COOKING LOSSES OF JUICE, HEME IRON, B3 AND B6 VITAMINS IN BEEF MEAT AS RELATED TO COOKING PRACTICES – CONSEQUENCES ON NUTRITIONAL VALUE OF MEAT

G. Gandemer[1,3], V. Scislowski[2], C. Duchène[3] and A. Kondjoyan[4]

[1] National Institute of Agronomic Research, Center of Lille, 2 chaussée Brunehaut, Estrées- Mons, 80207 Péronne, France

[2] ADIV, 10 rue Jacqueline Auriol, ZAC des Gravanches, 63039 Clermont Ferrand, cedex 2, France

[3] Centre d'Information des Viandes, Tour Mattei, 207 rue de Bercy, 75587 Paris cedex 12, France

[4] National Institute of Agronomic Research, UR370 QuaPA, 63122 St Genes Champanelle, France.

Abstract – Cooking leads to losses of juice and nutrients. To formulate accurate nutritional advices, it is required to know the extent of these losses depending on consumer cooking practices. The present paper deals with the losses of juice, B3, B6 vitamins and heme iron in beef meat cooked according to the main consumer practices in France. Results were that:

- **Grilling or pan frying meat led to small cooking losses (5-30%)**
- **Boiled and braised meats presented the highest losses (up to 75%). The highest losses were for iron and B6 because of a partial thermal degradation in addition to juice losses.**
- **Roasted meat had intermediate losses (20-35%).**

Cooking losses caused by long time cooking (braising and boiling) must be taken into account for the evaluation of the nutritional supplies in B vitamins and iron by cooked meat.

Key Words – Cooking mode, nutritional value, meat, B3 and B6 vitamins, total and heme iron .

I. INTRODUCTION

Meat is eaten quasi-exclusively after cooking. During cooking, numerous physical and chemical reactions occur as temperature increases in meat. The most important phenomenon is protein denaturation which starts when temperature in meat increases above 60°C. The consequences are a decrease in water holding capacity of meat and shrinkage of muscle causing juice expulsion out of meat [1]. Juice expulsion sweeps along a partial loss of soluble nutrients (myoglobin, B vitamins, nucleotides, free amino-acids) contained in raw meat. Additional cooking losses can occur through a partial degradation of thermo-sensitive nutrients such as B6 vitamin or heme iron. All these phenomena affect the nutritional value of cooked meat. Consequently, it's of main interest to quantify nutrient losses during cooking to deliver proper nutritional information on meat according to the main consumer practices. Data available in the literature are mainly related to raw meat. Data on cooked meat are sparse and cooking conditions are not always well described. Consequently, it is difficult to have a clear understanding of the consequences of cooking on the nutritional value of meat. Since 2010, Kondjoyan and co-workers have developed models describing the kinetics of nutrient losses in meat according to a broad range of time-temperature conditions [2, 3, 4]. Such models were built for juice and for 4 nutrients (B3 and B6, and total and heme iron) for which we have observed a significant loss in extreme cooking conditions. According to these models, we have established tables including cooking yields of the whole meat cut and those of the 4 nutrients listed above for the main French cooking practices. The present paper is focused on the calculation of the content of cooked meat in the 4 nutrients in according to consumer practices and on the consequences of cooking on the nutritional value of beef meat.

II. MATERIALS AND METHODS

Juice and nutrient yield calculations. From models, we have calculated cooking yields for the whole cut and iron (total and heme), B3 and B6 according to the different cooking modes (grilling, pan frying, roasting, boiling, braising) and doneness (from very rare to well-done). For each mode-doneness couple, results were given with a range of several percents taking into account parameters uncontrolled by consumers and which influence cooking yields (water content of raw

meat, type of materials, initial temperature of meat …). Results are presented in table 1. Very rare, rare and well-done corresponded to an endpoint cooking temperature at meat core ranging from 21-30°C, 47-53°C and over 60°C respectively.

Table 1 Cooking yields for meat weight, iron and heme iron and B3 and B6 vitamins according to the cooking mode and doneness.

