Sous vide: A revolution in industrial cooking

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SUMMARY

Meat tenderness is one of the most important organoleptic properties for the acceptance of fresh meat by the consumer and significantly influences purchasing decisions. This article studies the influence of different temperatures and cooking times on several types of meat, using the *sous vide* cooking technique on an industrial and automated cooking and cooling line. Depending on the origin species of the animal and the end market, the sensory characteristics of toughness and juiciness determine the acceptability of the product by the consumer. For this reason, it is necessary to study each type of cut to obtain the desired characteristics. The results demonstrate that with different time and temperature combinations, different sensory qualities of toughness and juiciness are obtained. To obtain a suitable product that meets consumer demands, a precise, highly reliable, time- and temperature-controlled cooking system is needed to record the entire process to provide good traceability and repeatability.

INTRODUCTION

Sous vide ("under vacuum") cooking is a type of cooking that has revolutionised the world of industrial gastronomy and signature cuisine in recent years. This cooking consists of vacuum-sealing a food and cooking it at controlled temperatures for set times. This control allows the processes to be standardised, selecting between different textures, improving storage, and the organoleptic characteristics of the product (Ruiz, 2010). It also offers a series of advantages to business entities because it facilitates the management and handling of products (Terlizzi, Perdue, & Young, 1984).

"Vacuum" cooking has been applied to the majority of industrial meat products for many years, especially in lines for cooked hams, bologna, etc. (Rosinski, Barmore, Dick, & Acton, 1990; Terlizzi et al., 1984). In 1970 Laakkonen, Wellington, & Sherbon had already published an article demonstrating the relationship between tenderness and slow cooking at low temperature. Many famous chefs began using this technique, but it was not until the start of the 2000s that it was popularised or industrialised for catering products and prepared meals (Ready-to-eat).

The primary advantage highlighted by this type of cooking is the variety of textures that can be obtained, and the majority of chefs that offer *sous vide* dishes emphasise the tenderness they can achieve with this technique (Roca & Brugués, 2003). In addition to texture, juiciness and chewiness have made this form of cooking meats, fish, seafood, and almost any type of vegetable, appealing for restaurants and industrial kitchens. The vacuum-cooked product retains all the flavour and juiciness because it cooks in its own juices.

From a food safety standpoint, it offers major advantages because it eliminates the risk of re-contamination after cooking, as it has been demonstrated by many published studies (Díaz, Nieto, Garrido, & Bañón, 2008; Hansen, Knøchel, Juncher, & Bertelsen, 1995; Nyati, 2000). The product remains sealed until its time of use, also avoiding losses due to evaporation.

Cooking, Texture, and Colour

Meat texture depends on many factors, some of which are directly related to the cooking process. When cooking, we use heat to denature proteins and dissolve collagen. The majority of sarcoplasm proteins denature between 40 and 60°C, and myosin loses its secondary structure between 55 and 60°C and actin tends to resist up to 80°C (Ruiz, 2010).

A large part of the tenderising of meat comes from the concentration and solubility of collagen, the connective tissue that surrounds muscular fibres, which become a gelatinous structure that comes undone in the mouth. These changes occur from about 60-65°C depending on the speed of cooking (Ruiz, 2010).

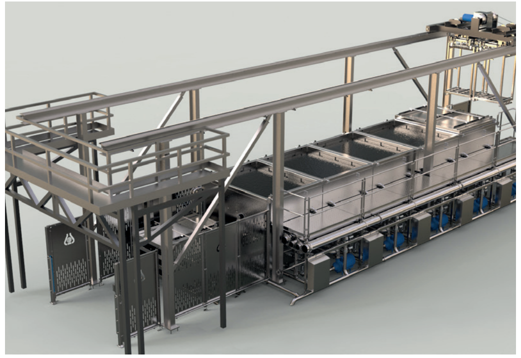
On the other hand, the increase in temperature causes a retraction in myofibrillar proteins, reducing the water holding capacity of the muscle. The primary loss is due to longitudinal retraction of the fibres and occurs above 60-65°C, growing nearly linearly up to 80°C. The greater the loss of water, the less juicy the meat (Martens, Stabursvik, & Martens, 1982).

Meat colour also depends on the speed to obtain a set temperature and the time it remains there. The greater the speed, the redder the colour. The longer the time at the same temperature, the more the colour tends to turn pale (Baldwin, 2012).

