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Characteristics and properties of goat meat gels as affected by setting temperatures

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ABSTRACT

Effects of different setting temperatures (40–70 °C) on properties of goat meat gels after heating at 90 °C were investigated. Setting at 60 °C with subsequent heating at 90 °C yielded the gel with the highest breaking force along with coincidentally lowest expressible moisture content ($p < 0.05$). The highest TCA-soluble peptide content was found in gel set at 70 °C ($p < 0.05$). Slight decrease in myosin heavy chain band intensity was noticeable when setting temperature increased. As setting temperatures increased, a^* and b^*-values of gels generally increased, while L^*-values decreased ($p < 0.05$). Gel set at 60 °C had highest hardness, gumminess and chewiness ($p < 0.05$). Gel set at 60 °C had the most compact network with immense connectivity of protein strands. Gels set at 40–60 °C had higher texture and overall likeness scores, compared to the control ($p < 0.05$). Prior setting at 60 °C was recommended for making the good quality goat meat gel.

1. Introduction

Goat meat has been widely consumed in Asia and Africa (Arain et al., 2010). Goat meat is also a crucial food, which is one of the main products of different traditional dishes in Mediterranean (Teixeira, Pereira, & Rodrigues, 2011). Goat meat has gained interesting attention by the ethnic consumers. Popularity and use of goat meat vary with communities (Wattanachant, Sornprasitt, & Polpara, 2008). Additionally, culture, social and economic conditions determine the preference of consumer for goat meat. In Thailand, the production of goat meat has gradually increased in recent years (Wasiksiri, Pongprayoon, Srimai, & Nasae, 2010), due to an increasing consumer's demand. Additionally, goat meat can be extended to the Middle East and niche markets in Asia. Western countries with ethnic communities that traditionally consume goat meat are another market, where there are inadequate supplies of goat meat or products (Wattanachant et al., 2008).

To widen the consumption of goat meat, value-added products should be manufactured to meet the consumer's requirement. Goat meat can be used for production of gel-type products. Gel-forming ability and viscoelastic property are integral for meat products. These properties are governed by bonds stabilizing the gel network (Tammatinna, Benjakul, Visessanguan, & Tanaka, 2007). Several approaches have been used to enhance gelling property of mince or washed mince of fish meat known as 'surimi'. "Setting" is generally implemented in surimi paste at temperature range of 25–40 °C, in which cross-linking of myosin is mediated by endogenous transglutaminase (TGase). This contributes to the enhanced gel strength (Tammatinna et al., 2007). For direct cooking (without prior setting), TGase has a limited activity due to its thermal inactivation at high temperature. TGase (EC 2.3.2.13) is able to catalyze the acyl transfer from γ-carboxyl amide groups of glutamine to ε-amino groups of lysine, resulting in the formation of ε-(γ-glutamyl) lysine isopeptide (Dondero, Figueroa, Morales, & Curotto, 2006). To produce gel with good quality from the meat of land animals including beef and pork (Dondero et al., 2006; Kim, Carpenter, Lanier, & Wicker, 1993; Park, Brewer, McKeith, Bechtel, and Novakofski, 1996a, 1996b; Torley & Lanier, 1991), rabbit (Ishioroshi, Samejima, & Yasui, 1982; Samejima, Ishioroshi, & Yasui, 1981), chicken (Smyth and O'neill, 1997) and quail (Ikhlas, Huda, & Noryati, 2011), setting is employed before heating or cooking. Nevertheless, Niwa, Suzumura, Nowsad, and Katoh (1993) classified some mammalian vertebrates such as bovine, pig and whale as non-setting species. Low setting in those meat species might be owing to low level of cross-linking enzyme. Moreover, substrate available for enzyme activity is restricted. Nevertheless, Dondero, Figueroa, Morales, and Curotto (2006) stated that endogenous TGase was found in beef. Torley and Lanier (1991) reported that some beef appeared to have setting phenomenon at 25 °C. Additionally, Akamittath, Ball, and Hershell (1992) found that setting occurred in actomyosin from turkey at 4 and 37 °C with the aid of guinea pig liver transglutaminase. TGase or Factor XIII from crude pig plasma induced the formation of isopeptides in

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chicken meat ball heated at internal temperature of 71 °C (Tseng, Liu, & Chen, 2000). For fish mince or surimi, optimum setting temperature was governed by heat stability of myosin and varied with species (Benjakul, Chantarasuwan, & Visessanguan, 2003). The optimal setting temperature generally relates to the habitat and body temperatures of animal (Benjakul et al., 2003; Kim et al., 1993).

To our knowledge, no information regarding setting and gel formation of goat meat exists. Based on our preliminary study, goat meat had poor gel-forming ability, compared to fish meat. This may be associated with low setting phenomenon mediated by endogenous TGase or poor aggregation or alignment of muscle proteins. The objective of this investigation was to study the effect of setting temperatures on properties of heat induced gel from goat meat.

2. Materials and methods

2.1. Chemicals

Sodium dodecyl sulfate (SDS) and β-mercaptoethanol (βME) were purchased from Sigma (St. Louis, MO, USA). Trichloroacetic acid and Foline-Ciocalteu's phenol reagent were obtained from Merck (Darmstadt, Germany). Bis-acrylamide, acrylamide and *N,N,N′,N′*-tetramethylethylenediamine (TEMED) were procured from Fluka (Buchs, Switzerland). All chemicals used were of analytical grade.