Cooking		Cooking yield (%)			
Mode	doneness	Weight	Total & heme iron	B3	B6
grilled or pan fried	Very rare	90-95	90-95	90-95	90-95
	rare	80-85	80-85	80-85	80-85
	well-done	70-75	70-75	70-75	70-75
roast	rare to well-done	65-80	70-85	65-80	60-80
braised	well-done	55-70	30-55	55-70	30-55
boiled	well-done	50-65	25-50	50-65	25-50

Evaluation of the effects of cooking on the nutritional value of meat. B3, B6, total and heme iron were measured in shoulder clod of 16 cows as previously described [5]. This muscle was chosen because it can be cooked in all the cooking modes. The composition of cooked meat was calculated by multiplying nutrient content in raw meat by its cooking yields (mean, maxi, mini) for all the mode-doneness couples. Results were expressed as mg per portion of cooked meat obtained by cooking 100g of raw meat. The weight of cooked meat portion was calculated using the cooking yield. To evaluate the consequences of cooking, the nutrient contents of meat were compared to the Daily Reference Intake (DRIs) for an adult [6] and were expressed in percent of the corresponding DRI. The DRIs expressed as mg/day were 14 for total iron, 16 for B3 and 1.40 for B6. No DRI was defined for heme iron.

III. RESULTS AND DISCUSSION

Results are reported in table 2 for B vitamins and table 3 for total and heme iron. Mean, maxi and mini values for a given nutrient on the same raw referred to variability in the content of nutrients in raw meat. In contrast, mean, maxi and mini in column referred to the variability of cooking yields for each cooking mode. Note that the nutrient contents of cooked meat are expressed as g per portion of cooked meat coming from 100g raw meat in the corresponding cooking mode. Thus, roasting 100 g raw meat with a 65% cooking yield leads to a 65g cooked portion.

Grilled and pan fried meat. Cooking losses remained low whatever the final doneness (5 to 25%). This is explained by short cooking times and relatively low temperatures in the core of meat (21-60°C). Cooking yields slightly decreased from very rare to well-done (5-10% to 25-30%). The higher the internal temperature in meat the higher was the amount of juice expulsed from meat. Similar trends were observed for both vitamins and iron. The losses in the 4 nutrients were equal to global cooking yield (from 5-10% to 25-30%). No additional loss due to thermal denaturation was observed because temperature in meat was too low to cause significant denaturation of nutrients. The relative contributions of cooked meat portion to DRIs of the 4 nutrients were in the same range as those of raw meat (15-31% versus 22-33% for B3, 17-41% versus 25-43% for B6, for total iron). Variations in the 4 nutrients due to cooking mode and doneness remained lower than the variations observed in raw meat. Indeed, variations in nutrient contents in raw meat were high from one animal to another (from 40 to up to 50%). So estimating B3, B6, total and heme iron supplies by 100g raw meat cooked on a grill or in a pan from the nutritional composition of raw meat does not induce significant errors.

Braised and boiled meat. Cooking yields were very low (50-65%) because the temperature in meat remained over 70°C for a long time (1.5 to 3 h). This causes intense protein denaturation and collagen shrinkage enhancing juice expulsion. The range in cooking yields was wide because of the large range in cooking time (for 1.5 to more than 3h) and the different types of cooking materials (simple pot or pressure cooker) used by consumers. In braised meat, core temperature in meat was between 75-85°C while it reached 90-100°C in boiled meat. That is why cooking yields of the whole cuts were lower for boiled meat (50-65% *vs* 55-70%). Cooking yields of B3 were similar to those of whole meat cuts as a conjunction of three facts. First, B3 is a soluble vitamin.

Table 2. B3 and B6 vitamin contents of cooked meat as related to cooking mode and meat doneness.