As we can see, the temperature affects toughness in two different ways, due to solubility of the collagen and loss of water. The *sous vide* technique has allowed the study of cooking temperatures far below traditional ones, for example, cooking at between 56-65°C for meat, and lower for fish. The lack of temperature is compensated with longer cooking times (from 3 to 24 hours, depending on muscles and measurements), and allows a greater variety of textures to be obtained depending on the desired product. On the other hand, there are certain microbiological risks at such low temperatures, so this risk must be evaluated in each case. It is therefore important to respect the recommended temperatures and times to obtain suitable bacterial reduction. However, it is not just cooking parameters that must be defined. Parameters for cooling, which must occur immediately after cooking, must also be established. Some authors suggest that the temperature should be below 3°C within the 2-3 hours after cooking (McIntyre, Jorgenson, & Ritson, 2017).

Working under such narrow temperature margins, precision and reliability of the cooking equipment, and process control is needed to obtain results that can be standardised. Church & Parsons (1993) suggested the use of water as a cooking method to ensure the uniformity of thermal treatment and subsequent cooling. On the other hand, the use of steam can lead to wide variations in temperature in this type of process due to the lower capacity of distribution for steam, jeopardising the standardisation of products.

From an industrial standpoint, process control and having an exhaustive automated log of all the operations to which foods have been subjected is important. These data allow statistics to be generated, to facilitate decision-making, and offer product traceability. There is the possibility of integrating this log into corporate platforms, leading the *sous vide* cooking method (and cooling) directly to 4.0 industry.



▲ **Figure 1:** Cookline 4.0 (Metalquimia) automated cooking and cooling system.

TESTS

Taking into account these trends, it was decided to perform trials with different types of meat to experiment with *sous vide* cooking at different times/temperatures in a water immersion cooking system. For this, the Cookline 4.0 (Metalquimia S.A.U.) system was used, an automated cooking/cooling system with continuous water circulation during the process and cooking/cooling recycling to external reservoirs, where it is stored for subsequent reuse.

The process is software-controlled, with programmable cycles for each type of product and records of all operations performed, which allows full product traceability.

Packaging

The meat pieces were vacuum-sealed (98%) in shrink bags (Prolan MO V 64 HGB 3 XL). To eliminate variables, the weight and size of the products was uniform for each type of meat. The different pieces were placed in special baskets with sufficient space for the water to circulate between them and thus achieve uniform cooking.

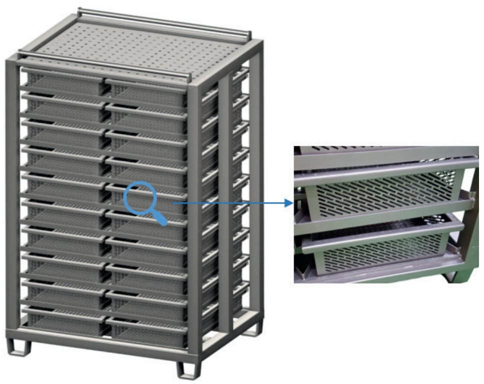
Cooking/Cooling

For the tests, a Metalquimia Cookline 4.0 cooking/cooling line was used, adapted for *sous vide* cooking processes. Once the product was placed in the boiler, hot water from the external reservoir was added and was adjusted to the programmed temperature. The different probes installed in the water and in the centre of the product verify that the temperatures are correct and uniform.

When the programmed cooking temperature/time was reached, the product was then cooled. The pumps send hot water to the corresponding external reservoir, and it is replaced by water at 1-3°C to rapidly cool the product. When the centre reaches the final programmed temperature/time, the boiler is emptied of the water and the product is ready to be unloaded.

Products

As already mentioned in this article, one of the primary objectives of low-temperature cooking for longer time periods is to obtain more tender meat. For this reason, different tests were carried out with turkey, chicken, pork, and beef. For each product, cooking was performed at different temperatures and times in order to determine the tenderness and sensory properties that can be obtained with each combination.



▲ **Figure 2:** Special baskets for sous vide cooking using Cookline 4.0.

The preparation of the meat was performed based on each type of product:

• Turkey breast: individually vacuum-sealed without the addition of brine or additives in pieces of approximately 150 g and 2 cm thickness in the centre.

• Chicken breast: similar to the above, but in 250 g pieces.

