness (P < 0.05); however, inoculation with only *S. xylosus* has no significant effect on the hardness, gumminess and chewiness (P > 0.05). These results indicated that texture improvement is more likely to be associated with acid production.

Table 1 Texture profile analysis of dry sausages after a nine-day fermentation: control and inoculated with bacterial strains

	Hardness (N)	Springiness	Cohesiveness	Gumminess (N)	Chewiness (N/mm)
control	55.47 ± 1.44^{c}	0.70 ± 0.01^{c}	0.74 ± 0.01^{a}	30.67 ± 0.96^{b}	24.39 ± 1.02^{b}
Pp	59.45 ± 1.23^{ab}	0.74 ± 0.01^{b}	0.73 ± 0.01^{a}	32.92 ± 0.65^{ab}	26.88 ± 0.88^{ab}
Lc	60.56 ± 0.99^{a}	0.76 ± 0.02^{ab}	0.73 ± 0.01^{a}	33.12 ± 0.69^{ab}	26.44 ± 1.26^{ab}
Ls	60.90 ± 0.98^{a}	0.76 ± 0.01^{ab}	0.74 ± 0.01^{a}	33.06 ± 1.56^{ab}	26.89 ± 1.39^{ab}
Sx	57.20 ± 1.20^{bc}	0.74 ± 0.02^{ab}	0.73 ± 0.01^{a}	33.18 ± 0.49^{ab}	25.84 ± 1.12^{ab}
Pp+Sx+Lc	62.04 ± 0.96^{a}	0.77 ± 0.01^{ab}	0.72 ± 0.01^{a}	33.71 ± 0.34^{a}	27.68 ± 1.17^{a}
Pp+Sx+Ls	61.53 ± 1.12^{a}	0.78 ± 0.01^{a}	0.73 ± 0.01^{a}	33.64 ± 0.10^{a}	27.50 ± 1.25^{a}

$^{a-c}$ Means within the same column with different superscript letters differ significantly (P < 0.05).

IV. CONCLUSION

The analysis of moisture content, water activity, distribution and TPA showed that the inoculation of bacterial strains promotes water release and texture development, especially with inoculation of multiple strains (Pp+Sx+Lc and Pp+Sx+Ls). Thus, the quality characteristics were improved by fermentation with multiple bacterial strains.

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