CHEMICAL COMPOSITION OF DRY CURED HAMS FUMIGATED WITH CARBON DIOXIDE

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Dry cured hams are fumigated with methyl bromide to prevent the infestation of ham mites (*Tyrophagus putrescentiae*), ham beetles (*Necrobia rufipes)*, cheese skippers and dermestid beetles (EPA, 2006). Currently, there are at least 22 dry cured ham processing facilities in Kentucky, Missouri, North Carolina, Virginia, Tennessee, and Georgia that fumigate dry cured pork with methyl bromide (Rentfrow *et* al., 2008). Methyl bromide is a broad spectrum pesticide that is the only known fumigant that is effective at eradicating ham mite infestations. However, this fumigant also depletes the stratospheric ozone layer (Marriott and Schilling, 2004) and is classified as a Class 1 ozone depleting substance (EPA, 2007). Minimal research has been reported on the use of methyl bromide alternatives. Alternative fumigants must be evaluated for their efficacy against pests, their economic viability and their effects on the sensory quality and safety of the ham product.

Carbon dioxide (CO_2) treatment of dry cured hams is a potential alternative to methyl bromide fumigation since it does not produce harmful residues, is effective at killing insects at all stages of their life cycles and could be used for long-term storage of products (Ryan *et* al., 2006). If practiced under completely sealed storage, carbon dioxide is very effective at controlling pests of stored products, especially organic commodities that undergo long-term storage. Carbon dioxide has a unique quality to dispense insecticide chemicals and it is an approved organic grain fumigant. Carbon dioxide alone in concentrations greater than 99% can kill ham mites (UNEP Report, 2007).

Dry cured hams that had not previously been exposed to fumigants were obtained and cut into sections (28 cm x 11 cm x 11 cm) that were approximately half the size of a whole ham so that they would fit into commercially available fumigation jars. Three replications of hams were fumigated with CO_2 for 0% (control), 60% for 48 h (low CO_2) and 60% for 96 h (high CO_2). The fumigated hams were then evaluated in triplicate (within each replication) for peak areas of volatile aroma compounds. A randomized complete block design was utilized to evaluate the effects ($p<0.05$) of fumigation concentration on the peak area of volatile aroma compounds. When significant differences occurred among treatments ($p<0.05$), Tukey's mean separation test was utilized to separate treatment means. In addition, orthogonal contrasts were used to determine if differences existed between fumigation treatments and control samples for GC-MS data.

Volatile aroma compounds were tentatively identified using the library search algorithm, NIST02 Mass Spectral Database on the GC-MS and were further substantiated by obtaining odor descriptors from the gas chromatograph-olfactometer/flame ionization detector (GCO-FID). In addition, retention indices (RIs) were calculated and compared to RIs that are reported in literature, and authentic standards were injected to verify the presence of compounds. The aroma active compounds that were present in the ham samples included carbon disulfide, 2-butanone, 3-methylbutanal, hexanal, heptanal, methional, 2,5- dimethyl pyrazine, limonene, benzeneacetaldehyde, 2-methoxy phenol, 2-nonen-1-ol, 4-methyl-2-methoxy phenol, 4-ethyl-2-methoxy phenol and 2,6-dimethoxy phenol. Results revealed that samples had mostly similar odors but that the control sample had more cheesy, green, baked potato, buttery popcorn and cocoa odors and the fumigated sample had more rose like, fresh, clean, floral, roasted meat, savory, smoky and sweet ham odors associated with the volatile aroma impact compounds in the ham.

There were minimal differences in the peak areas of volatile compounds among the different fumigation treatments. In the lipid fraction, there were larger peak areas ($p<0.05$) for 2-methoxy phenol, 4-methyl-2-methoxy phenol and 2,6-dimethoxy phenol in the high CO_2 fumigated samples when compared to control and low fumigation treatments. For the lean muscle fraction, orthogonal contrasts revealed that there were larger peak areas for 2-methoxy phenol, 2,5-dimethyl pyrazine, 4-ethyl-2-methoxy phenol and 2,6-dimethoxy phenol in fumigated samples when compared to the non-fumigated control. Orthogonal contrasts also showed that the peak areas of 4-ethyl-2-methoxy phenol and 2,6-dimethoxy phenol were larger in high CO_2 samples when compared to low CO_2 samples. In addition, there were elevated concentrations of volatile compounds in high fumigation treatment samples when compared to other treatments.

Sensory testing was performed to verify that minimal flavor differences existed between fumigated and non-fumigated hams. Consumers were unable to detect a difference ($p>0.75$) between the high CO_2 fumigated samples and the non-fumigated control samples. Only 18 out of 54 people (33.3 %) chose the correct ham, which is the probability of randomly guessing which ham is different (33.3 %). Since the p-value was so high ($p>0.75$) and three replications of hams were evaluated, there was sufficient evidence to demonstrate that sensory differences did not exist between non-fumigated hams and hams that were fumigated at CO_2 for 96 hours. Even though minor differences in volatile compound peak areas occurred, this study revealed that there were minimal aroma/flavor differences in the different ham treatments based on GC-MS, GCO and sensory analyses.

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