

# Beef's optimum internal cooking temperature as seen by consumers from different countries using survival analysis statistics

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## Abstract

A total of 306 consumers from Argentina, Spain and the USA, segmented by age groups (young and middle-aged adults) and stated preference for degree of doneness (rare, medium, well-done) looked at pictures from the American Meat Science Association (AMSA) Color Guide and decided if these were under-cooked, ok or over-cooked. Survival analysis statistics were applied to the data to predict optimum internal cooking temperatures. These  $\pm 95\%$  confidence intervals were:  $75 \pm 6.2$  °C,  $78 \pm 4.3$  °C and  $82 \pm 2.6$  °C, for consumers stating a preference for rare, medium and well-done beef, respectively. Country of residence and age group had little influence on optimum temperatures. Relatively high optimum temperatures, and the fact that only 4% of the consumers found the “55 °C-very rare” and “60 °C-rare” pictures ok, suggests the necessity of revising the range of the AMSA Color Guide.

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## 1. Introduction

Color change in the protein pigments (hemoglobin and myoglobin) is a primary indicator of beef's degree of doneness. As the temperature of the beef increases, the muscle becomes progressively opaque, changing from red to pink to brown. The color of beef juices also changes from pink to pale amber. These color changes are perceived by consumers when evaluating the degree of meat doneness. In the USA, a Beef Steak Color Guide (American Meat Science Association, Chicago, USA) illustrates these color changes from “very rare” to “well-well done” beef. This Color Guide has six pictures of beef steaks labeled as: “55 °C-very rare”, “60 °C-rare”, “63 °C-medium rare”, “71 °C-medium”, “77 °C-well done” and “82 °C-well well

done”. In other countries, such as Argentine or Spain there are no local equivalents to the Color Guide.

The American Meat Science Association (1995) recommends cooking to an internal temperature of 71 °C for sensory evaluation of meat, basically to guarantee microbiological safety (Rhee, Lee, Hillers, Mc Curdy, & Kang, 2003). This internal temperature corresponds to “medium” according to the Color Guide. Some consumers will find this degree of doneness ok, others will find it under-cooked and others over-cooked. In recent published studies of beef steak, samples often have been cooked to an internal temperature of  $71 \pm 1$  °C in both consumer acceptance studies (Killinger, Calkins, Umberger, Feuz, & Eskridge, 2004; Oliver et al., 2006) and studies by trained panels (Yancey, Dikeman, Hachmeister, Chambers, & Miliken, 2005; Yancey et al., 2006). However, research studies of meat products have ranged from 63 °C for beef steaks (Campbell, Hunt, Levis, & Chambers, 2001) to 80 °C for

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ground meat (Chun, Chambers, & Chambers, 2005). McKenna et al. (2004) and Goodson et al. (2002), in studies in different USA cities found that approximately 50% of consumers cooked their beef to “medium and less” and 50% to “medium well and more”; showing a clear segmentation on consumers’ preferred degree of doneness. No publications were found where the optimum internal cooking temperature has been addressed from a consumer acceptability perspective.

Survival analysis mathematical procedures have proved to be an adequate tool to estimate optimum concentrations of a food ingredient (Garitta, Serrat, Hough, & Curia, 2006). These authors applied their model to red color in a strawberry yogurt, where the color can be too light, ok or too dark; leading to two events of interest: the transition of too light to ok and the transition of ok to too dark. When a consumer sees a piece of cooked beef he/she can decide it is under-cooked, ok or over-cooked; also leading to two events of interest: the transition of under-cooked to ok and the transition of ok to over-cooked.

People who travel abroad get the impression that meat receives different degree of doneness in different countries, but these impressions have not been confirmed. Oliver et al. (2006) measured acceptability of beef from different origins with consumers from Britain, Germany and Spain. Samples were all cooked to an internal temperature of 72 °C. There was no consideration of consumers’ preferred degree of doneness, with possible differences between consumers from different countries.

Consumers’ age can be an influencing factor in chosen degree of doneness. Middle-aged (40–60 years) consumers in comparison to young (20–30 years) consumers, may be more acquainted with home cooking, eat less in fast food restaurants, and give higher value to traditional recipes, to name a few differences. Russell and Cox (2004) performed a repertory grid study on young, middle-aged and older consumers’ perceptions of different meat products. Only subtle differences between age groups were observed, although degree of doneness was not considered; all products were cooked to a medium level. There are no publications comparing different age-group’s preferred degree of doneness.

The purpose of this work was to predict the optimum cooking temperatures of beef based on acceptance or rejection data obtained from consumers using survival analysis statistics. Consumers from different countries, age groups and stated preference for degree of doneness were considered.

