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How to limit cook loss when preparing cod (*Gadus morhua*): The constraints of temperature and time

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A B S T R A C T

It is a common practice to prepare cod by simmering it in salty water (brine), and this is one of the standard methods among chefs and regular consumers. Cod, like seafood in general, is very sensitive to overcooking. This results in cook loss and renders the fish dry and unappealing. Professional chefs have enough expertise to time the cooking process skillfully. On the other hand, the typical modern consumer spends less and less time in the kitchen and needs more familiarity with preparing different types of food. In this study, we aimed to detail how to avoid excessive cook loss while preparing cod. This by framing accurate scientific methodology (measurements of temperature, liquid loss, salt content, and sensorial properties) to a more gastronomical approach. To do so, we used sous vide preparation to assess the effect of preparation time, temperature, and addition of salt. We show that traditional simmering is comparable to sous vide preparation if the temperature in the heating system is comparable. However, lengthy preparations produce excessive cook loss for both kinds of preparation, even when the target temperature is kept low. For meat, long thermal treatments are often used for tenderization purposes. Because most fish, including cod, are easily digestible and sufficiently tender to be served raw, minimizing the cooking time reduces the cook loss without any apparent gastronomical penalty. Our results show that adding salt further limits the cook loss during preparation, especially if salt is added before preparation. This effect is noteworthy for cod, and adding salt before cooking might be a routine useful for chefs and consumers alike. Any professional chef of course welcomes an overall reduction of cook loss that raises the gastronomic level. Regular consumers might appreciate less focus on perfect timing for a satisfactory meal.

1. Introduction

Two major trends are currently seen in Western European food culture; (1) an increased focus on health and diet (Anon, 2015; Bacopoulou et al., 2017; Di Daniele et al., 2017; Wolk, 2017) and (2) a decrease in cooking skills (Cutler et al., 2003; Jaffe and Gertler, 2006; Slater, 2013; Øvrebø, 2011). Since modern consumers also spend less time preparing meals (Harding, 2014; Monsivais et al., 2014; Smith et al., 2013), a need for convenient fish products has emerged (Anon, 2015). Despite advice to eat more fish for health reasons, today's consumers are increasingly unwilling to deal with traditional handling of fish, such as gutting, trimming, and removing bones (Candel, 2001; Olsen et al., 2007). Consequently, there is a rising demand for gutted fish pre-packed and trimmed for skin and bones. The "easy to handle" aspect is attractive to the consumer, and products that fulfill this requirement are "easy to sell". Easy-to-handle products usually have high quality and improved shelf life and come in convenient-sized portions (Altintzoglou and Heide, 2016).

From a food safety point of view, fish preparation (cooking) requires a minimum thermal load to kill bacteria effectively. However, excessive thermal load (i.e., too long, too hot, or both) often comes with a culinary penalty. Fish overcooks easily, resulting in a pronounced cook loss and ensuing dry and tough texture. The thermal load is proportional to the collective contribution from several factors, such as; time, temperature, kind of medium (air, water, fat), packaging, and size/geometry. In scientific literature, the term *thermal load* typically refers to the food safety aspects of preparation. According to the North American authorities, fish is adequately cooked when it is subjected to 63 °C for at least 15 s (FDA, 2009). When food safety is not an issue, the cooking conditions are typically optimized in relation to sensory attributes. For most consumers, the minimum cooking temperature is the point at which muscle protein (and blood) denatures - in cookbooks often referred to as the "flaking" temperature (Lauer, 2004; Rombauer et al., 1997).

Most people can recognize and appreciate a well-prepared fish meal, but many people find it more challenging to prepare fish than meat. A sense of incompetence may originate from the narrow "window" of optimal preparation time for fish, and cooking skills founded on meat preparation might lead to a high risk of overcooking. Undercooking is, as previously mentioned, unacceptable due to health risks but also undesirable from a culinary point of view. Optimizing the timing can be done using more defined product sizes and improved control of the thermal load. The increasing popularity of sous vide cooking equipment, also for

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home cooking, offers handy control of the thermal load. Sous vide is a technique that involves cooking the food in temperature-regulated water bath. The preparation temperature is usually lower during sous vide preparation compared to conventional preparation, and the water bath temperature is typically set at the food's optimal internal preparation temperature. Even during long preparations, the temperature never exceeds the optimal temperature, and sous vide preparation is often referred to as LTLT (low-temperature long-time)-cooking. Another important aspect of sous vide that the food is vacuum-packed in plastic pouches to retain aroma and juices that otherwise might be lost during preparation. Another useful method can be the addition of salt. Most fish meals are seasoned with salt. Salt can be added during industrial processing steps, during meal preparation, or at the table. In addition to its culinary function as a taste enhancer, salt also has a physical function in that it affects the water-holding capacity of the fish muscle and thus influences its succulence and texture. Since sous-vide is a technique that normally uses vacuum-packed products, no salt can be added during preparation. Therefore, salt must be added before packaging to utilize the practical benefit of salt during preparation.

