

Effects of NaCl Replacement with Gamma-Aminobutyric acid (GABA) on the Quality Characteristics and Sensorial Properties of Model Meat Products

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Abstract

This study investigated the effects of γ -aminobutylic acid (GABA) on the quality and sensorial properties of both the GABA/NaCl complex and model meat products. GABA/NaCl complex was prepared by spray-drying, and the surface dimensions, morphology, rheology, and saltiness were characterized. For model meat products, pork patties were prepared by replacing NaCl with GABA. For characteristics of the complex, increasing GABA concentration increased the surface dimensions of the complex. However, GABA did not affect the rheological properties of solutions containing the complex. The addition of 2% GABA exhibited significantly higher saltiness than the control (no GABA treatment). In the case of pork patties, sensory testing indicated that the addition of GABA decreased the saltiness intensity. Both the intensity of juiciness and tenderness of patties containing GABA also scored lower than the control, based on the NaCl reduction. These results were consistent with the quality characteristics (cooking loss and texture profile analysis). Nevertheless, overall acceptability of the pork patties showed that up to 1.5%, patties containing GABA did not significantly differ from the control. Consequently, the results indicated that GABA has a potential application in meat products, but also manifested a deterioration of quality by the NaCl reduction, which warrants further exploration.

Keywords: GABA, low sodium, physicochemical, sensory, pork patties

Introduction

Sodium chloride (NaCl), which is called a common salt, table salt or halite, is an important compound added to a variety of foods such as meat products, breads, and dairy products, and it provides several advantages such as the improvement of flavor, preservation of food quality, or contributions to food structure (Ahn *et al.*, 2013; Noort *et al.*, 2010). For those reasons, NaCl is a main ingredient in processed foods, which has triggered higher NaCl consumption than the acceptable daily intake (Michell, 1985; WHO, 2012). It has been recognized that NaCl plays a key role in maintaining the homeostasis of living bodies by assisting absorption of glucose, amino acids, and water. In addition, it contributes to the control and regulation of

osmotic pressure and blood pH, and assists in both muscular contraction and the transmission of nerve signals. Consequently, over intake of NaCl, particularly Na, causes many health risks including high blood pressure, osteoporosis, heart disease and stroke. Therefore, the World Health Organization (WHO) changed the recommended daily sodium intake from 6 g in 2007 to 2 g in 2012 (WHO, 2012). Consumption of NaCl should be appropriately controlled to reduce health problems while improving food quality at the same time.

Gamma-aminobutyric acid (GABA, $C_4H_9NO_2$) is a four-carbon, non-protein amino acid which is a naturally occurring in the human body (brain and spinal cord neurotransmitter), or by action of fermenting microorganisms (Lamberts *et al.*, 2012). GABA has been found to attribute to improved brain blood flow, brain cell metabolism, insomnia, anxiety, and the physiological activity of nervous stability. GABA produced by microbial fermentation contributes to increase the nutritional, functional, and sensorial properties of foods (Abe *et al.*, 1995; Joye *et al.*,

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2011; Masubuchi *et al.*, 2004). Hence, it has attracted much attention in the functional food industry, and has been applied to processed foods and beverages (Jung and Chung, 2013; Kim *et al.*, 2013; Pyo, 2008). GABA is a non-protein amino acid, and only the health and medical functions that have been explained in the many studies to date are known. Generally, amino acids have taste and flavors like sweetness (glycine, alanine, serine, proline etc.), bitterness (arginine, valine, leucine, phenylalanine, histidine etc.), sourness (aspartic acid, glutamic acid, asparagine etc.) and savory tastes (glutamin acid and aspartic acid). Among non-protein amino acids, several amino acids such as theanine, tricholomic acid and alliin contribute to taste, particularly savory taste. In the study of Cho *et al.* (2011), GABA was included in kimchi, and improved the saltiness in the sensory evaluation.

In meat formulation, NaCl has been an important additive not only to provide flavor, but also to extract salt-soluble proteins, mainly myofibrillar proteins. Recently, the meat industry has also faced challenges to reduce Na in the formulation. Numerical investigations have been conducted to manufacture low-Na meat products; nevertheless, little information is available regarding techniques which can reduce Na without drawbacks in organoleptic properties of the meat products. As a saltiness enhancer, GABA has potential application for partial replacement of NaCl in food formulations. It was hypothesized that GABA can be used either in the form of a NaCl/GABA complex, or as an additive in food formulation. Regardless of the usage type, enhancement of the salty flavor by GABA might allow less use of NaCl. Therefore, the present study was carried out to characterize the NaCl/GABA complex, and to evaluate the effects of partial replacement of NaCl with GABA on the physicochemical and sensorial properties of pork patties.