• Pork loin (*Longuissimus dorsi*): prepared in 1,000 g pieces vacuum-sealed with two different processes, some pieces injected up to 20% with brine for marinated products and the rest of the pieces without injecting.

• Beef round (*Biceps femoris*), for Roast Beef, was cut into 1,200 g pieces; a portion was injected up to 20% with the same brine as the pork loin, and the rest were not injected. They were vacuum-sealed.

The times and temperatures evaluated for each product are described in Table 1. In the case of turkey, chicken, and pork, standard cooking with water at 75°C was used to be able to compare the results with low-temperature cooking methods. With beef, due to prior experience, it was decided to use increasing temperature-scaled cooking methods to obtain better results.

Properties evaluated

Tenderness/Toughness

Toughness is defined as the force needed to chew foods between molars and its evaluation was carried out using the TPA method of the texture analyser (TA-XTplus by Stable Micro Systems). In addition, a sensory evaluation was conducted using a trained panel on a scale from 1 to 5 (1=not at all tender/very tough; 5=very tender/not at all tough).

Product	Water Temp	Time (h)					
Turkey Breast	57°C	4	-	-	10	-	16
	60°C	4	-	-	10	-	16
	65°C	4	6	8	10	-	-
	75°C	< 1	-	-	-	-	-
Chicken Breast	60°C	4	6	-	10	-	-
	75°C	< 1	-	-	-	-	-
Non-injected Pork Loin	62°C	4	6	8	10	-	-
20% Injected Pork Loin	62°C	-	-	8	10	-	-
Non-injected Beef Round	Method 1	4.5	-	-	-	-	-
	Method 2	5	-	-	-	-	-
20% Injected Beef Round	Method 1	4.5	-	-	-	-	-
	Method 2	5	-	-	-	-	-

▲ **Table 1.** Cooking temperatures and times used for each product.

Juiciness

Another important quality that also depends on cooking is juiciness, which is defined as the amount of juice perceived during chewing. It was evaluated by a trained panel scored on a scale from 1 to 5 (1=not at all juicy; 5=very juicy).

Loss

The loss of water/liquid during cooking is directly related to juiciness, so if there is more loss to cooking, the result is normally a product that is less juicy. The loss was measured by weighing the sample before and after cooking.

Acceptability

The acceptability of a product by the consumer depends on many factors and is a subjective quality. In general, for these cooking tests, a tender product with a meaty texture and some juiciness is sought after. The acceptability was measured using a panel of consumers, where they were asked to score acceptability on a scale from 1 to 5 (1=unacceptable; 5=highly acceptable).

RESULTS

Table 2 demonstrates the results obtained by the panel of tasters specialised in tasting fresh meat. Below, the results for each type of meat are analysed.

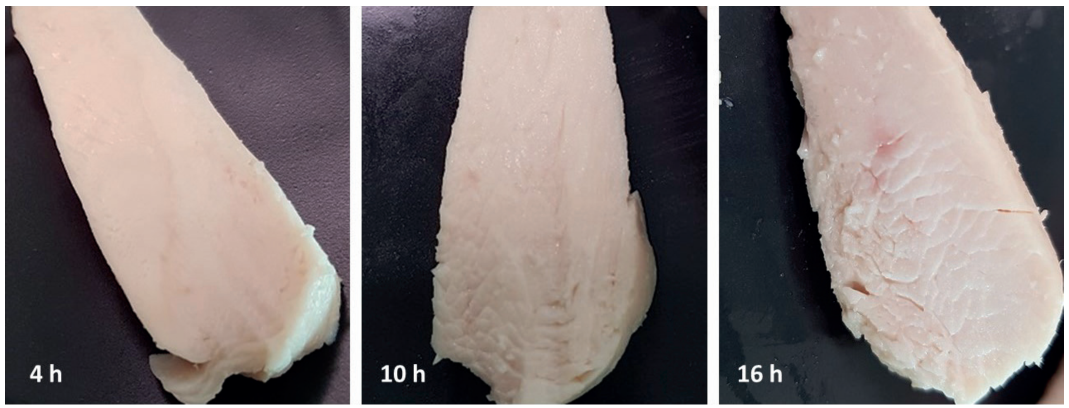
Turkey Breast

Figure 3 shows the photographs of the tests performed with turkey breast cooked at 57°C for 4, 10, and 16 hours, in which it can be easily seen that cooking for 16 hours yields the softest product with a less meaty texture. The majority of tasters considered that the longest cooking time (16 hours) gave a texture that was too soft (scores of 5) and was not pleasant. The sample cooked for 10 hours was considered the most pleasant, tender (4) and juicy (4), while the 4 hour method resulted in a less juicy (3) and less tender (3) sample. The tenderness data assessed with the texture analyser confirmed those obtained by the panel of tasters.