Cooking		Portion weight		B3 content in raw or cooked meat portion						B6 content in raw or cooked meat portion					
Mode	doneness		(g)	Mean (mg)	% DRI	***Min*** (mg)	% DRI	***Max*** (mg)	% DRI	Mean (mg)	% DRI	***Min*** (mg)	% DRI	***Max*** (mg)	% DRI
Raw			100.0	4.43	28	3.50	22	5.20	33	0.44	32	0.35	25	0.60	43
Grilled or pan fried	very rare	**Mean**	**92.5**	**4.09**	**26**	**3.24**	**20**	**4.81**	**30**	**0.41**	**29**	**0.32**	**23**	**0.55**	**39**
		Maxi	95.0	4.20	26	3.33	21	4.94	31	0.42	30	0.33	23	0.57	41
		Mini	90.0	3.98	25	3.15	20	4.68	29	0.40	28	0.31	22	0.54	38
	rare	**Mean**	**82.5**	**3.65**	**23**	**2.89**	**18**	**4.29**	**27**	**0.37**	**26**	**0.28**	**20**	**0.49**	**35**
		Maxi	85.0	3.76	24	2.98	19	4.42	28	0.38	27	0.29	21	0.51	36
		Mini	80.0	3.54	22	2.80	18	4.16	26	0.35	25	0.28	20	0.48	34
	well-done	**Mean**	**72.5**	**3.21**	**20**	**2.54**	**16**	**3.77**	**24**	**0.32**	**23**	**0.25**	**18**	**0.43**	**31**
		Maxi	75.0	3.32	21	2.63	16	3.90	24	0.33	24	0.26	18	0.45	32
		Mini	70.0	3.10	19	2.45	15	3.64	23	0.31	22	0.24	17	0.42	30
Roasted	rare to well-done	**Mean**	**72.5**	**3.21**	**20**	**2.54**	**16**	**3.77**	**24**	**0.32**	**23**	**0.25**	**18**	**0.43**	**31**
	rare	Maxi	80.0	3.54	22	2.80	18	4.16	26	0.35	25	0.28	20	0.48	34
	well-done	Mini	65.0	2.88	18	2.28	14	3.38	21	0.27	19	0.21	15	0.36	26
Braised	well-done	**Mean**	**62.5**	**2.77**	**17**	**2.19**	**14**	**3.25**	**20**	**0.19**	**13**	**0.15**	**10**	**0.25**	**18**
		Maxi	70.0	3.10	19	2.45	15	3.64	23	0.24	17	0.19	14	0.33	23
		Mini	55.0	2.43	15	1.93	12	2.86	18	0.13	9	0.10	7	0.18	13
Boiled	well-done	**Mean**	**57.5**	**2.54**	**16**	**2.01**	**13**	**2.99**	**19**	**0.14**	**10**	**0.11**	**8**	**0.19**	**14**
		Maxi	65.0	2.88	18	2.28	14	3.38	21	0.22	16	0.17	12	0.30	21
		Mini	50.0	2.21	14	1.75	11	2.60	16	0.11	8	0.09	6	0.15	11

DRI = Daily Reference Intake for an adult in French population.

Secondly, its concentration in expulsed juice is similar to that in the juice remaining in meat. Third, it does not undergo thermal denaturation. In contrast, B6, and both total and heme iron showed lower cooking yields than B3. This is due to a significant additional thermal denaturation for these nutrients resulting in an exposure to high temperature (60°C to 100 °C) for long times (over 1.5 h). The additional losses related to thermo-denaturation were comprised between 10-15% but reached 25% when meat was cooked in a pressure cooker. Consequently, as 100 g raw meat contained in mean 4.4 mg B3, 0.44 mg B6, 2.86 mg total iron and 1.90 heme iron, the contents of these nutrients in braised or boiled meat dropped down to 2.2-3.1 mg for B3, 0.11-024 for B6 , 0.7-1.6 mg for total iron and 0.5-1.0 for heme iron. These data clearly show that these modes of cooking divided, at least, by two the amount of B6 and iron in meat portion. This throws new light on the relationships between meat iron and human health. Even if braised and boiled meats supply half heme iron compared to raw and grilled meats, they remain an interesting source of iron because of the high absorption efficiency of heme iron and the positive effect of meat proteins on non heme iron absorption. Secondly, as red meat through putative mechanisms such as oxidation by heme iron is held up as risk factor for colorectal cancer, the reduction in heme content of meat during cooking process must reduce this potential risk.

Roasted meat. Global yield and yields of the 4 nutrients of roasted meat were intermediate between those of grilling and braising or boiling modes (65-80%). The highest values corresponded to rare roasted meat cut immediately while the lowest ones corresponded to meat cooked well-done and carved after several minutes at room temperature. An additional loss due to thermal denaturation was observed only for B6 (5%).The nutrient content of roasted portions was lower than in raw meat but not significantly different because of the large variability in the amounts of these nutrients in raw meat.

Table 3. Total and heme iron contents of cooked meat as related to different cooking modes and doneness.