Materials and Methods

Materials

Pork leg and backfat were obtained 48 h post-mortem from carcasses, and all visible fat and connective tissue were trimmed off. The meat and backfat were separately ground using a 3 mm plate, and vacuum packed in polyethylene pouches. Prior to patty preparation (within 3 h), the meat and fat were kept at 4°C. GABA was kindly donated by BioVan Co. (Korea). Food grade NaCl (Taepyungsalt Inc., Korea) and maltodextrin (MD, Dextrose equivalent: 15-20, Weifang Codi Imp. & Exp. Co., Ltd., China) were purchased for experiments.

Characterization of NaCl/GABA complexes

To prepare the NaCl/GABA complex, MD was used as a carrier of the NaCl matrix. Initially, 20% (w/v) NaCl and 10% (w/v) MD were completely dissolved in distilled water using a magnetic stirrer at 500 rpm for 30 min; thereafter, different concentrations (0.5-2.0%, w/v) of GABA were added to the mixtures. Each mixture was spray-dried using a spray-dryer (SD-1000, Eyela, Japan) under the conditions of 150°C inlet temperature, 180 kPa atomizing pressure, 0.6 m³/min blow rate, and 500 mL/h flow rate, which were the conditions adopted from our preliminary trials.

Dried NaCl/GABA complexes were observed by microscope (Olympus CX31, Olympus Corp., Japan), and the surface dimensions of the complex particles were measured using an UTHSCSA image tool (USA). Over 100 particles were captured in one image for calculation of the average dimensions. Microstructure of the NaCl/GABA complex was observed by scanning electron microscopy (FE-SEM, S-4700, Hitachi, Japan). All samples were dried in a desiccator for 24 h and then coated for 40 s with platinum using ion sputter (E-1010, Hitachi, Japan) at a current of 15 mA. For rheological properties, the dried powder (1%, w/v) was dissolved in water and shear stress of the solution was measured using a rheometer (MCR-302, Anton-Paar, USA) with the 303316 standard measuring system (DG26.7/T200/AL) by linearly increasing the shear rate from 1/s to 100/s for 500 s under the controlled temperature of 25°C. Viscosity of each solution was numerically calculated from the obtained shear rate-stress data.

To evaluate saltiness of the complex, 1% (w/v) of the powdered complex was completely dissolved in water and tempered at ambient temperature for 2 h. Eight panellists were trained by testing 12 different concentrations (25 mM to 80 mM) of NaCl solution, after which they carried out the saltiness evaluation. Saltiness intensity was estimated using a 5-point hedonic scale. In other words, the strongest sample was given 5 points, and other samples were compared with the strongest one.

Characteristics of model meat products manufactured with GABA

In this study, GABA was used to substitute NaCl, and was directly added to pork patty formulations. As a curing ingredient, powdered NaCl and GABA were mixed at ratios of 3:0, 2:1, 1:2 and 0:3 (w/w), respectively. Pork patties were prepared by mixing 80 g meat, 20 g fat, and 1.5 g curing ingredient using a homomixer (5K5SS, Kit-

chen Aid, USA) The mixture was shaped manually as a cylinder (2 cm thickness) and placed in a plastic bag. All patties were thermal treated in a 95°C water bath for 30 min, and cooled down with running water.

The pork patties were cut into 2 cm cubes and tempered at ambient conditions for 15 min in a plastic bag. The sample cubes were served to the trained panelists to estimate saltiness, juiciness, tenderness, and overall acceptability. Sensorial intensities of each sample were rated by the ranking method. The results were analyzed by the rank sum method, and the differences among the means were compared using Kramer's statistical chart (Kim and Lee, 2001; Kramer, 1974; Senthil *et al.*, 2002).

For quality analyses of the pork patties, cooking loss and compression tests were selected as the quality indicators of the treatments. Cooking loss was determined by assessing the value of exudation after thermal treatment. Each sample was weighed before and after cooking at 95°C for 30 min, and loss was expressed as a percentage of the initial weight. After measuring the cooking loss, hardness and adhesiveness were measured using a texture analyzer (CT3 Texture Analyzer, BROOKFIELD, USA) equipped with a probe (TA43 sphere 25.4 mm D, BROOKFIELD, USA) under the conditions of a target value of 10 mm, trigger load of 20 g, test speed of 0.50 mm/s, target type of 10 mm distance, and 2 cycles.

