PS7.03 **Meat preparation and eating quality** 379.00

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***Abstract*—Pre-cooking preparation and cooking method cause changes in meat appearance, tenderness, juiciness, flavour and nutritive value. While freezing, thawing or tempering have slight effects on eating quality, some physical preparations such as trimming, piercing or cooking on the bone can significantly affect meat flavour, tenderness and juiciness. The use of salt and other additional ingredients (e.g., marinades) seem to improve quality attributes of meat, especially tenderness and juiciness, but the mechanisms of action are not completely understood. On the other hand, the most common types of cooking affect meat in different ways, which are related to the heat transfer and rate, and in some cases (e.g., frying) to the absorption of substances from the cooking media. The denaturation of proteins and the gelatinization of collagen must be considered to recommend optimal cooking temperature rates for different meat cuts based on their composition. Finally, higher endpoint temperatures are associated with higher flavour, but lower tenderness and juiciness scores. Given the numerous factors and interactions affecting meat eating quality specific recommendations need to be based on scientific testing.**

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***Index Terms*—cooking, doneness, temperature, marinade**

I. INTRODUCTION

HISTORICALLY meat was cooked to improve its palatability [1] and digestibility, and has contributed to human evolution [2]. In modern times, meat is cooked not only to enhance its palatability and digestibility but also to improve its hygienic quality and shelf life by inactivation of pathogenic and spoilage microorganisms. As our understanding and control of meat cookery has improved, its use to improve targeted aspects of palatability has also improved.

Meat quality is influenced by numerous factors [3] such as species, breed, sex, age, diet, production system, pre- and post-slaughter management, muscle type, location within muscle, ageing, etc. However, the importance and perception at consumption of these effects is ultimately influenced by pre-cooking preparation and cooking methods [4]. Many cooking standards are based on popular recommendations or cooking lore rather than on scientifically validated evidence with resultant consumer confusion. Taking into account the difficulty of making clear-cut conclusions due to the numerous interactions amongst factors, the aim of the present work is to identify the main effects of the most popular pre-cooking and cooking treatments on whole meat eating quality (i.e., appearance, tenderness, juiciness, flavour and nutritive value).

II. PRE-COOKING

Prior to cooking, meat can be handled by consumers in many different ways in an attempt to enhance quality attributes and/or extend shelf life.

A. Pre-Cooking Temperature

According to our research, the main effect of cooking meat from the frozen state is an increase in cooking time (50% longer) [5] with no clear effects on eating quality (Table 1). However, Fulton and Davis [6] reported improved tenderness and juiciness when cooking meat from a frozen state. This likely relates to a lower water loss in comparison to thawed meats [7]. Magnitude of freezing/thawing effects will depend on the size of ice-crystals formed within the meat structure. A more rapid temperature drop results in smaller crystals and less destruction of internal cell membranes and, therefore, lower loss of water [8]. Freezing and thawing rates are also highly dependant on the size and shape of the meat cut [9].

Cooking literature also recommends tempering the meat at room temperature prior to cooking in order to improve tenderness, juiciness and flavour. Some scientific evidence suggests higher initial temperature prior to cooking results in increased tenderness and lower cooking losses [10]. In our research [5] tempering up to 1h tended to improve objective measures of beef tenderness (Figure 1). During tempering at room temperature, however, surface and internal temperatures rose quickly reaching temperatures where bacterial proliferation could be problematic. Thus, due to food safety issues, in a home environment meat should be kept refrigerated until cooking.

B. Physical Preparation

Fat trimming has a considerable effect on meat flavour characteristics since lipid-derived volatiles contribute significantly to the overall flavour of meat which is distinct and species-specific [11]. As a direct effect, total fat content decreases and, consequently, the fatty acid composition shifts as subcutaneous fat is trimmed. In general, intramuscular fat is richer in polyunsaturated fatty acids than subcutaneous fat, and trimming cover fat improves the polyunsaturated/saturated ratio. Conversely, cooking losses are lower and thus nutrient retention is higher in meat cooked without trimming [12]. Also, meat cuts cooked with external fat normally require longer cooking times due to the difference in heat transfer between muscle and fat [13].

Cooking meat on the bone (Table 1) improves palatability, including juiciness and flavour [5]. The insulating properties of the bone and/or the infusion of flavour from the bone marrow into the meat have been speculated as the causes for improved eating quality [14].