Cooking		Portion weight		Total Iron content in raw or cooked meat portion						Heme iron content in raw or cooked meat portion		
Mode	doneness		(g)	Mean (mg)	% DRI	***Min*** (mg)	% DRI	***Max*** (mg)	% DRI	***Mean***	***Min***	***Max***
Raw			100.0	2.86	20	1.89	13	3.57	26	1.90	1.51	2.54
Grilled or pan fried	very rare	**Mean**	**92.5**	**2.64**	**19**	**1.75**	**12**	**3.31**	**24**	**1.76**	**1.40**	**2.35**
		Maxi	95.0	2.71	19	1.79	13	3.39	24	1.80	1.43	2.41
		Mini	90.0	2.57	18	1.70	12	3.22	23	1.71	1.36	2.29
	rare	**Mean**	**82.5**	**2.36**	**17**	**1.56**	**11**	**2.95**	**21**	**1.57**	**1.25**	**2.10**
		Maxi	85.0	2.43	17	1.61	11	3.04	22	1.61	1.28	2.16
		Mini	80.0	2.28	16	1.51	11	2.86	20	1.52	1.21	2.03
	well-done	**Mean**	**72.5**	**2.07**	**15**	**1.37**	**10**	**2.59**	**19**	**1.38**	**1.10**	**1.84**
		Maxi	75.0	2.14	15	1.42	10	2.68	19	1.42	1.13	1.91
		Mini	70.0	2.00	14	1.32	9	2.50	18	1.33	1.06	1.78
Roasted	rare to well-done	**Mean**	**72.5**	**2.21**	**16**	**1.46**	**10**	**2.77**	**20**	**1.47**	**1.17**	**1.97**
	rare	Maxi	80.0	2.43	17	1.61	11	3.04	22	1.61	1.28	2.16
	well-done	Mini	65.0	2.00	14	1.32	9	2.50	18	1.33	1.06	1.78
Braised	well-done	**Mean**	**62.5**	**1.21**	**9**	**0.80**	**6**	**1.52**	**11**	**0.81**	**0.64**	**1.08**
		Maxi	70.0	1.57	11	1.04	7	1.97	14	1.04	0.83	1.40
		Mini	55.0	0.86	6	0.57	4	1.07	8	0.57	0.45	0.76
Boiled	well-done	Mean	57.5	1.07	8	0.71	5	1.34	10	0.71	0.57	0.95
		Maxi	65.0	1.43	10	0.94	7	1.79	13	0.95	0.76	1.27
		Mini	50.0	0.71	5	0.47	3	0.89	6	0.47	0.38	0.64

IV. CONCLUSION

Cooking causes losses in B3, B6 and iron in meat whatever the cooking modes or doneness which were significant only for long cooking modes such as braising or boiling. This must be taken into account to deliver proper nutritional advices notably for iron for which sub-deficiency are often observed in European populations.

REFERENCES

1. Lawry R.A. The eating quality of meat. In Meat Science 5th Ed (pp 184-224), Pergamon Press.
2. Ollic S., Lemoine E., Gros J.B., Kondjoyan A. (2011). Kinetic analysis of cooking losses from beef and other animal muscles heated in a water bath — Effect of sample dimensions and prior freezing and ageing. Meat Science 88: 338-346.
3. Portanguen S., Duchène C., Gandemer G., Kondjoyan A. (2012). Utilisation de modèles de transferts et de réactions pour déterminer les pertes en micronutriments au cours de la cuisson des viandes. Illustration de l'approche dans le cas de la vitamine B6. In actes des Journées Sciences du Muscle et Technologies des Viandes (pp101-102), 11-12/11/2012, Caen, France
4. Scislowski V., Gandemer G., Kondjoyan A. (2011). Changes in heme iron content in beef meat during wet heating. Consequences for human nutrition. In Proceedings of 57th International Congress of Meat Science and Technology, 7-12th August 2011. Ghent, Belgium.
5. Bauchard D., Chantelot F., Gandemer G. (2008). Qualités nutritionnelles de la viande et des abats chez les bovins : Données récentes sur les principaux constituants d'intérêt nutritionnel. Cah. Nutr. Diét., 43, 1s29-1s39.
6. Regulation (EU), No 1169/2011 of European Parliament and of council of 25 October 2011 on the provision of food information to consumers. OJ L 304, 22.11.2011, p18-63.