This work aims to investigate how the quality of a traditionally well-prepared cod meal can be enhanced in a more controlled manner through the preparation of vacuum-packed cod loin portions. We investigated how basic preparation parameters such as the temperature of the medium, temperature in the product, preparation time, and the addition of salt influence the cook loss of vacuum-packed cod loin portions (sous vide style). By doing so, we highlight how to minimize cook loss while preparing cod. To that end, we have consolidated scientific tools with a practical approach to uncover pitfalls and underscore best practices when preparing lean whitefish such as cod.

2. Materials and methods

2.1. Raw material and sample preparation

Raw material: Atlantic cod was killed by a blow to the head and gutted prior to storage on ice (4 days). After filleting sample cylinders were stamped from the back loin of the filet using a cork borer (Ø = 50 mm, H = 30 mm). The traditionally simmered samples were prepared directly after stamping, described in more detail in section 2.2. In contrast, for the sous vide experiment, the samples were vacuum-packed (99%) in sous vide plastic pouches (20 μm polyamide inside layer and 70 μm polyethylene outside layer, O_2 permeability: 45 $cm^3/(m^2\ d\ bar)^{-1}$). All samples were kept on ice (<1 h) before heat processing and cold storage at 4 °C.

2.2. Traditional simmering

The way the samples were simmered in this work is based on the preparation method of the Norwegian chef, Ørjan Johannessen, winner of Bocuse D'Or 2015. He prepares cod by letting the cod cutlets simmer for 10 min in a brine (6% NaCl) solution brought to boiling point. The casserole with the brine is removed from the hot plate immediately after the fish is immersed. We did an equivalent preparation on geometric cod samples mounted with thermocouples in the center to document the core temperature profile during brine simmering. Sample cylinders of cod were placed in boiling water (3 L, 6% salt), and the casserole was removed from the heat source and left simmering for 10 min (with a lid). Then the fish samples were removed and left resting at room temperature.

2.3. Vacuum-packed thermal processing

In traditional cod preparation, simmering fillets in 6% brine results in an adequate salt uptake. A 10 min brining in salt solution (10% NaCl) was performed before vacuum packaging. A 10 min pre-salting, often dry salt on fish, is commonly described as a quick salt treatment prior to preparation. To minimize dehydration during this process a brining solution was chosen instead of dry salt. A 10% NaCl solution produced an adequate salt content for samples that were to undergo sous vide heat treatment. A thermocouple wire was placed in the center of the cylindrical samples to monitor the temperature. The very thin thermocouple wire was positioned in the sample through a syringe needle placed in the center of the sample (Fig. 1). The fish sample with the thermocouple was placed in a plastic bag and vacuum-packed. This could be done since the very thin (Ø = 0.3 mm) thermocouple wire did not disrupt the plastic bag seal. Heating of the vacuum-packed samples was carried out by placing the samples in a temperature-controlled water bath with circulation to ensure good heat distribution. Heating was done at 70 °C, 85 °C, and 95 °C in temperature-controlled water baths. The lowest temperature (70 °C) was used to investigate whether a relatively low temperature effectively reduces cook loss in pre-salted samples. In both 85 °C and 95 °C water baths, samples were heated to a core temperature of 55 °C and 82 °C. For both core- and water bath temperatures, pre-salted and unsalted samples were used. An additional cook loss experiment at 95 °C was done with pre-salted samples over an hour, measuring cook loss after 2.5, 5, 7.5, 10, 15, 20, 25, 30, 40, 45 and 60 min (n = 5 each sampling). After processing, the samples were immediately cooled in iced water for 30 min prior to refrigerated storage (4 °C).

2.4. Cook loss

Cook comprises the fish products' weight- and nutrition-loss (water-soluble proteins, amino acids, minerals, etc.). The amount of cook loss is also associated with product quality, and consumers tend to take high cook loss during meal preparation as an indication of poor quality. The vacuum-packed samples containing fish muscle and expelled cook loss were opened after heat processing, and the cook loss (CL, %) was determined gravimetrically according to the formula:

$$CL = \frac{m_0 - m_L}{m_0} \times 100\ \%$$

where m_0 is the initial weight of the loin piece sample, and m_L is the weight of the sample after packaging and heat processing.