Statistical analysis

Completely randomized block design was adopted to estimate the effects of GABA levels on the characteristics of the NaCl/GABA complex, or on the quality characteristics of the pork patties. Analysis of variance was conducted, and the means were separated by Duncan's test using the SPSS 20.0 software (SPSS Institute, USA), when the main effect (GABA concentration) was significant ($p < 0.05$).

Results and Discussion

Characteristics of dried NaCl/GABA complexes

Fig. 1 presents the surface dimensions of the NaCl/GABA complexes as a function of GABA concentration. The mean surface dimension of NaCl without GABA was around 25 μm^2 at 60% cumulative distribution, while the surface dimension of the NaCl/GABA complexes increased to 75 μm^2 regardless of the GABA concentrations ($p < 0.05$). Morphological observations of the NaCl/GABA complexes are presented in Fig. 1. It was observed that GABA was adsorbed on the surface of the NaCl/MD

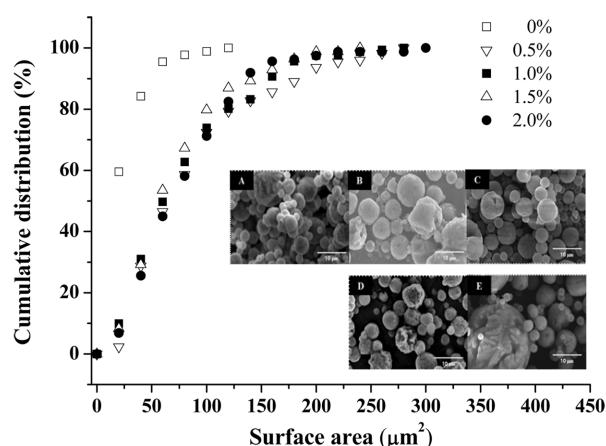


Fig. 1. Surface area of NaCl complexes added various concentration of GABA and morphology image of NaCl added various concentration GABA by scanning electron microscope magnification of 3000 \times (A: 0%, B: 0.5%, C: 1.0%, D: 1.5%, and E: 2.0%).

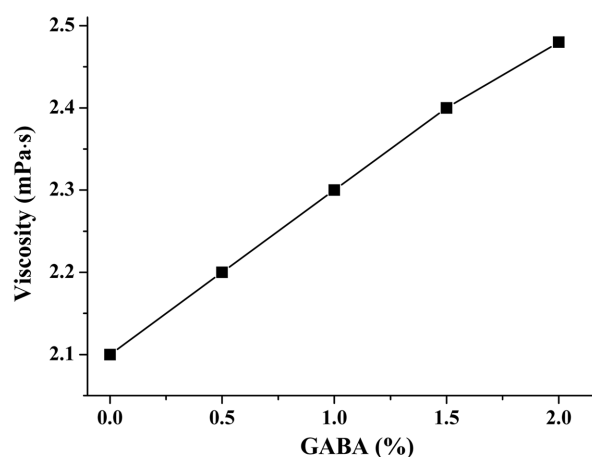


Fig. 2. Shear stress or viscosity of solution added NaCl mixed various concentrations GABA.

complex, especially when using 1.5% GABA. In previous studies, the surface of the NaCl/MD complex was smooth. Halliday *et al.* (2012) and Sivadas *et al.* (2008) explained that the morphology of spray dried powder is strongly influenced by the type of polymer used. Depending on the polymer type and spray-drying conditions, it is possible to form two kinds of particles: smooth-surfaced microspheres, or porous inhomogeneous microparticles. We expected that the GABA position and increased surface area of the NaCl/GABA complexes, which were on the surface of the NaCl/MD complexes, may affect the sensory properties of the NaCl/MD complexes, including saltiness, because larger surface area may affect the flavor intensity or time of flavor perception.