## 2. Materials and methods

### 2.1. Consumer studies

Consumers who consumed cooked beef at least once a week were recruited from the cities of Nueve de Julio (Buenos Aires, Argentina), Manhattan (Kansas, USA) and Valencia (Spain). One hundred and two consumers were

recruited in each city, half with ages ranging from 21 to 30 years (young) and half with ages ranging from 40 to 60 years (middle-aged). Approximately half of them were female and half male. In each city tests were conducted in central locations (Stone & Sidel, 2004). To allow the test to be answered by several consumers simultaneously, a total of 30 Color Guides were acquired from the National Cattlemen’s Beef Association (Centennial, CO, USA) by the Argentine group who received them by post. They were checked for similarity and sorted randomly into three groups of 10, one for each country. From Argentina they were sent to Spain and the USA.

The pictures (without any description) from each color guide were cut out and coded with 3-digit random numbers. Consumers received the six pictures monadically order of presentation was balanced over consumers. For each picture consumers had to tick a box indicating if they considered the meat in the picture “under-cooked”, “ok” or “over-cooked”. Pictures were evaluated under natural daylight conditions. After evaluating the six pictures, consumers in Argentina and Spain were asked: “At home or in a restaurant, how do you normally consume beef? Rare, medium, well done or other?” The term ‘other’ was used should the first three options not satisfy the consumers’ opinion. Answers to ‘other’ were few and they were re-classified in the other three options reclassification was made considering if consumers’ opinion using others words, could be related with the other three options (rare-medium-well done) i.e. “leaning toward rare” was re-classified as “rare”.

In the USA consumers are used to using more categories so they were asked: “At home or in a restaurant, how do you normally consume beef? Rare, medium-rare, medium, medium-well, well-done, or other?” In order to be able to compare data between countries, USA consumers’ data were re-categorized: “rare” and “medium-rare” were considered “rare”; and “medium-well” and “well-done” were considered “well-done”. Before leaving consumers received a reward for their participation.

### 2.2. Survival analysis concepts

The model is basically the same as that developed by Garitta et al. (2006) for determining the optimum color of yogurt. In that research, the explanatory variable was the color of the yogurt expressed by the Hunter Lab  $a^*$  parameter. In the present work, the explanatory variable was internal cooking temperature (ICT).

Let  $T$  be the random variable representing the optimum ICT of beef for a given consumer. Assume that  $T$  is absolutely continuous with distribution function  $F$ . For each value of ICT  $t$ , there will be two rejection functions:

$R_u(t)$  = probability of a consumer (or proportion of consumers) rejecting beef with  $ICT = t$  because it is under-cooked, that is  $R_u(t) = P(T > t) = 1 - F(t)$ .

$R_o(t)$  = probability of a consumer (or proportion of consumers) rejecting beef with  $ICT = t$  because it is over-cooked, that is  $R_o(t) = P(T < t) = F(t)$ .

In seeking beef's optimum ICT, the acceptance/rejection patterns of consumers receiving these pictures will be explained:

*Rejection of the beef because it is under-cooked:* if a consumer rejects the 63 °C picture (medium rare) because it is under-cooked and accepts the 77 °C picture because it is ok, the exact ICT at which the consumer passes from “rejection because it is under-cooked” to “acceptance because it is ok” could be any value between 63 and 77 °C. This is defined as interval censoring. Left censoring occurred if a consumer found the 55 °C picture ok, thus the event of passing from under-cooked to ok would have occurred at some unknown ICT < 55 °C. If the consumer rejects all pictures because they are under-cooked, acceptance would occur for an ICT > 82 °C and this consumer's data is right censored.

*Rejection of the beef because it is over-cook:* if a consumer accepts the 63 °C picture and rejects the 77 °C picture because it is over-cooked, the exact ICT for which the consumer passes from accepting the beef to rejecting it because it is over-cooked could be any value between 63 and 77 °C, a case of interval censoring. Left and right censoring can also occur for rejection of the beef because it is over-cooked.

The likelihood function, which is used to estimate the failure function, is the joint probability of the given observations of the  $n$  consumers (Klein & Moeschberger, 1997). In our study there are two likelihood functions:  $L_u$  (under-cooked) and  $L_o$  (over-cooked):

$$L_u = \prod_{ieR} R_u(l_i) \prod_{ieL} (1 - R_u(l_i)) \prod_{ieI} (R_u(l_i) - R_u(r_i)) \quad (1a)$$

$$L_o = \prod_{ieR} (1 - R_o(r_i)) \prod_{ieL} R_o(l_i) \prod_{ieI} (R_o(r_i) - R_o(l_i)) \quad (1b)$$

Both in Eqs. (1a) and (1b),  $R$  is the set of right-censored observations,  $L$  the set of left-censored observations, and  $I$  is the set of interval-censored observations. Eqs. (1a) and (1b) show how each type of censoring contributes differently to the likelihood functions.