2.5. Salt-content

The salt content was measured for three groups; simmered to 55 °C, sous vide to 55 °C, and fresh (untreated) control. The whole sample was homogenized before analysis, and all sample other than the control was homogenized after preparation. The salt content was determined using a modified potentiometric titration method (ISO, 2006). Homogenized samples (1 g) were diluted with deionized water (50 ml, heated to 55 °C) and left for 1 h. The sample was then titrated in an automated titration unit consisting of a T70 Titrator with one burette for nitric acid and one for silver nitrate, an In Motion Sample Changer, a DM141-SC Combined

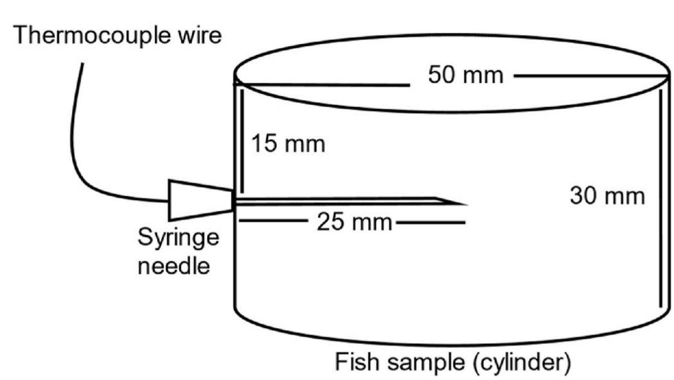

Fig. 1. The temperature log setup. A thermocouple wire is mounted through a syringe needle placed in the core of the fish sample.

silver ring electrode and a DGi115-SC pH electrode (all components by Mettler Toledo, USA). The NaCl content was determined from the analyzed Cl-content.

2.6. Sensory analysis

For the sensory analysis, two groups were compared: traditional simmering (to 55 °C core temperature) vs sous vide preparation to 55 °C core temperature using a 95 °C water bath. Samples were salted before (sous vide method) or during (simmering method) preparation. Since the core temperature was identical, the main difference between the two groups was how salting was done (before or during preparation). The treatment time was comparable (8.8 min sous vide vs 10.0 min traditional simmering), and the salt content of the samples was measured after preparation as described in section 2.5.

Cod samples were subjected to sensory analysis after heat processing using Quantitative Descriptive Analysis (QDA®) (Stone and Sidel, 2004). Eight attributes were defined and described for cooked cod fillets: freshness odour, protein precipitation, colour, flaking, freshness taste, salty taste, juiciness, and stickiness. The attributes were modified from the Torry freshness score sheet (Shewan et al., 1953) using a structured 9-point scale from 1 (low intensity) to 9 (high intensity).

The QDA was carried out by five panelists who were trained according to ISO 8586 (ISO, 2012) and familiar with the QDA method and sensory analysis of cod. The samples presented to the sensory panel were prepared as described in the experiment, coded with a three-digit number and presented to the panel immediately after preparation. Each panelist evaluated triplicates of each sample in random order during two sessions including a "warm-up" sample.

A computerized system, EyeQuestion Software version 3.5 (Logic8 BV, Wageningen, the Netherlands), was used by the panelists' for collecting data. Average score of attributes were calculated. The data was further analyzed using an ANOVA oneway (ANOVA, MINITAB® Version 15, Minitab Ltd., Brandon Court, Coventry, UK) with confidence level 95%.

3. Results

3.1. Thermal control: traditional simmering vs vacuum-packed stable temperature processing

For fish samples prepared in the traditional manner (simmering in brine), the temperature of the hot brine decreased from 100 to 80 °C during the 10 min preparation period. The temperature decrease largely depends on the mass ratio of fish and brine solution, the temperature of the fish, and the ambient temperature (convectional energy loss). A lid was used to reduce the loss of heat from the casserole. Because the brine temperature is critical for such a short heat treatment, measures to control or monitor this temperature are imperative. In our experiment, we had brine solution in excessive amounts (3.00 kg) compared to the mass of the fish (0.06 kg), which stabilizes the brine's temperature.

For the vacuum-packed samples heated in water baths at 85 °C (n = 5) and 95 °C (n = 5), the core temperature progress is shown in Fig. 3. For treatment at 85 °C and 95 °C, the core temperature reached 55 °C, the same core temperature as the simmering method, after 8.8 min and 9.3 min, respectively. Timewise, both treatments reached the target temperature faster than traditional simmering (10 min) despite the insulating plastic layer of the packaged samples.

3.2. Salt content

The salt and dry matter content of the raw, simmered, and vacuum-packed samples are shown in Table 1.

The results indicate that the salt content is higher in samples exposed to the simmering in brine heat treatment than samples marinated in brine prior to sous vide heat treatment.