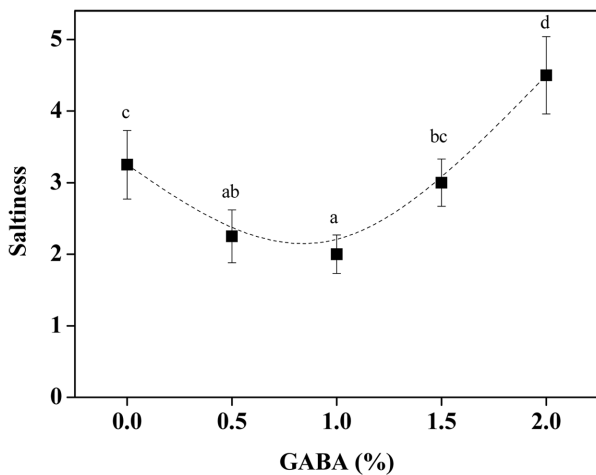


Fig. 3. Saltiness evaluation of NaCl added various concentrations GABA.

As shown in Fig. 2, all NaCl/GABA complexes exhibited a Newtonian fluid property, irrespective of GABA concentrations. Viscosity of the NaCl/GABA complexes tended to increase with increasing GABA concentration. However, the differences were not significantly different from the control. Although the NaCl/GABA complexes showed water-like rheological properties due to their low concentration in water, it is possible that the addition of GABA could provide a more viscous solution. Therefore, the critical concentration of GABA should be considered depending on the type of food, because high GABA concentrations may increase food viscosity.

For saltiness of the NaCl/GABA complex (Fig. 3), the addition of GABA in the range of 0.5-1.0% was found to decrease the saltiness of NaCl ($p < 0.05$), whereas the saltiness was improved again by increasing GABA up to 1.5%, while the 2.0% GABA treatment displayed significantly higher saltiness than the control ($p < 0.05$). Many researchers have studied the function of GABA in various food products (Cho *et al.*, 2012; Jung and Chung, 2013; Pyo, 2008), but investigation into the effects of GABA as a flavor enhancer have not yet been performed. From these results, the critical concentration of GABA required to enhance the saltiness of NaCl would provide useful information for food manufacturers.

Characteristics of model meat products manufactured with GABA

To identify the effects of GABA as an NaCl replacement, the NaCl concentration in a pork patty formulation was reduced, and was replaced with the corresponding amount of GABA (total 1.5%). In general, reducing NaCl

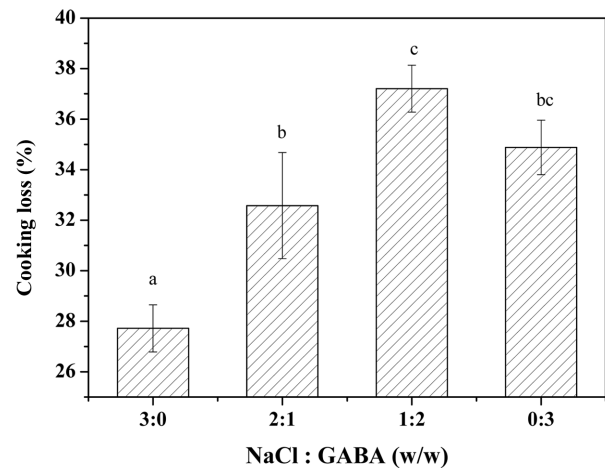


Fig. 4. GABA concentration on sensory properties of meat patties (No significant difference between 19 and 36 by Kramer's statistical charts ($p < 0.05$)).

in meat formulations should result in poor water-binding properties, as well as poor textural properties of the meat products. Considering the water-binding property, the control patty had approximately 28% cooking loss (Fig. 4). Reducing the NaCl resulted in significantly higher cooking loss than the control ($p < 0.05$). In the case of 0.5% GABA treatment, the cooking loss increased to 32%, with a further increase to 37% for the 1.0% GABA treatment. In this study, pork patties were selected as model meat products, and the patties were coarsely ground. For that reason, decrease in the cooking loss with decreasing NaCl was considerable. When the GABA concentration in the pork patty increased to 1.5% (no NaCl), cooking loss was not different from the 1.0% GABA treatment.

As can be seen in Fig. 5, both the hardness and adhesiveness of the patties did not differ based on GABA concentration, reflecting that GABA did not affect the textural properties of the pork patties. Based on less extraction of salt-soluble proteins, it was expected that reducing NaCl would lead to deterioration of the textural properties of meat products (Hong *et al.*, 2008; Hong and Chin, 2010). It is likely that the high amount of cooking loss was compensated for by the lack of difference in the texture of the patties. These results indicated that additional ingredients are necessary to prevent loss of quality from reducing NaCl, which warrants further exploration.

