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*Research Article*

# The Potential For Soluble Gas Stabilization (Sgs) Technology In A Simulated Post-Frying Cooling Step Of Commercial Fish Cakes.

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## Abstract

Soluble gas stabilization (SGS) technology is a unique method for improving the effectiveness of modified atmosphere (MA) packaging. However, SGS can be time-consuming and difficult to integrate into an existing process. This can be solved by incorporating CO2 into an existing manufacturing step, such as the product's cooling phase. A full factorial design was created using SGS times (0.5, 1.0, and 2.0 h) and fish cake temperatures (chilled (0 ◦C) or during chilling (beginning at 85 ◦C) as factors. MA-packaged fish cakes were used as a control. The answer was the equilibrium composition of headspace gases. After 0.5 hours, hot fish cakes with equilibrium headspace gas composition had considerably less dissolved CO2 ($p < 0.05$). Compared to cold cakes. However, there were no significant changes between hot and cold at 1.0 and 2.0 hours. Also, regardless of time or temperature, all SGS samples had more CO2 than modified atmosphere packaging (MAP).

**Keywords** : *modified atmosphere; soluble gas stabilization; minced fish; chilling.*

## INTRODUCTION

Soluble gas stabilization (SGS) technology, which consists of a pre-packing step in which carbon dioxide (CO2) is dissolved into the food matrix, has been shown to improve the shelf life of muscle foods [1-5] and the sustainability of modified atmosphere (MA) packaging by increasing the degree of filling (DF) [1,2]. However, appropriate well-designed industrial applications and commercial technology solutions must continue to be made available. One issue raised by the industry is that changes in processing logistics may have an impact on internal product flow, diminishing production efficiency.

Diffusion is a time-consuming process influenced by a number of parameters, including product form [6], headspace CO2 concentration [6,7], chemical composition of the food matrix [8-13], product and surrounding temperature [8,9], and product salt content [7,14-16]. Depending on the criteria indicated, past research has shown that 3-4 days at refrigerated temperatures are required to achieve equilibrium between the product headspace and the food matrix [8,13]. Shorter treatments, such as 1 to 2 hours, can produce a good effect on product quality or the potential to improve DF [12].

One option to incorporate SGS technology into a fish cake processing line without sacrificing production efficiency is to use the existing post-frying cooling step to dissolve CO2 into the food matrix. The product's beginning temperature of 85 C is a practical challenge due to its poor CO2 solubility. The ability to dissolve CO2 efficiently remains due to rapid cooling rates on the product surface and subsequent improved solubility during the first minutes of the cooling process. The current study sought to investigate the feasibility of applying SGS technology in the manufacturing of fish cakes, namely the post-frying cooling stage to dissolve CO2 into the product before MA packing.

## MATERIALS AND METHODS

The current investigation used commercial fish cakes acquired from a Norwegian provider, and the experiment was performed the day after manufacturing. The supplier did not pre-treat the fish cakes with CO2 or other packing solutions, which could have affected the trial results. The fish cakes were made using 51% silver smelt (Argentina silus) and 2% haddock (Melanogrammus aeglefinus), as well as milk (fat 4.5%), water, tapioca starch, rapeseed oil, onion, nutmeg extract, salt (1%), yeast extract, dextrose, and spices. The maker specified the proximate composition as fat (8%, 1.1% saturated fatty acids),

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proteins (11%), carbs (9.2%, 1.3% sugar), and salt (1%), for a total dry matter value of 29.2%.

The experimental setup included 'starting temperature' and 'SGS processing time' as experimental parameters. The fried fish cakes were first heated in a steam cabinet (Convoterm, Elektrogeräte, Eglfing, Germany) to 85 C. Twenty-four of fifty-six samples were immediately treated with SGS (96-97% $CO_2$) while being cooled for 0.5, 1.0, and 2.0 hours, respectively ($n = 8$ for each group).

A TrackSense Pro Double Sensor (Ellab AS, Hillerød, Denmark) was used to log core temperature in four samples from each SGS treatment group during cooling. The remaining 32 samples were chilled to 0 C in plastic bags with wet ice. Then, 24 cold samples were treated with SGS for the same duration as their hot counterparts (0.5, 1.0, and 2.0 h, $n = 8$ for each group), but without the use of dry $CO_2$ as a cooling medium. The final eight samples were held in air prior to packaging (0 h SGS time) and used to imitate a conventional commercial technique and serve as a control group.

Rotabakk et al. [17] proposed a modified approach for performing SGS treatments. Dry ice was employed as a cooling medium for immediately processing cooked fish cakes. The treatment resulted in an average headspace $CO_2$ content of 99.3 ± 0.7%. Following SGS treatment (Figure 1), all samples were repackaged in MA-trays (C2187-F, Fearch Plastics, Holstebro, Denmark; OTR: 66-78 cm3 × 25 μm/m2/24 t/atm at Using a Multivac T200 semiautomatic tray-sealing system (Sepp Haggenmüller SE & Co. KG, Wolfertschwenden, Germany) and a top film (Cryovac® OSF33ZA, Sealed Air Food Care, Charlotte, NC, USA; OTR: 60 cm3/m2/24 t/bar at 23 C and 0% relative humidity) with 99% PET and 1% PE for improved sealing properties.