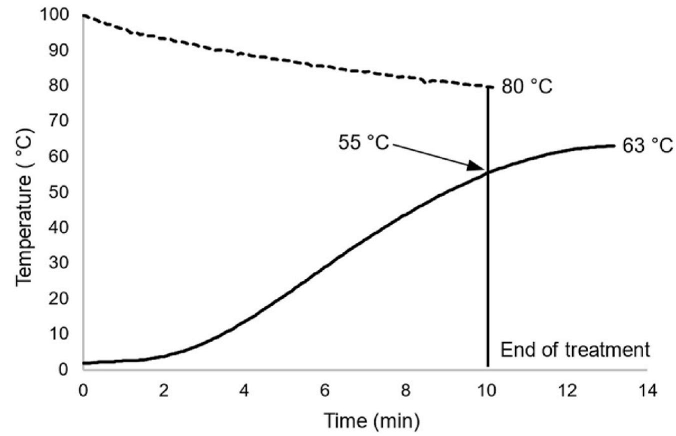

Fig. 2. Temperature in brine and sample-core during dynamic heating for 10 min. Solid line: sample core temperature (3 replicates), dashed line: brine temperature.

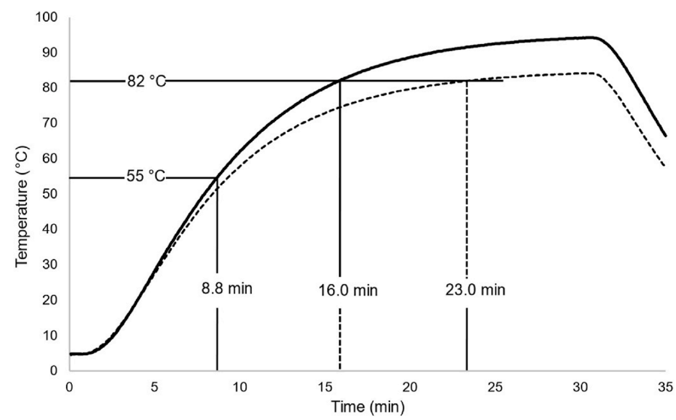

Fig. 3. Cod samples core temperature during static heat treatment (30 min) in water baths at 95 °C (solid line) and 85 °C (dashed line).

Table 1
Salt and dry matter content of samples (n = 3).

Sample	Salt (%)	Dry matter (%)
Raw	0.18 ± 0.03	17.77 ± 0.44
Simmered (55 °C)	1.24 ± 0.23	22.33 ± 0.49
Sous vide (55 °C)	0.88 ± 0.11	19.38 ± 0.71

3.3. Sensory evaluation

Sensory evaluation was carried out to describe the effects of the heat treatments. Through key sensory attributes, a sensory analysis can ascertain differences between cod prepared traditionally simmered in brine and sous vide prepared pre-salted cod. The results show no significant sensory difference between the two preparation methods, and this was the case for all the included attributes (Fig. 4).

3.4. Cook loss – effect of temperature, time and salt

The impact of core temperature on cook loss was investigated by heat treating both salted and unsalted vacuum-packaged samples. A relatively high water bath temperature (95 °C) was used to reach sample core temperatures of 55 °C and 82 °C (Fig. 5). There is a significant increase in cook loss for unsalted samples when the core temperature is raised from 55 °C to 82 °C. Adding salt (0,88% NaCl) prior to heat treatment in vacuum-packed samples significantly reduced the cook

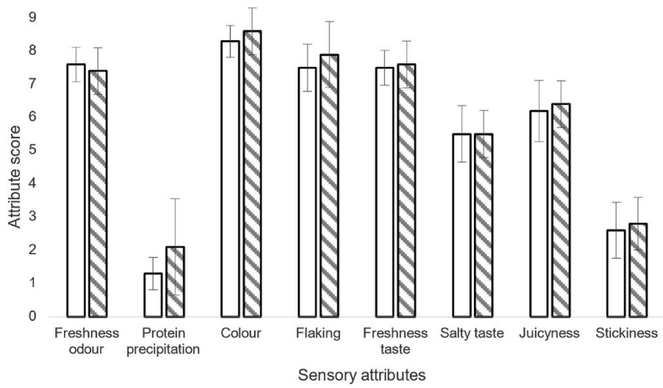

Fig. 4. Sensory attributes used to evaluate samples of cod prepared through traditional simmering in brine heat treatment (blank bars) and pre-salted and vacuum-packed samples undergoing sous vide heat treatment (lined bars).