The sensorial intensities and overall preference for the pork patties containing various concentrations of GABA are shown in Fig. 6. Saltiness, juiciness and tenderness of the non-GABA treated control had the lowest rank sum, indicating that GABA treatments revealed less intense

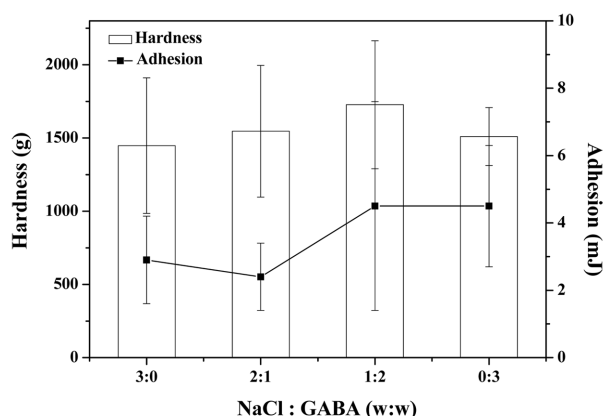


Fig. 5. GABA concentration on cooking loss (%) of meat patties.

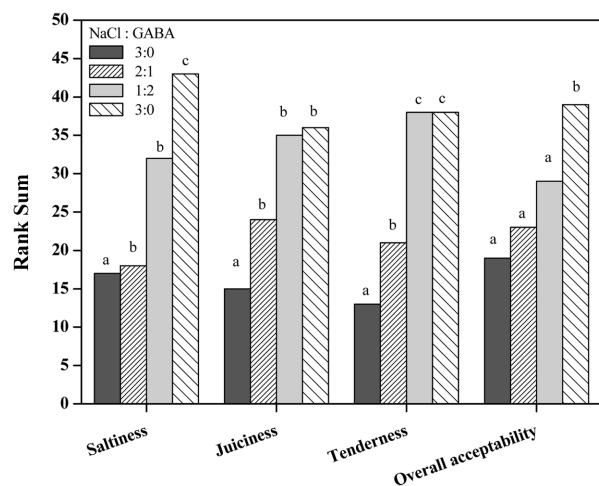


Fig. 6. GABA concentration on hardness and adhesion of meat patties.

sensorial properties than the control. Due to the reduced NaCl concentration, all patties including GABA showed significantly higher rank sum than the control ($p < 0.05$). While the GABA treatments containing 0.5-1.0 g in the patty formulation exhibited no significant difference in saltiness, the inclusion of no NaCl (1.5% GABA) had the highest rank sum ($p < 0.05$). The properties revealed in the actual meat products were not consistent with the results obtained by the NaCl/GABA complex alone (Fig. 3).

This could be explained by considering that the reduction in NaCl affected the functional properties of the meat proteins, thereby influencing the sensorial properties of the pork patties. In the case of juiciness, all GABA treatments had lower juiciness intensity than the control ($p < 0.05$), although the juiciness of the individual GABA treatments did not significantly differ from one another.

In tenderness, the control showed the lowest rank sum ($p < 0.05$). For GABA treatments, patties containing 0.5% GABA had significantly lower rank sum of tenderness than those containing more than 1.0% GABA ($p < 0.05$). These results were also confirmed by the quality properties (cooking loss and texture).

On the other hand, overall acceptability indicated that patties containing 0.5-1.0% GABA showed no significant difference in overall acceptability compared to the control. Although inclusion of no NaCl (1.5% GABA) had higher rank sum in the overall acceptability than the control, GABA could be used as a saltiness enhancer. GABA did not demonstrate water-binding or meat texturizing effects in the present study. It has been applied to brown rice, green tea and tomato paste, without drawbacks caused by NaCl reduction (Cho *et al.*, 2012; Jung and Chung, 2013; Pyo, 2008). For meat product application, additional binding agents should be applied to products containing GABA with reduced NaCl. Nevertheless, it should be possible to apply GABA as an NaCl replacement if binding agents are also combined in the formulation.

Conclusion

This study explored the effects of GABA on the saltiness of both the NaCl/GABA complex and actual meat products. Although, the relationship between particle size of the complex and salty flavor was still obscure in the current study, the addition of 2% GABA was demonstrated to effectively enhance the salty flavor. However, the enhancement of salty flavor by GABA was not effective when actually applied to meat products containing reduced amounts of NaCl. In addition, decrease in the quality also manifested due to reduction of NaCl. In conclusion, it is possible to replace NaCl with GABA by simultaneously adding binding agents to the low-Na meat formulation.

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