Usually, failure values are not normally distributed; instead their distribution is often right skewed. In this case a log-linear model is chosen:

$$Y = \ln(T) = \mu + \sigma W$$

where  $W$  is the error term distribution. That is, instead of the optimum ICT, its logarithmic transformation is modeled. In Klein and Moeschberger (1997), or Lindsay (1998) different possible distributions for  $T$  are presented, for example the log-normal or the Weibull distribution. If the Weibull distribution were chosen, the rejection functions are:

$$R_u(t) = 1 - F_{\text{sev}}\left(\frac{\ln(t) - \mu_u}{\sigma_u}\right) \quad (2a)$$

$$R_o(t) = F_{\text{sev}}\left(\frac{\ln(t) - \mu_o}{\sigma_o}\right) \quad (2b)$$

Both in Eqs. (2a) and (2b),  $F_{\text{sev}}(\cdot)$  is the distribution function of the smallest extreme value distribution:  $F_{\text{sev}}(w) = 1 - \exp(-e^w)$  and  $\mu_u$ ,  $\mu_o$  and  $\sigma_u$ ,  $\sigma_o$  are the model's parameters.

The parameters of the log-linear model are obtained by maximizing the likelihood functions (Eqs. (1a) and (1b)). The likelihood function is a mathematical expression which describes the joint probability of obtaining the data actually observed on the subjects in the study as a function of the unknown parameters of the model being considered. To estimate  $\mu$  and  $\sigma$  for the Weibull distribution, the likelihood function is maximized by substituting  $R_u(t)$  and  $R_o(t)$  in Eqs. (1a) and (1b) by the expressions given in Eqs. (2a) and (2b), respectively.

In order to establish whether consumer age group, stated preference for degree of doneness, and country of residence influenced rejection times, the following log-linear regression model with inclusion of covariates was applied (Meeker & Escobar, 1998):

*Under-cooked rejection model:*

$$\begin{aligned} \ln(t_u) &= \mu_u + \sigma_u W \\ &= \beta_{0u} + \beta_{1u} Z_{1u} + \beta_{2u} Z_{2u} + \beta_{3u} Z_{3u} \\ &\quad + [\text{two-way interactions}] + \sigma_u W \end{aligned} \quad (3a)$$

where

- $t_u$  is the ICT at which a consumer rejects a sample because it is under-cooked;
- $\beta_{0u}$ ,  $\beta_{1u}$ ,  $\beta_{2u}$  and  $\beta_{3u}$  are the regression coefficients;
- $Z_{1u}$  is the covariate indicating the country of residence: Argentina ( $Z_1 = 1$ ), Spain ( $Z_1 = 2$ ) or USA ( $Z_1 = 3$ );
- $Z_{2u}$  is the covariate indicating stated preference for degree of doneness: rare ( $Z_2 = 1$ ), medium ( $Z_2 = 2$ ) or well-done ( $Z_2 = 3$ );
- $Z_{3u}$  is the covariate indicating consumer age group: young ( $Z_3 = 1$ ) and middle-aged ( $Z_3 = 2$ );
- $\sigma_u$  is the shape parameter, which does not depend on the covariates;
- $W$  is the error distribution.

*Over-cooked rejection model*

$$\begin{aligned} \ln(t_o) &= \mu_o + \sigma_o W \\ &= \beta_{0o} + \beta_{1o} Z_{1o} + \beta_{2o} Z_{2o} + \beta_{3o} Z_{3o} \\ &\quad + [\text{two-way interactions}] + \sigma_o W \end{aligned} \quad (3b)$$

where

- $t_o$  is the ICT at which a consumer rejects a sample because is over-cook,
- $\beta_{0o}$ ,  $\beta_{1o}$ ,  $\beta_{2o}$  and  $\beta_{3o}$  are the regression coefficients,
- $Z_{1o}$ ,  $Z_{2o}$  and  $Z_{3o}$  are the same covariates of under-cooked rejection model.
- $\sigma_o$  is the shape parameter, which does no depend on the covariates and  $W$  is the error distribution.