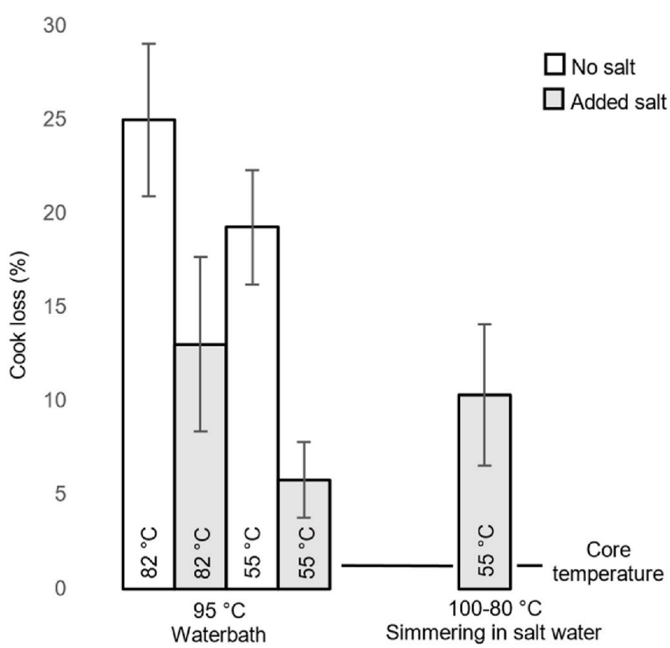

Fig. 5. Cook loss in fish undergoing traditional heat treatment in simmering brine (un-packaged samples) and salted and un-salted samples in a 95 °C water bath (vacuum packed).

loss. This effect is evident both at low (55 °C) and high (82 °C) core temperatures (Fig. 5). The simmered (traditionally prepared) samples heated to a core temperature of 55 °C showed a significantly higher cook loss than the pre-salted vacuum-packed samples heated to 55 °C ($p < 0.034$, unpaired *t*-test).

Our findings show that temperature and treatment time affect cook loss strongly. Tests conducted at a lower temperature (70 °C, Fig. 6) further suggest treatment time is essential even when the temperature is moderate. Samples kept at a core temperature below 70 °C showed more than 25% cook loss after 45 min heat treatment.

A time series study of pre-salted and vacuum-packed samples at 95 °C was done to illustrate the effect of treatment time where conditions presumably are better. Better conditions in this context mean salting prior to heat treatment and a high heat treatment temperature to increase the target core temperature faster. The cook loss was recorded between 2.5 and 60 min; the results are shown in Fig. 7.

During the first 20 min, the cook loss plotted against preparation time forms a straight line, indicating that cook loss increases over time in a linear fashion (Fig. 7). Here the cook loss increases by 1% for every

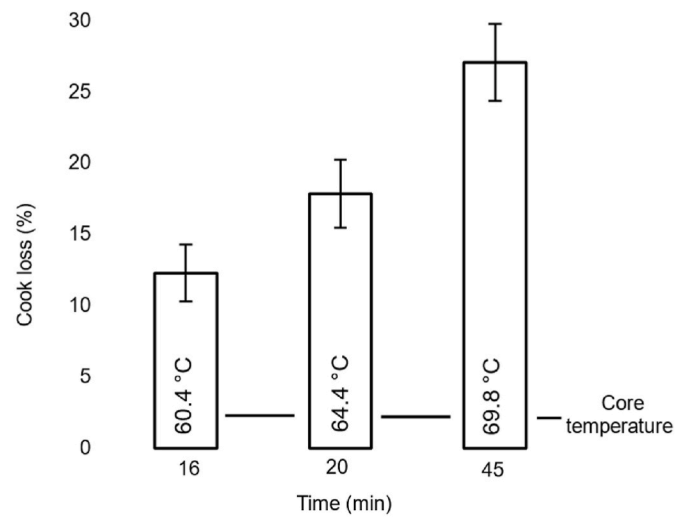

Fig. 6. Cook loss of vacuum packaged cod heat treated for 16,20 and 45 min in a 70 °C water bath.

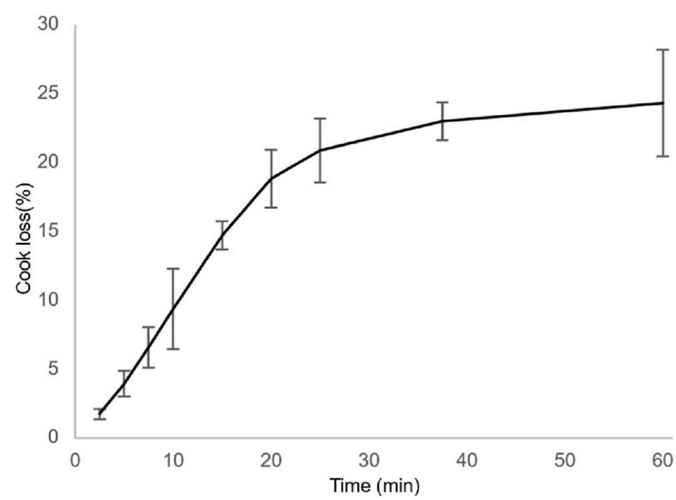

Fig. 7. Cook loss in vacuum-packed, salted samples heat treated for t = 2.5, 5, 7.5, 10, 15, 20, 25, 30, 40, 45, and 60 min (n = 5 for each sampling temperature) at 95 °C (circulating water bath).

additional minute of heat treatment. After 20 min heat treatment, the cook loss levels off and stabilizes at approximately 25% cook loss after 60 min of heat processing. Since the salt pre-treatment consisted of a 10-min immersion in 10% NaCl, and a subsequent 10-min heat treatment would result in an approximate cook loss of 10%, a convenient rule of thumb emerges: a 10 min immersion in 10% brine before cooking will result in 10% cook loss after 10 min of heat treatment.