Cooking at 60°C also gave positive results for the 10 hour samples. At this temperature, the pieces had no losses and the texture was very tender and juicy. The flavour was also very pleasant. In the case of 65°C, it was considered that the texture, juiciness, and flavour did

Product	Water Temp.	Cooking (hr)	Loss (%)	Rating scale from 1 (min) to 5 (max)		
				Tenderness	Juiciness	Acceptability
Turkey Breast	57ºC	4	3	3	3	3
		10	2,5	4	4	4
		16	2,3	5	4	3
	60ºC	4	0	3	4	3
		10	0	4	5	5
		16	0	5	4	3
	65ºC	4	5	3	3	2
		6	7	3	3	3
		8	4	3	3	3
		10	5	3	3	2
	75ºC	< 1	3	2	3	2
Chicken Breast	60ºC	4	0,6	4	4	4
		6	10	4	2	3
		10	10	4	2	2
	75ºC	< 1	15	3	2	2
Pork Loin	62ºC	4	10	3	3	2
		6	15	2	3	2
		8	20	2	2	3
		10	20	2	2	3
Inj. Pork Loin 20%		8	20	4	4	4
		10	20	4	4	4
Beef Round	Method 1	4,5	12	2	2	3
	Method 2	< 5	14	2	2	2
Inj. Beef Round 20%	Method 1	4,5	15	4	4	4
	Method 2	< 5	20	3	4	4

▲ **Table 2.** Results of tenderness, juiciness, and acceptability of the products evaluated



▲ **Figure 3.** Comparison of cooking turkey breast at 57°C for 4, 10, and 16 hours.

not improve; on the contrary, the pieces were less juicy (3) and less tender (3), and had losses of around 5%.

Standard cooking at 75°C to 72°C in the centre resulted in a less tender (2), less juicy (3) product with losses of 3% and an acceptability of 2.

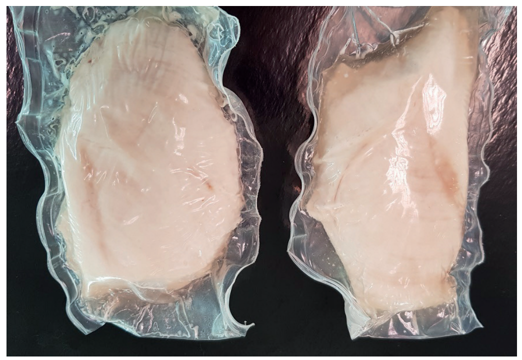
Chicken Breast

The tests performed with cooking at 60°C for 6 and 10 hours presented losses greater than 10% and juiciness values of 2. Despite the fact that the texture measured using the texture analyser was softer with longer cooking times, the tasters felt that cooking for 4 hours was more pleasant (acceptability of 4) and had a juicier (scores of 4) and tender (4) texture.

The samples cooked at 75°C to 72°C in the centre, had losses greater than 15%, and juiciness scores of 2, with low acceptability (2).

Pork Loin

The pieces weighing approximately 1 kg were cooked at 62°C. At this temperature, with relatively short processing times (4 and 6 hours) for cooking, the meat had the appearance of "raw meat", a characteristic not generally acceptable in pork. It was determined that 8 hours was the minimum cooking time to avoid this appearance. The problem with pork loin is the large losses that result from long cooking times (15-20%),



▲ **Figure 4.** Chicken breast after cooking for 6 hours at 60°C.

which translates into dry meats (juiciness scores of 2) and lack of acceptability (scores between 2 and 3).

To improve the yield, it was decided to inject the meat up to 20% and cook for 8 and 10 hours. The result was very satisfactory, achieving a product with high acceptability (scores of 4) for the tasters. A tender (4), meaty and juicy (4) texture was obtained, while achieving yields of around 95%.

The texture values from the texture analyser corroborate those perceived by the tasters, with the 20% injected loin cooked for 8 hours presenting the least toughness, as can be seen in Figure 6.