Once the likelihood is formed for a given model, specialized software can be used to estimate the parameters ( $\beta$  coefficients and  $\sigma$ ) that maximize the likelihood function for the given experimental data. The *CensorReg* procedure from *S-PLUS* (Insightful Corporation, Seattle, USA) was used to estimate the models' parameters, quantiles and corresponding standard deviations. Five percent or less was considered for significance.

### 3. Results and discussion

#### 3.1. Raw data and censoring considerations

Table 1 presents the data for six consumers to illustrate the interpretation given to each subject's data. Consumer 1 behaved as expected. He rejected the first, accepted pictures of intermediate degrees of doneness and rejected those that were over-cooked. The exact ICT below which this consumer rejects steaks because they were under-cooked is unknown; it was between 63 °C and 71 °C, and his data were thus interval censored for under-cooked rejection. Analogously, the exact ICT above which this consumer rejected the steaks because they were over-cooked is unknown; it was between 71 °C and 77 °C, and his data were interval censored for over-cooked rejection. Consumer 2 rejected all steaks because they were under-cooked, not finding any sample ok. Thus his data were right censored for under- and over-cooked rejection. Consumer 3 behaved similarly to consumer 1, only rejecting the first ICT and those cooked at 77 °C and 82 °C. Consumer 4 rejected the first three ICT's and then found the rest ok. His data were interval censored for under-cooked rejection and right censored for over-cooked rejection. Consumer 5 presented inconsistency and his rejection is presented in Table 1. Consumer 6 was so inconsistent that his data had to be removed. 18 consumers presented this type of data (1 from Argentina, 12 from Spain and 5 from USA), most probably because they did not concentrate on the task or did not understand it to start with. In other studies (Garitta et al., 2006; Hough, Langohr, Gómez, & Curia, 2003) this type of inconsistent behavior was also observed. Although, as stated above, subjects who indicated they had vision problems were excluded from the test, there could have been some consumers who did not report their problem and thus produced inconsistent results.

For the present data, the following standard distributions were compared: smallest extreme value, normal, logistic, Weibull, log-normal and log-logistic. The Weibull distribution adjusted best or as well as other distributions and being a very flexible model for survival data, it was chosen to model rejection ICT's. To choose the model, covariates were not included in this initial stage of calculations.

A log-likelihood test (Meeker & Escobar, 1998) indicated that there were no significant differences between the models with or without the two-way interaction terms. This was valid both for the undercooked event and the overcooked event.

#### 3.2. Influence of covariates

In the following presentation of results and discussion it must be remembered that consumers received the six pictures of the AMSA Color Guide in balanced order, labeled with 3-digit codes, and not with the labels that accompany the original Color Guide (for example: "55 °C-very rare"). After expressing if they found each picture under-cooked, ok or over-cooked, they were asked for their stated preference for beef doneness: rare, medium or well-done.

For the under-cooked to ok event, stated preference for degree of doneness ( $Z_2$ ), the country of residence ( $Z_1$ ), and the consumer age group ( $Z_3$ ) were all significant. For the ok to overcooked event, stated preference and consumer age group were significant, while country of residence was not.

Regression coefficients and  $\sigma$  values corresponding to Eqs. (3a) and (3b) for under-cooked and over-cooked data are in Table 2. The magnitude of the coefficients indicates that the factor most influencing rejection due to being under-cooked was stated preference, followed by country of residence and age group. Also, stated preference influenced rejection due to under-cooked more than rejection due to over-cooked. Age, on the other hand, influenced rejection due to over-cooked more than rejection due to under-cooked. These parameters can be used to relate percent consumer rejection to ICT for each event.

Fig. 1 shows how stated preference was distributed over countries. Argentina had the highest % who ask for beef "well-done", while USA had the highest % who ask for beef "rare"; Spain had the highest % who ask for beef cooked to "medium". Fig. 2a and b illustrate the effect of

Table 1  
Acceptance and rejection data for six consumers and their corresponding censoring

Consumers	55 °C	60 °C	63 °C	71 °C	77 °C	82 °C	Under-cooked rejection	Over-cooked rejection
1	1 <sup>a</sup>	1	1	0	2	2	Interval (63–71)	Interval (71–77)
2	1	1	1	1	1	1	Right (>82)	Right (>82)
3	1	0	0	0	2	2	Interval (55–60)	Interval (71–77)
4	1	1	1	0	0	0	Interval (63–71)	Right (>82)
5	1	0	1	1	1	0	Left <63 °C	Right (>82)
6	2	0	0	1	0	1	Not considered	

<sup>a</sup> 1: rejection due to under-cooked, 0: acceptance due to ok, 2: rejection due to over-cooked.