2.2. Collection and preparation of goat meat

Meat from the Boer goat with the age of approximately 1.5 year was obtained from a local slaughter house in Hat Yai district, Songkhla province, Thailand. Goats were slaughtered, following the Muslim practice (Halal means) by cutting the throat and major blood vessels in the neck. Goat meat was dissected, pooled and used as the composite samples. It was placed in polyethylene bag. Then it was transported in an insulated box containing ice (meat/ice ratio of 1:10, w/w) to the laboratory of halal research institute, Prince of Songkla University, within 30 min. Upon arrival, meat was immediately washed with cool water (5 °C). The external fat and connective tissue were removed manually. The meat was then postmortem-aged at 4–5 °C for 24 h. After aging, it was placed in polyethylene bag, heat-sealed and stored at -20 °C until use. The storage time was not longer than 1 month.

2.3. Effect of setting temperatures on property of goat meat gels

Frozen goat meat was thawed at 4 °C for 4–5 h until the core temperature of 0–2 °C was obtained. Meat samples were washed thoroughly with running water (4 °C). Sample was minced to uniformity using a mincer (National Model MK-5080 M, Selangor, Malaysia) for 3 min. Subsequently, 2.8% NaCl, 0.3% mixed phosphate (sodium tripolyphosphate/potassium polyphosphate at a ratio of 7:3), 2.5% sugar, 3% modified tapioca starch (distarch phosphate) and 0.3% ground black pepper were added. The mixture was mixed well for 2 min. The temperature was maintained below 10 °C during chopping. Meat paste was added with distilled water, in which the final moisture content of 80% was gained. Thereafter, the mixture was chopped for 3 min. Resulting paste (200 g) was stuffed into a polyvinylidene chloride casing (a diameter: 2.5 cm, total length: 30 cm). Both ends were sealed and subjected to setting at different temperatures (40, 50, 60 or 70 °C) for 30 min in a temperature control water bath (W350, Memmert, Schwabach, Germany). Set samples were heated at 90 °C for 20 min and subsequently cooled in iced water for 30 min. The gel samples were kept at 4 °C for 24 h before analyses.

2.3.1. Breaking force and deformation

Breaking force (gel strength) and deformation (deformability) of goat meat gels were measured by a texture analyzer (Model TAXT2, Stable MicroSystems, Surrey, UK) as described by Buamard and Benjakul (2015). Cylindrical gel samples (2.5 cm in height) were equilibrated at room temperature (28–30 °C) for 1 h. A spherical plunger having a diameter of 5 mm and a constant depression speed of 60 mm/min were used for testing. Breaking force and deformation were recorded.

2.3.2. Texture profile analysis

Texture profile analysis (TPA) of gel samples was conducted following the method of Buamard and Benjakul (2015). A texture analyzer (Model TA-XT2, Stable Micro- Systems, Surrey, UK) with a cylinder probe (diameter 35 mm) was used. Hardness, springiness, cohesiveness, gumminess and chewiness were determined.

2.3.3. Expressible moisture content

Expressible moisture content was determined as per the method of Buamard and Benjakul (2015). Cylindrical gel sample with 5 mm in thickness was weighed accurately (X). It was sandwiched between three pieces of filter paper No.1 (Whatman International Ltd., Maidstone, UK) at the bottom and two pieces on the top. Subsequently, the samples were pressed by a standard weight (5 kg) for 2 min. After removal from the papers, the samples were weighed again (Y). Expressible moisture content was calculated with the following equation and expressed as percentage of sample weight:

$$\text{Expressible moisture content} = [(X-Y)/X] \times 100$$

2.3.4. Color of gel

Color of gels was measured by a Hunter lab colorimeter (Color Flex, Hunter Lab Inc., Reston, VA, USA). L^*, a^* and b^* values were measured. The colorimeter was warmed up for approximately 10 min. A white standard was used for calibration. Total difference in color (ΔE^*) was calculated as guided by Mad-Ali, Benjakul, Prodpran, and Maqsood (2017).

2.3.5. TCA-soluble peptide content

TCA-soluble peptide content as an indicator for protein degradation was measured following the method of Buamard and Benjakul (2015). Chopped sample (3 g) was added with cold 5% TCA (27 mL). Homogenization was implemented at 11,000 rpm for 2 min using a homogenizer (IKA Labortechnik, Selangor, Malaysia). After being stored in ice for 1 h, homogenate was centrifuged at 8000*g* for 10 min. Supernatant was collected and determined for TCA-soluble peptide as per the method of Lowry, Rosebrough, Farr, and Randall (1951).

2.3.6. SDS-polyacrylamide gel electrophoresis

Protein patterns of goat meat gels were analyzed by SDS-PAGE under the reducing condition following the method of Laemmli (1970). Firstly gel samples were finely chopped. Twenty-seven mL of heated SDS solution (85 °C) were mixed with prepared sample and homogenized at 11,000 rpm for 2 min. After incubation at 85 °C for 1 h, the mixtures were centrifuged at 3500*g* for 20 min to remove the debris. Protein concentration of the supernatant was measured by the Biuret method (Robinson & Hogden, 1940), where bovine serum albumin was used as standard. Prepared samples were mixed with sample buffer and the mixture (protein of 15 μg) was loaded onto the gel. SDS-PAGE gel comprising 10% running gel and 4% stacking gel was used. After separation, the proteins were subjected to staining and destaining as guided by Buamard and Benjakul (2015).

2.3.7. Microstructures

Microstructure of gel samples was examined using a scanning electron microscope (SEM). The samples (2–3 mm in thickness) were fixed with 0.2 M phosphate buffer (pH 7.2) containing 2.5% (v/v) glutaraldehyde for 3 h at room temperature. After rinsing with distilled water, the dehydration of specimens was conducted in ethanol with serial concentrations (25–100%). Samples were subjected to critical