Roast Beef

With beef, depending on the end market, the desired final colour changes. In addition to investigating the texture and juiciness, tests were conducted to seek the suitable temperature/time to achieve the desired colour.

Two types of cooking methods were used for both types of pieces:
• Method 1: 1 hour at 50°C + 2 hours at 55°C and 65°C until the centre of the piece reached 60°C.
• Method 2: 1 hour at 50°C + 2 hours at 55°C and 75°C until the centre of the piece reached 70°C.

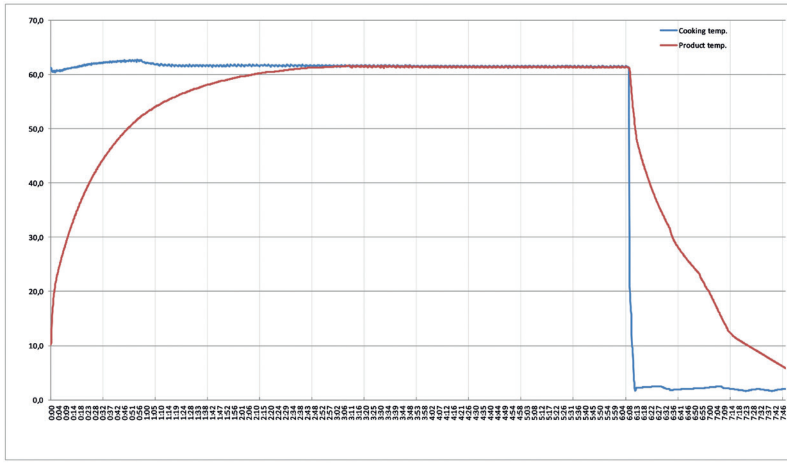
As occurred with the pork loin, the results of the evaluation were improved in the injected pieces. Higher scores for tenderness, juiciness, and acceptability were obtained, in addition to higher yields. Among the injected pieces, method 1 achieved higher scores for tenderness. There was no difference in juiciness despite there being a slightly different loss.

As expected, method 1 obtained a more reddish appearance for the cut, while method 2 obtained a brownish-grey appearance (of cooked meat). This colour difference can be observed in Figure 7.

COOKLINE

Date	Meat	kg	Size	Added subs.	packaged	Cooking	Time transition 1-2	Time transition 2-3
19/11/2018	pork loin	1000,00		No	vacuum	1 cooking vessel		

Phase	Time	Temperature	Initial time	Final time	Time	Max. Temp bath	Min. Temp bath	average temp	Temp. Prod.
1	4:00	62°C	11:09	15:09	4:00	62,6°C	61,2°C		62,4°C
2	1:04	2°C	15:09	15:46	0:37	61,8°C	1,1°C		4,0°C
1+2	5:04		11:09	15:46	4:37	Final prod. Temp = 4,0°C			



Time	min.	Cooking temp.	product temp.	Phase
19:18	0:00	61,5	12,0	1
19:22	0:04	62,5	18,3	1
19:26	0:08	61,5	21,2	1
19:30	0:12	62,9	24,3	1
19:34	0:16	64,0	27,3	1
19:38	0:20	62,6	30,1	1
19:42	0:24	62,1	32,4	1
19:46	0:28	61,8	34,4	1
19:50	0:32	62,0	36,5	1
19:54	0:36	62,9	38,4	1
19:58	0:40	63,5	40,3	1
20:02	0:44	63,3	42,0	1
20:06	0:48	62,9	43,4	1
20:10	0:52	62,5	44,8	1
20:14	0:56	62,4	46,0	1
20:22	1:04	62,6	48,2	1
20:26	1:08	62,8	49,2	1
20:30	1:12	62,9	50,1	1
20:34	1:16	63,0	50,9	1
20:42	1:24	56,3	51,4	2
20:46	1:28	56,5	51,6	2
20:50	1:32	56,3	51,8	2
20:54	1:36	56,2	52,0	2
21:02	1:44	56,3	52,7	2
21:06	1:48	56,4	52,9	2
21:10	1:52	56,2	53,1	2
21:14	1:56	55,9	53,3	2
21:22	2:04	56,3	53,7	2
21:26	2:08	57,2	54,0	2
21:30	2:12	56,9	54,2	2
21:34	2:16	56,8	54,4	2
21:42	2:24	56,8	54,7	2
21:46	2:28	4,6	47,5	3
21:50	2:32	3,8	42,2	3
21:54	2:36	2,9	38,9	3
22:02	2:44	2,9	33,5	3
22:06	2:48	2,8	29,8	3
22:10	2:52	3,3	27,3	3
22:14	2:56	2,5	24,5	3
22:22	3:04	3,1	22,3	3
22:26	3:08	3,6	21,3	3
22:30	3:12	2,5	20,0	3
22:38	3:20	2,1	18,3	3
22:42	3:24	2,2	17,6	3
22:46	3:28	2,5	16,7	3
22:54	3:36	3,0	15,4	3
22:58	3:40	3,3	14,4	3
23:02	3:44	3,6	13,9	3
23:10	3:52	2,4	12,5	3
23:14	3:56	2,9	12,1	3

