A KINETIC MODEL TO SIMULATE THE EFFECT OF COOKING TIME-TEMPERATURE ON THE GASTRIC DIGESTION OF MEAT

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Introduction

There is an increasing consumer demand for processed beef meat. However, during processing, the biochemical and structural changes of proteins can modify their digestion rate which is preponderant for their assimilation. This assimilation can impact muscle disease (sarcopenia) or colon cancer. Present work deals with the development of a kinetic model to predict the effect of cooking time and temperature on the gastric digestibility of myofibrillar proteins coming either from slices of beef meat heated in water bath or from a piece of meat roasted in a domestic oven.

Modeling approach

In vitro digestibility by pepsin of the myofibrillar proteins extracted from processed meat samples is determined by measuring the quantity of hydrolysed peptides (PM< 15 kDa) which increase the optic density (OD) of the solution. In a first approach, a first order reaction model has been chosen to describe the formation of the hydrolyzed peptides. This leads to the primary model (1). A secondary model is added to take into account the effect of temperature on k and Od_{max}.

Primary model

$$OD = OD_{max}\,(1-e^{-kt}) \qquad (1a)$$

$$OD_{max} = \delta_{max} \frac{E_T^{pH}}{E_T^{pH} + K} \qquad (1b)$$

$[E_T^{PH}]$: concentration of the active pepsin ;
k: rate constant of the enzymatic reaction ;
δ_{max} : factor of proportionality ;
K: cte has to be determined from experiments.

Secondary model

OD_{max} and the rate constant k vary with cooking time as:

$$X_{th} = (X_0 - X_{end}).\exp(-\alpha t_h) + X_{end} \qquad (2)$$

X_0: initial value of the parameter either k or OD_{max};
X_{end}: stable value obtained after a long heat treatment time;
t_h: time scale of heat denaturing which is rated by α.

Confrontation of model with experimental results

In a first step, model performance was tested by varying process conditions on slices of beef meat (Table 1). Proteolysis was measured following the procedure of Hassoun et al. (2011) and Bax et al. (2012)*. In a second step, experiments were performed using pieces of beef meat cut from frozen muscles, thawed and then roasted in an air oven. Two samples of 10 g of meat were taken for proteolysis measurements: one at the surface of the roast and one at core. The experiment was repeat at least three times.

Factors	Levels
NaCl	0.7%, no salt
pH	5.5
Muscles	*Infraspinatus (IS), Semitendinosus (ST), Semimembranosus (SM)*
Cooking temperatures (°C)	60, 70, 90, 250
Cooking method	Water bath, air oven
Red: on slices 2mm thickness Green: on piece of meat (110x60x60mm).	

Table 1: Experimental design.

Primary model at $[E_T^{pH}]$ = cte

If (1ab) are true and $[E_T^{pH}]$ is constant then relation (3) shall be verified using the same value of k for the 4 replicates.

$$\frac{OD}{OD_{max}} = 1 - e^{-kt} \qquad (3)$$

This was tested on slices for the 96 conditions. Results are illustrated in Fig. 1 for one case but the conclusion is the same under all the studied conditions. The average confident interval on the values of k was 9.6%.

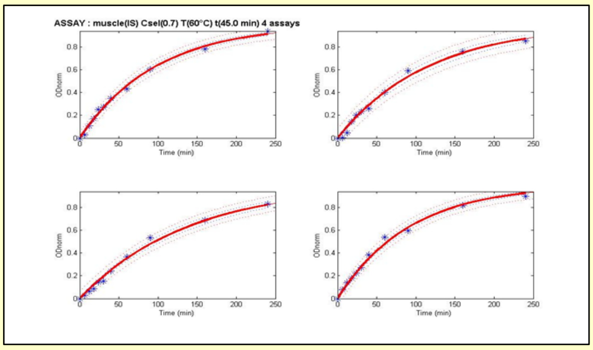
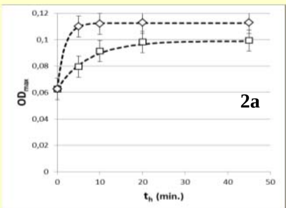


Figure 1: Test of relation (2) on 4 experimental replicates.

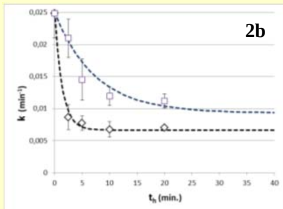
Secondary model

The secondary model (2) is able to describe the variation of k and OD_{max} due to process conditions. The main variations are due to temperature conditions which vary between 60 and 90 °C.

Figures 2a and 2b :



Evolution of OD_{max} and k with the heating time t_h (fig. 2a and 2b respectively), 60 °C, squares, and 90 °C, diamonds. Dotted lines represent the results calculated from the relation (2).



Effect of temperature on the digestion of meat slices

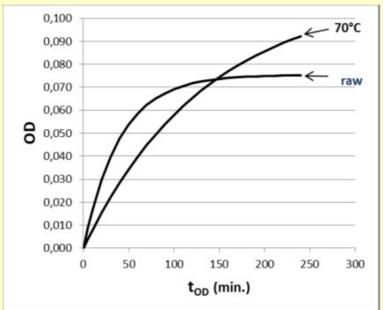


Figure 3: Variation in digestibility due to an increase in the cooking temperature was subjected to two opposing effects: (i) an increase in OD_{max}, and (ii) a decrease in k. Thus, the effect of cooking on the global *in vitro* digestibility depends on the digestion-time. For example raw meat is more digestible than the meat heated at 70 °C during the first two hours of gastric digestion and then it is the contrary.

Digestion of roasted meat

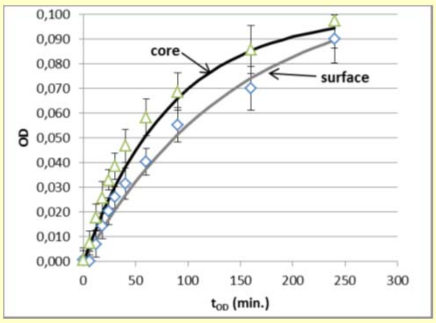


Figure 4: OD values predicted by our calculations using the temperatures measured during oven cooking are compared to the OD measured on the samples taken at two locations in the roast. In this case, the digestibility at the core of the roast is higher than at the surface due to the decrease in k with temperature which predominates on the increase in OD_{max} with temperature. Predictions issued from the model agree with the *in vitro* measurements.

Conclusion

Mathematical model was developed to predict the *in vitro* digestibility of myofibrillar proteins by pepsin. The model is able to simulate the results for meat pieces of different sizes cooked under different conditions. The effect of heating on digestibility depends on the digestion-time which *in vivo* can be linked to the residence time in the stomach. Model equations can also take into account the variation of pepsin activity with pH and the effect of enzyme concentration on digestibility (not detailed here). This can help to analyse the *in vivo* digestion of meat taking into account the fact that pepsin concentration and pH vary in the stomach depending on the meal and, on the physiology of the consumer.

*Hassoun et al. (2011). Incidence of various process parameters on *in vitro* protein digestibility of beef meat. 57th ICoMST, p140-141, Ghent, Belgium.
Bax et al. (2012). Cooking conditions affect *in vitro* meat protein digestion. J of Agri and Food Chem 60: 2569-2576.

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