Table 2

Values of the regression coefficients  $\pm 95\%$  confidence intervals corresponding to the Weibull distribution for the under-cooked and over-cooked event (see Eqs. (3a) and (3b)).

Regression coefficients	Under-cooked	Over-cooked
$\beta_0$	$4.1712 \pm 0.06$	$4.3470 \pm 0.05$
$\beta$ Stated preference	$0.0745 \pm 0.02$	$0.0358 \pm 0.02$
$\beta$ Country	$-0.0100 \pm 0.01$	NS
$\beta$ Age	$0.0035 \pm 0.02$	$0.0233 \pm 0.02$
$\sigma$	0.0901	0.0537

NS: non significant.

stated preference on the percent rejection for young Argentine consumers. As expected, for a given ICT, for example 71 °C, the probability of rejection due to under-cooked is higher for those consumers that stated they prefer “well-done” beef (Fig. 2a). Fig. 2b shows that for a given ICT, for example 81 °C, the probability of rejection due to over-cooked is higher for those consumers that stated they prefer their beef “rare”. As observed from the coefficients in Table 2, differences due to stated preference are of higher magnitude for the under-cooked event (Fig. 2a) than for the over-cooked event (Fig. 2b).

Another issue that arises from observing Fig. 2 is the validity of the ICT range of the AMSA Color Guide. The 55 °C picture was rejected as under-cooked by almost all consumers, including those who stated they preferred “rare” beef (Fig. 2a). At the other extreme, the 82 °C picture was rejected as under-cooked by 29% of those consumers who stated they preferred their beef “well-done”. Fig. 2b shows that not all consumers found the 82 °C picture over-cooked; in fact, 65% of those who stated they preferred “rare” beef found this picture over-cooked, leaving a substantial 35% who did not find this picture over-cooked. These observations are also valid for Spanish and USA consumers. The AMSA Color Guide would have to be revised to shift the ICT range to higher values. This necessity probably is a measure of the success of campaigns

in different countries for consumers to avoid under-cooked meat for safety reasons.

Fig. 3 shows the country effect for young consumers who stated a preference for “well-done” beef. For the over-cooked event there is a single curve as country effect was not significant. For a given ICT, for example 75 °C, rejection probability due to the beef being under-cooked was 63%, 60% and 56% for consumers from Argentina, Spain and USA, respectively. The magnitude of country differences was small. Although sampling 102 consumers from one city is not representative of a country’s whole population, the small differences found between the cities suggests that similar results would have been obtained from a larger consumer sample in each country.

The effect of age group was significant but its magnitude was small as shown in Fig. 4. For the under-cooked event both age groups practically overlapped. For a given ICT, for example 82 °C, the middle-aged consumers tended to have lower rejection probability (16%) than the younger consumers (23%) due to the beef being over-cooked.

As shown by Garitta et al. (2006) in determining optimum strawberry yogurt color, the optimum ICT can be obtained by combining Fig. 2a and b as shown in Fig. 5. The minimums of the resulting curves are the desired optimums.

As country (Argentina, Spain and USA), age (young and middle-aged) and stated preference (rare, medium and well-done) were significant for the under-cooked event, a total of 18 optimum ICTs were calculated, one for each covariate combination. The optimum ICTs and corresponding % rejection at each one of them are in Table 3. Confidence intervals were in the order of 10% of the calculated optimum ICT’s. Garitta et al. (2006) confidence intervals for optimum yogurt color were of similar magnitude. These confidence bands are relatively wide, reflecting the uncertainty inherent in the censored data. Also, there were few consumers in some segments, which impacts the calculations and widens the confidence bands.

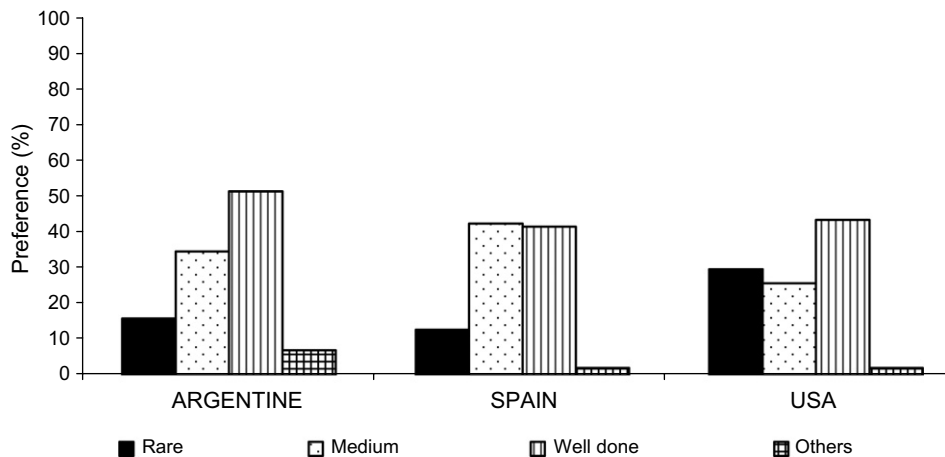


Fig. 1. Distribution of stated preference for degrees of doneness over country of residence.