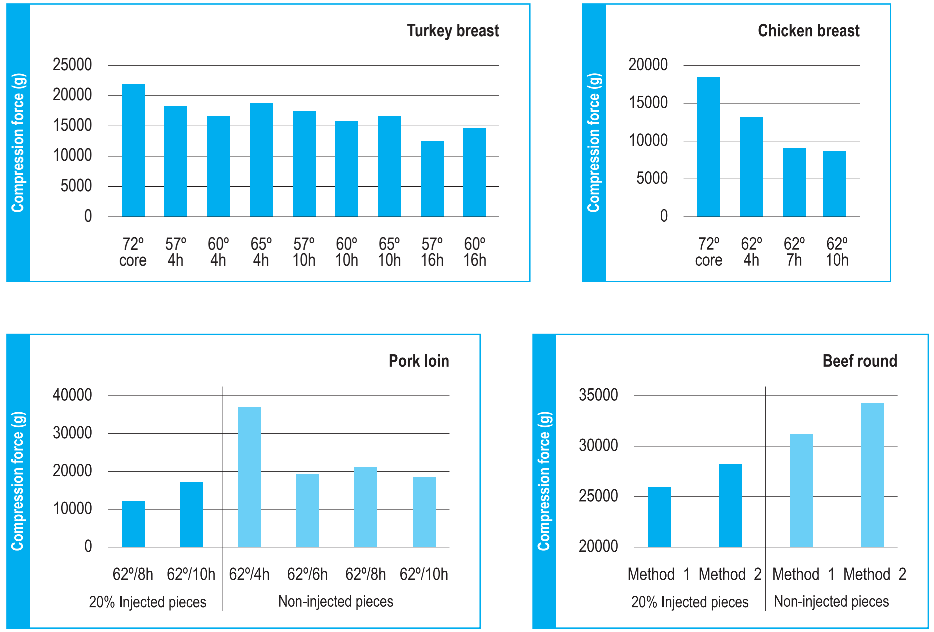
▲ **Figure 5.** Cooking graph for pork loin at 62°C for 8 hours obtained using the Cookline 4.0.

CONCLUSIONS

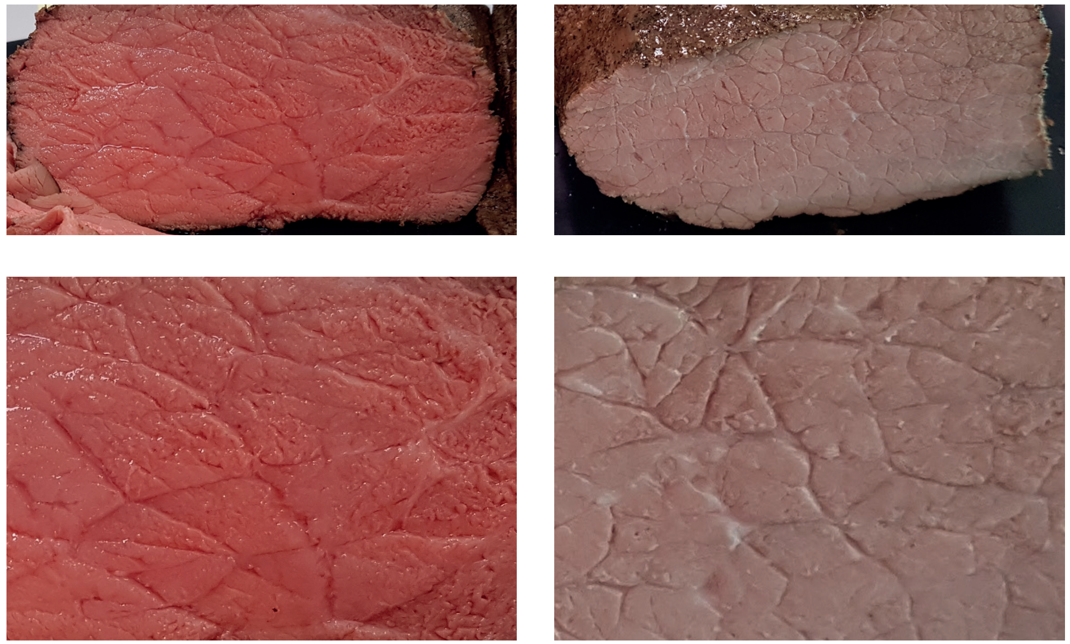
As can be seen in these tests, the tenderness (and acceptability) of meat is intimately tied to the combination of temperature/time, with lower temperatures and longer cooking times scored best. But this relationship seems to have a time limit, above which the texture can be too soft and cause rejection by the consumer.