Piercing roasts with a fork/home implement has been shown to improve objective tenderness (Figure 1), and the greatest improvement was achieved through piercing 24h before cooking [15]. Piercing showed no effect on moisture losses during cooking, however, it resulted in deeper external rings of metmyoglobin. The fibre disruption may create an increased opportunity for oxygen penetration and movement of sarcoplasmic proteins. Speculatively, piercing may increase the amino acids and sugars at the meat surface resulting in a more extensive Maillard reaction, providing a barrier to moisture loss and creating "moist" heat cookery conditions within the muscle.

During cooking, the meat cut is normally assumed to be homogeneous and dependence of thermal properties on meat shape are largely ignored [16]. However, cut shape affects heat transfer rates and can have a great influence on eating quality. For example, when equal weight roasts of uniform cylindrical and square shape were fabricated from the same muscle and cooked under similar conditions (Table 1), cylindrical roasts had higher tenderness, juiciness and flavour scores [5]. Hence, meat shapes that lead to a uniform heat transfer and a more homogeneous internal temperature improve eating quality.

C. Additional Ingredients

Different ingredients (i.e., acids, plant extracts, salt solutions, enzyme preparations) are commonly used in marinades or rubs to improve quality attributes. Acids, such as vinegar and lemon juice, disrupt hydrogen bonds within the collagen fibrils and cause the connective tissue to swell [3]. Plant extracts, besides contributing to flavour, often have high antioxidant activity which in some cases has been shown to protect against the formation of harmful heterocyclic amines during cooking [17]. Enzyme preparations (i.e., bromelain, papain, ficin) typically degrade meat proteins, tenderizing the meat and increasing peptide and free amino acid levels which in turn provide more substrate for the Maillard reaction [18]. However, time and temperature considerations are important to prevent over-tenderization and mushy texture. Many available enzyme preparations are blended with spices and umami compounds (e.g., monosodium glutamate) which contribute to the flavour development. The effect of these tenderizers, unless the meat cuts are very thin, or they are somehow placed inside the meat, is mostly limited to contact surfaces [19].

Contrary to popular opinion, marinades do not penetrate beyond the surface of the meat, even when piercing is combined with marination [5]. However, including cornstarch in the marinade of narrow meat strips (Figure 1) improved both instrumental and sensorial tenderness [15], potentially due to the hydrophillic nature of the cornstarch contributing to a barrier to moisture loss.

Introducing an alcohol to an acid marinade may also increase marinade penetration since fats are soluble in alcohol, thus enhancing final tenderness (Figure 1) [15].

Salt is purportedly used to enhance the natural flavour of meat. Home-cooking literature recommends salting meat after cooking on the premise that salt increases moisture and metabolite losses. In addition, the recommendation to add salt after cooking is also based on efforts to limit salt intake for healthiness. However, recent studies have reported that seasoning with salt before cooking (0.3% w/w) is beneficial, enhancing tenderness, juiciness and browning [5, 20]. The effects of salt addition on flavour are limited to only an increased "salty" taste when assessed by trained panellists (Table 1).

III. COOKING

Cooking should be understood as an optimal heat-treatment of meat capable of destroying pathogenic organisms while maintaining a high product yield and leading to the development of final desirable eating characteristics.

A. Effect of Heating

During cooking, temperature increase results in important meat structural (i.e., protein denaturation, collagen gelatinization, Maillard reaction) and mass distribution (i.e., water/fat loss) changes [21] [22]. Major changes occur in the internal temperature interval of 40-60ºC, where sarcoplasmic proteins begin to denature, shrinkage of myofibrils begins, sarcomere length decreases, collagen and myoglobin start to denature, and raw meat changes the appearance towards that of cooked meat [23].

The denaturation of the contractile system in this temperature interval contributes to a 3-4 fold toughening [24] and a further 2-fold toughening occurs between 65-75ºC corresponding with collagen shrinkage. Above 75ºC collagen reaches a soluble gelatinized state [23].

The internal structure of different meat cuts/muscles determines differences in heat transfer capacities [25]. Furthermore the rate of heating for the same meat cut is affected by the temperature of the media, air circulation and relative humidity [23]. Similar internal temperatures can be achieved by different combinations of these factors, and increasing any of them will increase the rate of heating.