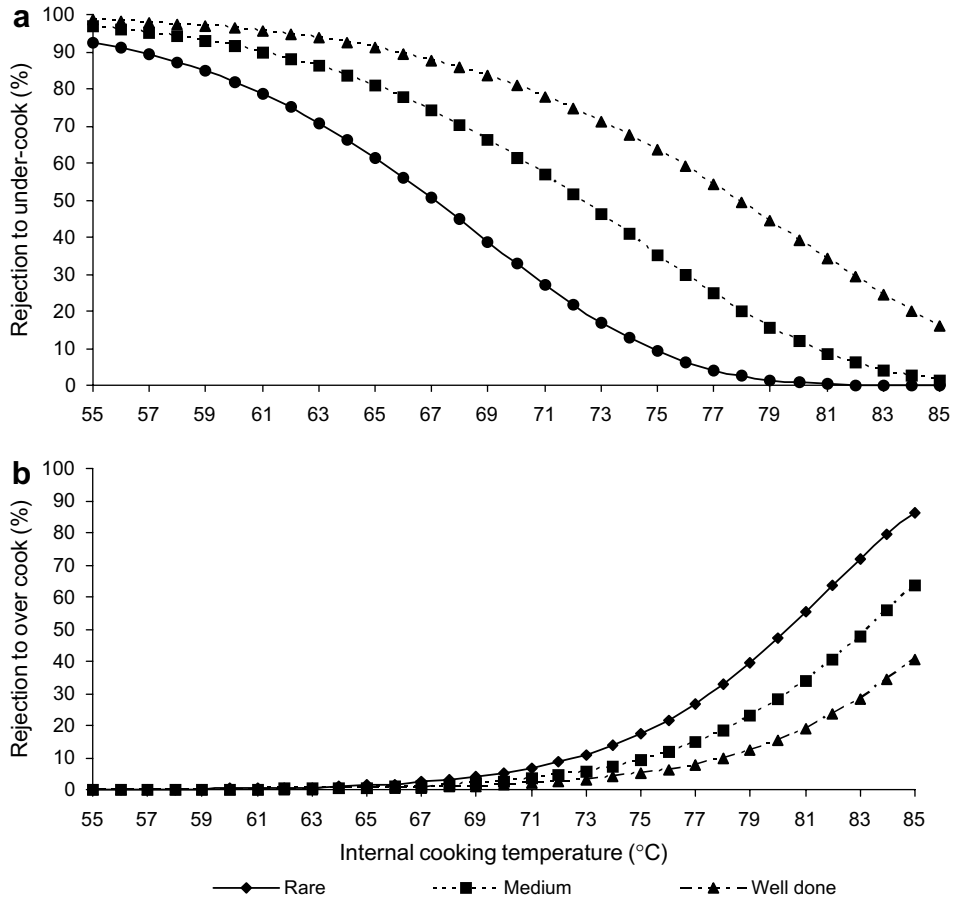


Fig. 2. Effect of stated preference of degree of doneness on the percent rejection to under-cooked beef (a) and to over-cooked beef (b) for young Argentine consumers.