The packed samples underwent SGS treatment and were stored for 96 hours in a refrigerated chamber at 1.8 ± 0.3 C.

The $CO_2$ solubility in fish cakes as impacted by the experimental conditions was determined as changes in headspace gas composition at the point of packaging ($n = 17$) and at equilibrium ($n = 8$ per group, 56 in total) using a Checkmate 9900 analyzer (PBI Dansensor, Ringsted, Denmark). The sample dry matter (DM) was quantified using ISO.6496 [18].

To compare groups, we utilized one-way ANOVA and Tukey's comparison test. All statistical analyses were carried out using Minitab 19 (Minitab Inc., State College, PA, USA).

## RESULTS AND DISCUSSION

SGS treatment considerably ($p < 0.001$, one-way ANOVA) increased $CO_2$ levels in the tray headspace compared to MAP (Figure 2). The solubility of $CO_2$ in a food matrix is proportional to the concentration of $CO_2$ in the headspace, as defined by Henry's Law [19]. However, this is only applicable when the system is in equilibrium. The headspace $CO_2$ content was therefore measured after 96 hours of storage, presuming that equilibrium had been established [8,12]. Longer SGS processing time resulted in a significant increase in $CO_2$ levels in the headspace ($p < 0.001$, one-way ANOVA).

As the amount of $CO_2$ in the headspace grows, so does the amount of dissolved $CO_2$ in the fish cakes, implying that the fish cakes can dissolve $CO_2$ during cooling. Fish cakes treated with SGS while chilling had considerably lower $CO_2$ concentrations ($p < 0.001$, one-way ANOVA) than those treated hot for 0.5 h, but not for 1.0 or 2.0 h. Henry's constant is affected by a variety of factors, including temperature [20], and $CO_2$ solubility has been shown to increase with decreasing temperature. The warm fish cake had an average core temperature of 71.9 ± 2.3 C at the start of the SGS treatment.

$CO_2$ is a gas that dissolves well in both water and liquid fat in food [8,16]. Furthermore, the solubility of the substance is determined by its total water and fat content. The dry matter in the fish cakes was 29.6 ± 0.1%. There were no significant changes ($p = 0.150$, one-way ANOVA) between the cakes treated warm or cold. The fat content was around 8%, according to the producer. The principal ingredient in the fish cakes, silver smelt mince, was primarily composed of saturated and monounsaturated fatty acids ranging from C14 to C22 [8]. Since the majority of the existing lipids will change their state during cooling, from a liquid form in warm fish cakes to a solid state after cooling,

However, high temperatures significantly reduce the solubility of $CO_2$ [9]. The higher temperature (25.6 C) in the hot SGS-processed fish cakes (0.5 h group) likely contributed to the observed difference between pre-cooled and 0.5 h samples, as the cakes' proximate composition was equal. According to Fick's second rule of diffusion [21], $CO_2$ begins to dissolve on the surface before diffusing into the food matrix, as the surface temperature drops faster than the core temperature of the fish cakes. The cooling of the fish cakes was slow enough in this system to demonstrate a significant difference after 0.5 h (the cold-treated samples had the greatest headspace $CO_2$ content).

However, this effect was negligible with SGS processing times of 1.0 and 2.0 hours. In a commercial setting, cooling will take significantly less time. The present fish cake producer uses a 40-minute cooling process after frying to ensure refrigerated temperatures (<4 C). More efficient cooling for 40 minutes is anticipated to result in an equal $CO_2$ absorbance as precooled fish cakes, as the surface and first millimeters below will decline in temperature more rapidly than reported in the current study's experimental setup.

Increasing the $CO_2$ level in the headspaces from 30.2% (MAP samples) to 34.8% with SGS during cooling (0.5 h SGS time) is likely to alter the product's shelf life. It is widely understood that the concentration of dissolved $CO_2$ in MAP determines its efficiency in preventing microorganism growth [22]. The microbiological and sensory shelf life of chicken breasts was dramatically enhanced by increasing the CO2 content in the headspace from 38.8 to 44.9 [17]. Furthermore, increasing chicken drumsticks from 51.5% to 56.8% resulted in a significant reduction in total aerobic bacteria and Pseudomonas spp. [23].

Rotabakk et al. [17] and Al-Nehlawi et al. [22] employed an SGS processing time of 2.0 h, which is similar to the design of the current experiment. It has also been demonstrated that longer SGS time results in an increase in the amount of dissolved CO2. SGS periods of up to 48 hours have been investigated [24], demonstrating that the dissolving rate of CO2 decreases with increasing SGS processing time used. In other words, by using SGS technology, the maximum amount of CO2 will be dissolved at the start of the process.

This highlights the possibility of increasing the shelf life of fish cakes even after 0.5 or 1.0 h of SGS processing as part of the existing post-frying cooling step in the commercial production of fish cakes.

## CONCLUSION

This trial demonstrates that it is possible to simultaneously chill down and dissolve CO2 into a newly fried product. It shows the possibility of including SGS technology in an already-existing production step without adding extra processing time. This is a big step toward an industrial application. Further work will be focused on scaling up and finding a secure way to maintain health and safety issues working with CO2 in a processing environment.

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