Consistently, meat cooked with slow rates of heating (60-65ºC) has been shown to improve tenderness which historically has thought to be due to collagen shrinkage or preservation of enzyme-activity at these temperatures [24]. Recently irreversible dissociation of actin and myosin has been shown to occur when cooking at low temperatures (improving tenderness) whereas denaturation of the actomyosin complex without dissociation (decreasing tenderness) occurs when cooking at higher temperatures (80ºC) [26].

Meat colour change during cooking depends on the denaturation of the three forms of myoglobin, which differ in their sensitivity to heat denaturation. Metmyoglobin forms the brown globin hemichromogen, while oxymyoglobin and deoxymyoglobin form the red globin hemochromogen, which can be readily oxidized to hemichromogen. Numerous factors (e.g. pH, thawing, packaging) can prolong the uncooked colour or cause premature browning of the meat. Therefore the use of a food thermometer is required to ensure the final recommended meat temperature [26].

Furthermore uniformity of the internal temperature depends on the rate of heating. Hence, during slow cooking the core temperature will be similar to the surface resulting in uniform meat colour. However, high heating temperature will produce meat with visible layers of different degrees of doneness [23]. Also, after removing the meat from the heating media, the cooking process continues and the core temperature continues increasing [27]. Thus, the recommendation to remove the meat from the heat source and allow to stand is made.

Cooking meat to different endpoint temperatures affects palatability traits. In a recent study [28], we observed that beef tenderness and juiciness peaked at a low internal endpoint temperature (63°C; Table 1). In contrast, the highest flavour and internal doneness scores were observed at an internal endpoint temperature of 71°C. Similar results have been reported by several authors [13, 29] and are likely related to the effects of heat on protein degradation (low temperature), volatile development (high temperature), and the Maillard reaction.

B. Cooking Methods

Depending on the heat transfer media, the primary home-cooking methods can be classified as dry (e.g., broiling, roasting, frying), moist (e.g., boiling, braising) and dielectric (e.g., microwave) heating. Different meat cooking techniques are closely linked to cultural and geographical differences. Thus, local preferences result in heat transfer, cooking rate, and endpoint temperature variations, leading to distinctly different final eating qualities.

During cooking, moisture, fat, vitamins and minerals are lost [30], altering the nutritional value of the meat. Losses may be reduced by initially high temperature searing the meat to create a surface barrier of denatured proteins.

Temperatures above 110°C facilitate the Maillard reaction, important for odour, flavour and colour development [31]. However, high relative humidity prevents this reaction from occurring, diluting flavour and odour components [27].

Moisture losses during dry cooking are due to evaporation losses while wet cooking is usually linked to exudation and diffusion [32]. Cooking may also generally contribute to fat losses and lipid oxidation. Frying meat in oil/fat, however, increases the total fat content of the final product (fat absorption) and changes its fatty acid profile according to the oil/fat source and the fatty acid exchange rate between product (meat) and media (oil/fat) [33].

The effect of cooking methods on tenderness depends mostly on the structural composition of the muscle. Muscles with high connective tissue content benefit from moist cooking due to gelatinization, while muscles with low connective tissue content benefit from dry cooking [22].

IV. . CONCLUSIONS

Overall, consumer preparation and cooking process should ensure the destruction of pathogens while maintaining a high product yield and desirable eating characteristics, adapted as much as possible to the type of meat cut. The main factors, as well as their complex interactions, must be taken into consideration to provide the consumer with effective instructions to achieve the best eating quality.