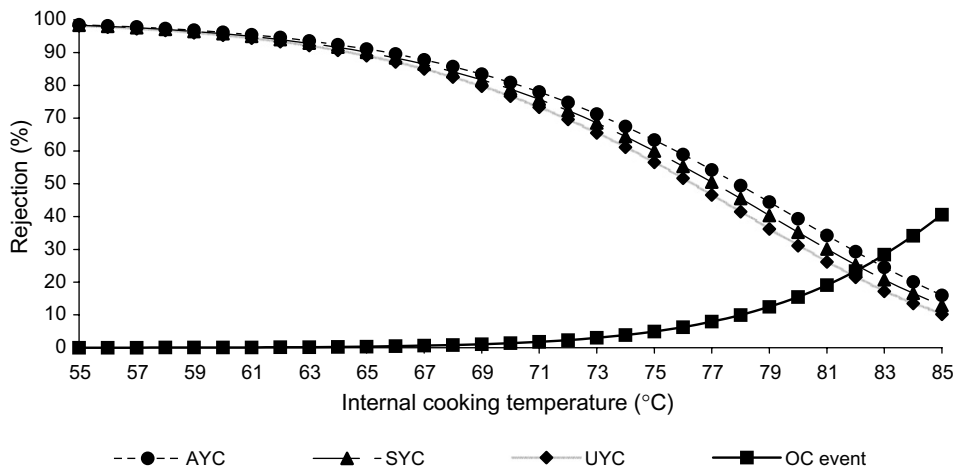


Fig. 3. Effect of country of residence on percent rejection due to under-cooked for Argentine young consumers (AYC), Spanish young consumers (SYC) and USA young consumers (UYC) who stated a preference for well-done beef (OC: over-cooked event was not influenced by country).

Stated preference influenced optimum ICT, but the other significant factors, country and age, did not. If a chef at an international restaurant receives, for example, a request for a well-cooked steak, he/she would not have to worry about the customers' country of residence (Argen-

tina, Spain or USA), as they all have approximately the same optimum ICT of 82 °C. What would be noticed would be a greater proportion of Argentine consumers asking for well-cooked steaks in relation to consumers from Spain or USA (Fig. 1).

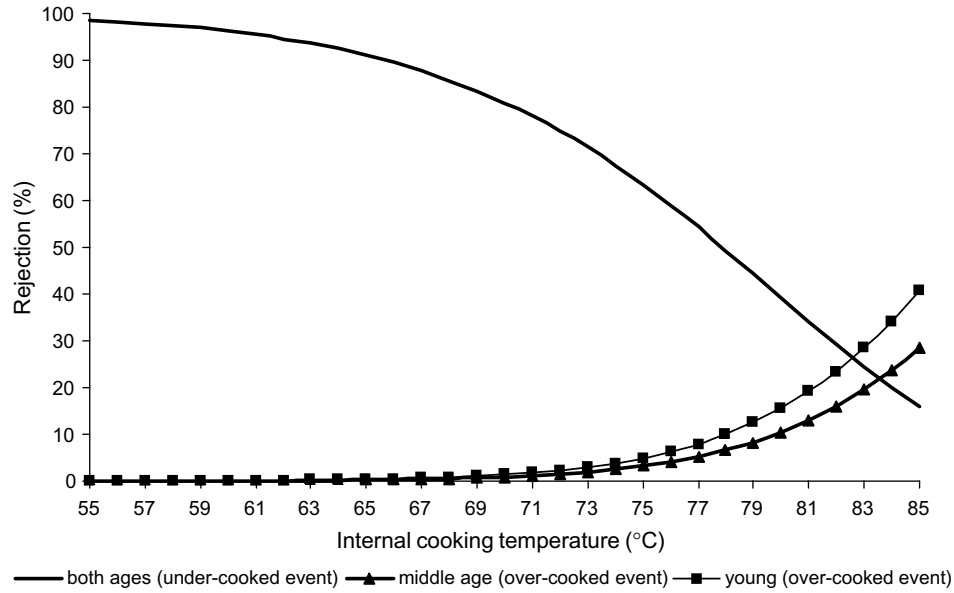


Fig. 4. Effect of age on percent rejection due to under-cooked and over-cooked for young and middle-aged consumers who stated a preference for well-done beef.

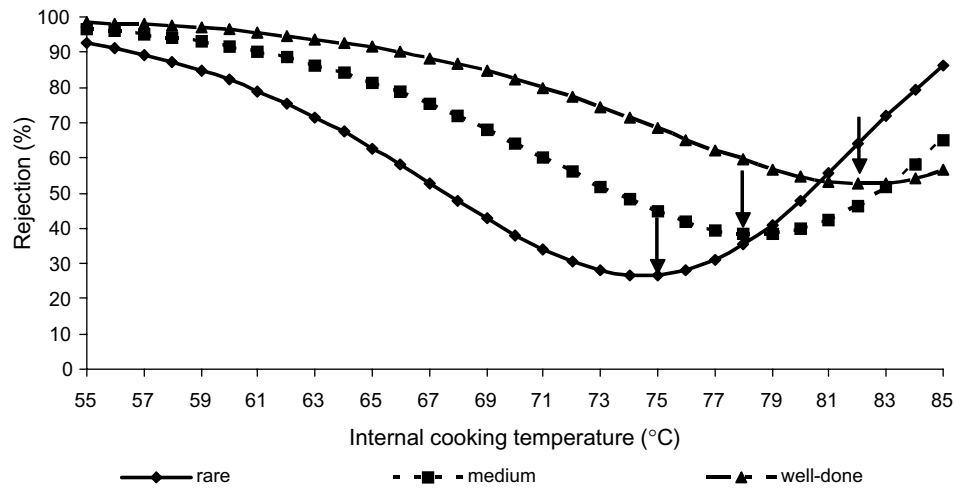


Fig. 5. Optimum cooking temperatures for young Argentine consumers (sum of under-cooked rejection + over-cooked rejection) who stated a preference for rare, medium and well done beef.