4. Discussion

4.1. Thermal control: traditional simmering vs. vacuum-packed stable temperature processing

For the traditional simmering method, the core temperature of the cod was 55 °C after a 10 min simmering period. (Fig. 2). From a culinary point of view, it is debatable whether 55 °C is the optimal core temperature for cod. But it can serve as a compromise when you want to minimize cook loss and attend to food safety simultaneously. After the samples were removed from the brine, the temperature increased for an additional 8 °C resting at room temperature. Thus, a post-treatment temperature increase will occur for short heat treatments, especially when there is a significant temperature difference (ΔT) between the target core temperature and the heating medium.

Sous vide heating at both 85 and 95 °C reached 55 °C core temperature faster than the traditional simmering method. The water circulation probably accounts for a more effective heat exchange. Using 85 °C water temperature only slightly delayed (0.5 min) the time to reach a core temperature of 55 °C compared to using 95 °C. The slight difference in treatment time between 95 and 85 °C reflects the large, and at this stage, comparable ΔT between the target core temperature and heating medium at this stage ($\Delta T_{95} = 40$ °C, $\Delta T_{85} = 30$ °C). When targeting a higher core temperature (82 °C) the relative difference of the ΔT is much more significant ($\Delta T_{95} = 13$ °C, $\Delta T_{85} = 3$ °C). Consequently, the time to reach the target temperature was significantly different, too (Fig. 3). Of course, reaching a core temperature of 82 °C leads to overcooking and corresponds to a temperature region where all protein groups denature and gradually lose water-holding capacity (Skipnes, van der Plancken, Van Loey and Hendrickx, 2008). Still, this is a realistic result for an unskilled cook when the treatment temperature is high and the timing is low. Therefore, targeting core temperatures exceedingly below the treatment medium (water bath) temperature requires precise timing. Targeting the core temperature closer to the medium temperature reduces the need for accuracy. The preparation of vacuum-packed food at constant temperature is often referred to as *sous vide* preparation, and here the process temperature is typically set close to the target temperature. In this way, the core temperature never exceeds this target. Fish that were sous vide prepared cod at 70 °C reached a core temperature of 65 °C after 21 min (Fig. 6). Even after 45 min, the temperature was still below 69 °C. So, if a specific core temperature is the principal goal and temperature monitoring is inconvenient, the sous vide approach offers a practical solution for controlling the temperature. In this study, the water bath temperature was for the most part much higher than what would be considered an optimal temperature for cod muscle. Therefore, the applicability of our results is somewhat limited compared to what is considered standard sous vide conditions. We did, however, go to temperatures lower than 70 °C, but this produced very long treatment times and consequently very high cook loss (data not shown).

4.2. Salt content

Both the pre-salted (vacuum packed) samples and samples salted during the simmering process experience an approximately 10 min exposure to brine. But the sous vide samples had lower salt content (Table 1) despite a higher salt content of the pre-treatment brine (10%) compared to the simmering brine (6%). The pre-salting of the sous vide samples was done at refrigerated temperature. At high temperatures, like for the simmering treatment, the diffusion rate of the salt increases as the brine viscosity decreases, so both higher diffusion rate and lower brine viscosity leads to higher salt uptake at higher temperatures (Chiralt et al., 2001). Changes in fish tissue microstructure during high-temperature treatment, such as denaturation of connective tissues, may also contribute to increasing the porosity of the muscle and in this way enhance the salt penetration. The dry matter content is higher for the simmered samples than the vacuum-packaged sous vide samples. Much more so than what the higher salt level account for. The cause of this is most likely the increased cook loss of the simmering compared to sous vide heat treatment, in which the core temperature of the fish samples were raised to 55 °C (Fig. 5). In this study, we only compared samples with and without added salt. We tried to keep the salt level within the realm of gastronomical acceptance, but a broader range of salt content would probably shed more light on salt's impact when preparing cod through simmering or packed in plastic pouches.