It has been observed that in the case of chicken, gentle and short cooking (4 hours at 60°C) was scored better, while with turkey, the best results for acceptability among all the tests were cooking for 10 hours at 60°C. The loin had better scores for the injected product than the non-injected product, due primarily to the losses in this cut of pork. With beef, good results were obtained for the desired colour, but different tests should be performed for different cuts of beef, both injected and non-injected, to obtain optimal values for time and temperature to attain good texture and juiciness.

In this study, set combinations of temperature/time have been set for each product, but there are many other combinations that could not be tested due to time restrictions and that can yield very positive results for the meat industry. It would also be interesting to study the effect of sous vide cooking on other types of meat and non-meat products like fish and vegetables, which will be analysed in a future study.

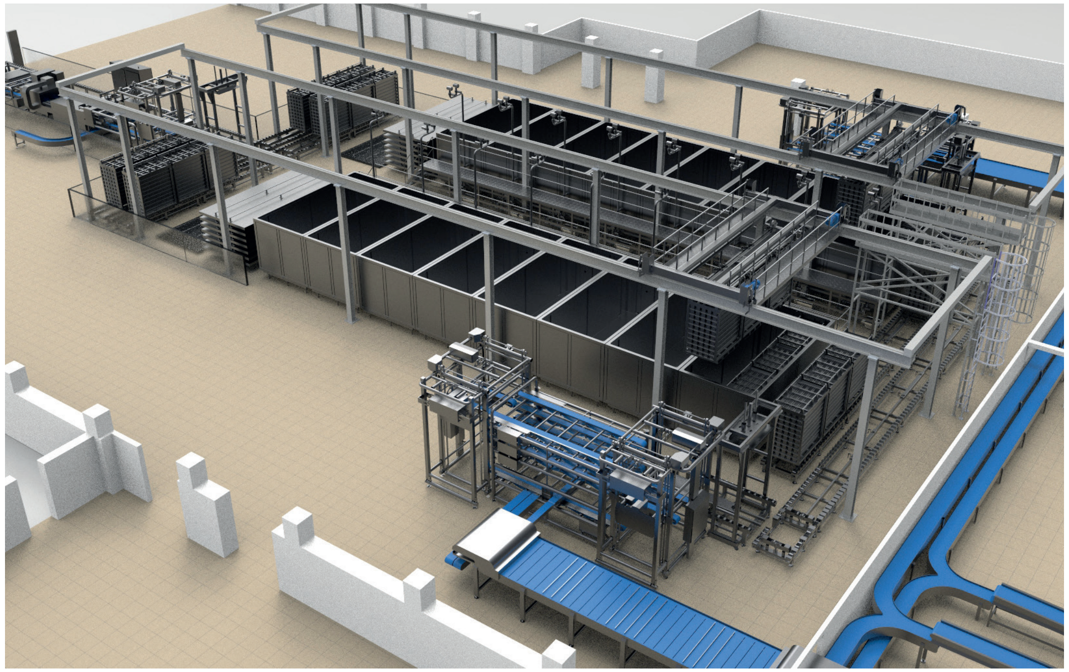


▲ **Figure 6.** Texture analyser results graphs.



Method 1 **Method 2**

▲ **Figure 7.** Comparison of cooking methods for beef round.



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