Estimated optimum ICT's were high. Goodson et al. (2002); Cox et al. (2006) and McKenna et al. (2004) in studies in different USA cities found that approximately 50% of consumers cooked their beef to "medium and less" and 50% to "medium well and more". In McKenna's study on consumers from San Antonio and Dallas only 4% consumers cooked their beef "very rare" or "rare". Our data on USA consumers is from Kansas, and showed that 54% answered "ok" for the pictures of "well done and more"; 46% answered "ok" for the pictures of "medium and less"; and 10% of the ok answers were "very rare" and "rare". Based on this information it would appear that our data are comparable to previous studies.

Interestingly, even those consumers who stated a preference for "rare" beef had an optimum significantly higher

than the 55 °C and 60 °C pictures. Consumers who stated a preference for "rare" beef, had 21% of their ok answers for "very rare" (55 °C) and "rare" (60 °C); while 35% of their ok answers were for "well-done" (77 °C) and "very well done" (82 °C). An optimum of 75 °C for this group is not surprising. This group's concept of "rare" is different from what is printed on the AMSA Color Guide. It is possible that some consumers felt they were not supposed to eat rare beef and, thus could have biased their answers upward towards higher temperatures than those they actually use. However, we do not think this is the case as eating beef steak cooked to "rare" is not a derogatory issue.

Percent rejections at the optimum ICTs were relatively high (Table 3). For example, the young Argentines who stated a preference for "medium" had an optimum ICT

Table 3

Optimum temperatures of cooking  $\pm 95\%$  confidence intervals and % rejection for young and middle-aged Argentine, Spanish and USA consumers with different degrees of doneness

Country	Age	Stated preference	Optimum temperature	% Rejection
Argentina	Young	Rare	75 $\pm$ 6.2	27
		Medium	78 $\pm$ 4.3	38.4
		Well done	82 $\pm$ 2.6	53
	Middle-aged	Rare	76 $\pm$ 7.7	27
		Medium	80 $\pm$ 6.7	32
		Well done	84 $\pm$ 3.6	45
Spain	Young	Rare	74 $\pm$ 16	24
		Medium	78 $\pm$ 4	35
		Well done	82 $\pm$ 5.3	49
	Middle-aged	Rare	75 $\pm$ 5	19
		Medium	79 $\pm$ 23	29
		Well done	84 $\pm$ 4.7	41
USA	Young	Rare	74 $\pm$ 5	22
		Medium	78 $\pm$ 3.7	32
		Well done	82 $\pm$ 5.1	44
	Middle age	Rare	75 $\pm$ 5.8	17
		Medium	79 $\pm$ 4.3	26
		Well done	83 $\pm$ 4.6	38

of 78 °C and a corresponding % rejection of 38%. This means that 62% of these consumers will be satisfied with this ICT, while 38% will not. Of these last, 20% will reject meat due to it being under-cooked and 18% will reject it due to the meat being over-cooked. The reason behind these relatively large % rejection values at the optimum ICTs is that the stated preference concepts were not uniform among consumers. What one consumer means when stating he/she likes beef cooked to “medium” does not necessarily coincide with what another consumer means by “medium”. Degree of doneness in beef is not easy to categorize in the mind of the consumer. It should be noted that in spite of these relatively high % rejections at the optimum ICTs, these are the “optimums”; thus other ICTs would have even higher % rejections.

#### 4. Conclusions

Survival analysis methodology was an adequate tool to estimate an optimum ICT of beef, based on consumer acceptability. The experimental sensory work applied in this study was relatively simple; only 102 consumers in a country had to decide if they found successive samples under-cooked, ok or over-cooked. The censored data set was sufficient to determine the optimum ICT. This methodology could be extended to other food products. Stated preference of degree of doneness was the covariate that most influenced under-cooked and over-cooked rejection probabilities (ITC). The influences of country of residence and age were of smaller magnitude.

The number of consumers who were not satisfied with the calculated optimum ICTs was relatively high. This means that when consumers say they want their steaks cooked to a determined degree of doneness it is difficult to understand what many of them really mean. Because

the optimum ICTs were high, revisions to the AMSA Color Guide should be considered to cover a higher ICT range.

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