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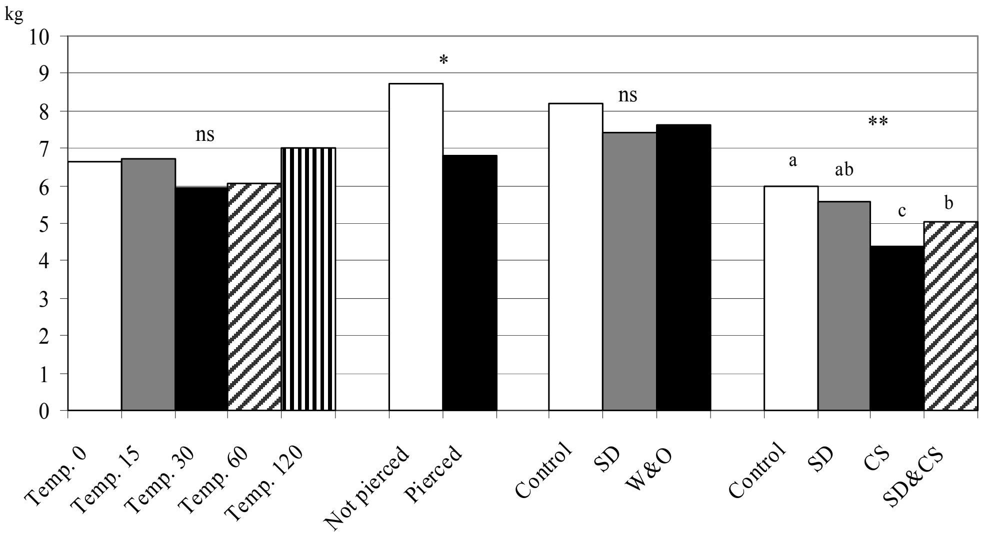
Table 1. Effects of meat preparation and endpoint temperature on beef cooking and sensory attributes [5, 28]

	Added salt			State				Bone			Shape			End point			
	No	**Yes**	**Sig.**	**Fresh**	**Frozen**	**Thawed**	**Sig.**	**In**	**Out**	**Sig.**	**Cylindrical**	**Square**	**Sig.**	**63ºC**	**65ºC**	**71ºC**	**Sig.**
CT	6.3	6.8	ns	5.6^{b}	9.5^{a}	6.0^{b}	**	5.6	6.0	*	8.5	11.5	***	-	-	-	-
CL	244	231	ns	169	203	198	ns	123	138	ns	156	211	***	-	-	-	-
EB	4.1	4.5	*	3.7	4.0	4.0	ns	3.7	3.7	ns	4.0	4.0	ns	-	-	-	-
ID	3.8	3.9	ns	3.7	4.0	3.3	ns	4.0	3.2	***	4.2	4.8	***	3.8^{c}	4.7^{b}	6.5^{a}	***
IT	5.7	5.9	ns	6.1	6.2	6.3	ns	5.9	5.8	ns	5.0	4.7	ns	6.0^{a}	5.8^{ab}	5.7^{b}	*
JC	5.0	5.3	*	5.7	5.4	5.6	ns	5.6	5.5	ns	5.3	4.7	***	5.4^{a}	5.1^{b}	4.4^{c}	***
FI	4.9	5.0	*	4.6	4.8	4.6	ns	4.7	4.5	ns	4.6	4.1	***	4.1^{b}	4.3^{b}	4.8^{a}	***
BF	4.1	4.7	***	2.6	2.9	2.7	ns	2.7	2.5	ns	3.0	2.6	***	2.4^{b}	2.5^{b}	3.0^{a}	***
SI	6.9	5.2	***	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CT	6.7	6.7	ns	7.1	7.1	7.1	ns	6.9	6.9	ns	6.1	5.8	ns	6.4	6.2	6.3	ns
OT	5.7	5.9	*	6.1	6.2	6.3	ns	6.1	5.9	ns	5.3	5.0	ns	6.0^{a}	5.8^{ab}	5.7^{b}	*
OP	4.9	5.1	ns	4.4	4.6	4.5	ns	4.7	4.4	ns	4.5	4.1	*	3.9^{b}	4.0^{b}	4.3^{a}	**

ns, non significant, $p>0.05$; *, $p<0.05$; **, $p<0.01$; ***, $p<0.001$.
CT: cooking time, sec g^{-1}; CL: cooking loss, mg g^{-1}; EB: external browning (1: slight, 5: extremely); ID: internal doneness (1: very rare, 7: very well done); IT: initial tenderness; JC: juiciness; FI: flavour intensity; BF: browning flavour; SI: salt intensity; CT: connective tissue; OT: overall tenderness; OP: overall palatability (1: very tough/dry/bland/intense/abundant/tough/undesirable, 8: very tender/juicy/intense/bland/none detected/tender/desirable).

Figure 1. Effects of tempering [5], piercing and marinating [15] on beef shear force in four different studies



ns, non significant, $p>0.05$; *, $p<0.05$; **, $p<0.01$.
Temp: Tempering time, min; S