4.3. Sensory evaluation

Despite the lack of difference between the two preparation regimes, the sensory evaluation still displays the characteristics of a well-prepared fish sample. While statistically non-significant, some differences observed in the sensory evaluation indicate fundamental distinctions between the two ways of preparing fish. For instance, more pronounced protein precipitation was observed in the vacuum-packed sous vide treated samples. This is a well-known phenomenon. Although the high salt content (10%) in the preceding brine treatment will dissolve some salt-soluble proteins from the sample's surface and rinse them off before packing, this reduction will be far from complete. As the simmering treatment leaves all the protein precipitate floating in the brine after the fish samples have been removed, the sous vide treated fish samples will trap the protein precipitate that did not rinse off before packaging and hence, appear to produce more pronounced precipitation.

Adding salt is essential from a gastronomical point of view. Previous sensory analysis of cod has shown that salt, beyond its influence on taste attributes, also softens the texture of the muscle (Esaiassen et al., 2004). This is linked to how increased levels of salt increase water retention, which is further discussed in the next section. It is, however, important to keep in mind the unhealthy aspect of excessive use of salt which can be linked to raised blood pressure and in turn cardiovascular disease (He and MacGregor, 2009). Chemical analysis revealed a slightly higher salt content in the simmered samples than in the pre-salted sous vide treated ones. Still, this difference was not significant in the sensory analysis. In traditional preparation (simmering), some variation in salt content will occur due to the geometric variation of the fish pieces, as small/thin pieces will absorb more salt relative to bigger ones. However, as our trained sensory panelists could not detect the chemically observable variations in salt content, it seems reasonable to believe that some variation in salt level is acceptable. Even to consumers who, in general, react negatively to variations in food products (Schifferstein et al., 1999).

4.4. Cook loss – effect of temperature, time, and salt

To test salt's effect, we aimed at two different core temperatures (55 and 82 °C). A mathematical model of heat and mass transport during the cooking of cod shows that WHC (water holding capacity) is reduced at temperatures as low as 20 °C (Blikra et al., 2019). An updated model shows a rapid increase of liquid loss in the temperature region of 50–75 °C, and a subsequent plateau at temperatures above 80 °C (Blikra et al., 2020). When adding the post-treatment temperature increase (8 °C) on top of 55 °C, a final temperature of approximately 63 °C was reached. Many chefs prefer a lower temperature than a final temperature of 63 °C, especially if quality and freshness are high. A lower temperature will decrease cook loss and consequently increase juiciness and bring about a softer texture. The lowest temperature in this study was limited to what general food safety aspects allow. Thus, from a gastronomical point of view, cook loss could have been further reduced by aiming for an even lower temperature than we did. Adding other measures prior to preparation, such as deep freezing, would increase the food safety aspect. However, we chose not to add freezing as a variable in this study.

For unsalted (vacuum-packed) samples both core temperatures displayed extensive cook loss. The explanation for the rapid onset of cook loss is that muscle protein denaturation leads to muscle shrinkage. This creates a water pressure, which leads to loss of liquid. This pressure is influenced both by the temperature gradient and the thermal expansion of water and gases in the fish muscle. Kong et al. (2007) observed a correlation between shrinkage and liquid loss for salmon, which can also be expected to exist for cod. The lack of salt during preparation is the likely cause of the large cook loss. For cod, water retention is dependent on the salt concentration (Johnsen et al., 2009). This becomes evident when comparing the vacuum-packed samples treated to 55 °C with the traditionally prepared samples simmered (in a salty brine) to a similar core temperature. In the latter, salt was added during the preparation process, which seems to reduce the cook loss by almost 50% compared to unsalted vacuum-packed samples. However, adding salt prior to heat treatment is an even more efficient way to decrease cook loss when aiming for a core temperature of 55 °C. While it is not surprising that adding salt limits the cook loss, we show that even a moderate addition of salt within the gastronomical acceptance level effectively reduces cook loss even at high core temperatures. The advantageous effect of pre-salting samples is explained by salt penetrating the sample more extensively prior to heat treatment. In the traditional simmering method, salt diffusion into the sample begins simultaneously with the heat treatment and the early onset of cook loss. The flow of liquid out of the sample (cook loss) will hamper salt diffusion into the sample, especially at the early stage. By contrast, the vacuum packaging is a barrier keeping the salt inside the sample while shielding it from the turbulent and laminar flow of simmering water. Hence, the reduction of cook loss for the pre-salted and vacuum-packaged samples might be a combined effect of physical protection and a higher salt concentration in the early stages of preparation.

To understand how a moderate temperature influences cook loss over time, cook loss was monitored for unsalted vacuum-packaged samples treated in a water bath at 70 °C (Fig. 6). Even if water holding capacity for cod muscle drops gradually at temperatures higher than 40 °C, by keeping the target temperature well below 80 °C should prevent the denaturation of some protein groups (Skipnes et al., 2008). Still, a clear correlation between treatment time and cook loss was observed, reflecting loss of WHC according to the denaturing rate of major protein groups (Skipnes et al., 2011). This indicates that cod muscle is very sensitive to lengthy heat exposures. Consequently, long treatment times will induce, even at moderate temperatures, extensive cook loss for cod.

The four times 10 rule proposed earlier is practical and shares many characteristics of a traditional cod preparation simmered to perfection. This rule meets strict culinary requirements concerning cook loss and salt level and is easy to remember. The timing aspect can be adjusted finely to limit further cook loss – possibly an endeavor mainly relevant to professional chefs. Although the rule is applicable for 3 cm thick sous vide samples in rather hot water (95 °C), it will most likely apply for geometrical sizes within a tolerable variation including most cod backloin cuts. Even if heat treatments were performed at various temperature regimes (from 70 °C to 95 °C), the time aspect seems to impact the cook loss to a greater degree than the temperature of the water bath (medium). Consequently, regarding fish, the sous vide method must be used cautiously concerning treatment time. Some sous vide strategies target temperature more accurately than preparation time. This is handy when preparing food, but our results show that cod is very sensitive to preparation time and that prolonged preparation time ultimately leads to a gastronomical penalty. This is in contrast to some meat products that can be left for hours at the target temperature (Baldwin, 2012), whereas in the case of fish, the optimum heat treatment time seems to be rather narrow. Because of the undesirable attributes of overcooking, any means to avoid this is very helpful from a culinary perspective. Minimizing the thermal load is a rational approach, especially since temperature to a little degree improves the tenderness of fish muscle. Fortunately, as described earlier, cook loss is minimized by adding salt. Adding salt as early as possible, but keeping it satisfactorily low from a sensorial point of view, significantly reduces cook loss. Still, adding salt is, as shown here, not sufficient to prevent extensive cook loss if the core temperature is too high or the processing time too long. Salt may have an overall effect during heat treatment, but cod muscle seems to be very sensitive to heat treatments.

5. Conclusions

Several approaches were tested to mimic the attributes of a skillfully simmered cod fillet to a pre-packaged product intended for sous-vide preparation. To achieve this, we studied how cod muscle is affected by temperature, treatment time, and the addition of salt during preparation. There are many ways to prepare cod besides sous vide and traditional simmering, and the results herein are somewhat limited to the temperatures used and the chosen methods. Other methods may produce similar or even better results. We, however, have chosen to focus on the more general aspects of preparing cod. For that purpose, the sous vide method is a practical way to minimize the variations during experiments. Also, by linking sous vide to a more standard preparation method (simmering), we tried to bridge the gap between the scientific and gastronomical point of view. We found that if cook loss is not extensive, the sensory profile is similar in a high-quality traditional preparation (simmering in brine) and fish heated in the packaging (sous vide style). Sous vide style cooking often targets a specific temperature and focuses more on the end temperature than the time aspect of cooking. Our results clearly illustrate that treatment time is very critical when preparing cod. Long treatment time, almost independent of temperature regime, is synonymous with unduly high cook loss. Salt, on the other hand, is a functional additive to limit cook loss during preparation. This property is known among professionals, and we show that adding salt before rather than during the preparation reduces the cook loss to a surprising degree. Adding salt prior to preparation might be the easiest and best way to enhance the quality when preparing cod. Coupled with perfect timing, this routine might be crucial for preparing the perfect cod dish. Luckily, adding salt is a handy trick casual consumers may take advantage of to elevate the quality of their fish meal. Hopefully, this may encourage hesitant home cooks to increase the amount of fish in their diet.

Implication for gastronomy

The proportion of consumers preparing fish at home is declining, and a contributing factor is that fish is susceptible to overcooking. This work highlights how to minimize cook loss while preparing cod. This moves professional chefs closer to the perfect cod meal and lowers the bar for regular consumers to prepare fish at home. To understand how to minimize cook loss, we studied how cod muscle is affected by temperature, treatment time, and the addition of salt during preparation. We show that long treatment time, almost independent of temperature regime, is virtually synonymous with unduly high cook loss. This means that the typical sous vide style preparation, where a long treatment time is combined with a set temperature, is not the most practical approach. On the other hand, adding salt before preparation provides an effective measure to reduce cook loss. In this way, the overall reduction of cook loss raises the gastronomic level when preparing cod. This might be relevant to professional chefs for the most part, but a more forgiving preparation regime might be highly welcomed also at the consumer level.

Declaration of competing interest

The authors have no conflicts of interest to declare. All co-authors have seen and agree with the contents of the manuscript and there is no financial interest to report. We certify that the submission is original work and is not under review at any other publication.

Data availability

Data will be made available on request.

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