

FOOD SYNERGY: THE EFFECT OF EATING KIWIFRUIT ON THE DIGESTION OF MEAT

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Abstract – Meat, like most other foods, is not usually eaten in isolation, and other foods eaten together with meat can modulate the digestion of meat in the stomach and small intestine. Kiwifruit has a proteolytic enzyme, actinidin, that can play a considerable role in enhancing the breakdown of meat proteins during digestion. We review a series of experiments from our laboratory using *in vitro* and *in vivo* human models (rats and pigs) to illustrate this effect and describe the benefits of eating kiwifruit as part of a meal containing meat.

Key Words – Food synergy, kiwifruit, protein digestion, stomach emptying.

I. INTRODUCTION

Kiwifruit (*Actinidia deliciosa*) are well known to contain a proteolytic enzyme, known as actinidin (or sometimes actinidain), [1,2] that has meat tenderising properties [3]. Given the demonstrated ability of the enzyme to tenderize meat, we hypothesized that actinidin might have post-consumption effects on the digestion of meat protein.

This paper reports an overview of a range of *in vitro* and *in vivo* studies that demonstrate the type and scope of effects of consumption of kiwifruit as part of a meal on the digestion of meat.

II. MATERIALS AND METHODS

In vitro digestion

Digestion experiments were carried out *in vitro* using a simple chemostat at 37°C using pepsin at pH 2.0 for 30 minutes to simulate gastric digestion and subsequent digestion using pancreatin at pH 8.0 for 3 hours to simulate small intestine digestion. The digestion of individual meat

proteins was determined using quantitative SDS-PAGE.

In vivo gastric digestion

Rat study: Rats were fed a meal containing meat with either green kiwifruit (*Actinidia deliciosa* cv “Hayward”: actinidin diet) or gold kiwifruit (*Actinidia chinensis* cv “HORT 16A”, which has no actinidin activity: control diet) as part of a balanced diet. Overall gastric protein hydrolysis was determined based on the release of free amino groups (*o*-phthalaldehyde method). In addition the hydrolysis of individual meat proteins was determined using quantitative SDS-PAGE.

Pig study: Growing pigs (n=120) were fed a meal containing meat and green kiwifruit and control diets with either gold kiwifruit, gold kiwifruit supplemented with commercially available actinidin, or green kiwifruit which had been treated to inactivate actinidin activity. The overall degree of protein hydrolysis and the digestion of individual proteins were determined as above.

In vivo stomach emptying rate

Rats were gavaged with a mixture that contained the same experimental diets used in the above described rat study and aluminum chloride, an indigestible marker. Stomach emptying in rats was determined in real time using whole body NMR and measuring ²⁷Al, which shows a loss of signal as it passes from the acid environment of the stomach to the neutral environment of the duodenum.

III. RESULTS AND DISCUSSION

In vitro experiments showed that the SDS-PAGE pattern of the protein digested for 30 min in the presence of pepsin and kiwifruit extract was quite

different from the one of protein digested with pepsin alone. All of the bands above 25 kDa were observed either to decrease in intensity or to disappear completely, indicating that actinidin enhanced the digestion of beef muscle protein under conditions present in the stomach [4], although little additional effect was seen following further digestion under conditions of the small intestine [5].

Experiments using rats fed a diet containing meat and kiwifruit (either green or a gold control) showed a substantial increase in gastric degradability of major meat proteins in the presence of green kiwifruit (i.e. actinidin) [6] (Table 1). The overall gastric digestion of meat protein, based on the free amino groups approach, increased from 9 to 15% [7].

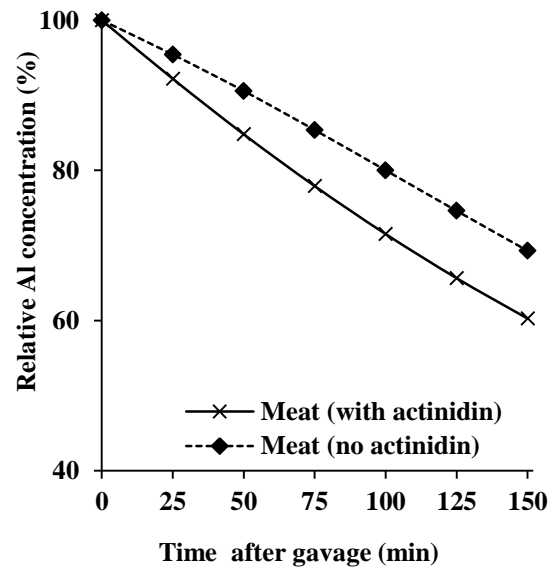
Table 1 Digestion of meat proteins by rats in the presence and absence of actinidin as determined by quantitative SDS-PAGE

Protein	% Mean Degradability	
	Green kiwifruit (n=7)	Control (n=8)
Myosin heavy chain	74***	38
β -Actinin	66**	14
α -Actinin	63***	5
Actin	55***	10
Myosin light chain 1	34*	8
Myosin light chain 2	49 ^{ns}	31

ns not significant; * p<0.05; ** p<0.01; *** p<0.001.

Direct measurement of ²⁷Al using whole body NMR showed a decreased stomach emptying time in the presence of actinidin (for example the calculated half-time for gastric emptying was reduced from 260 to 144 min) as seen in Figure 1[7].

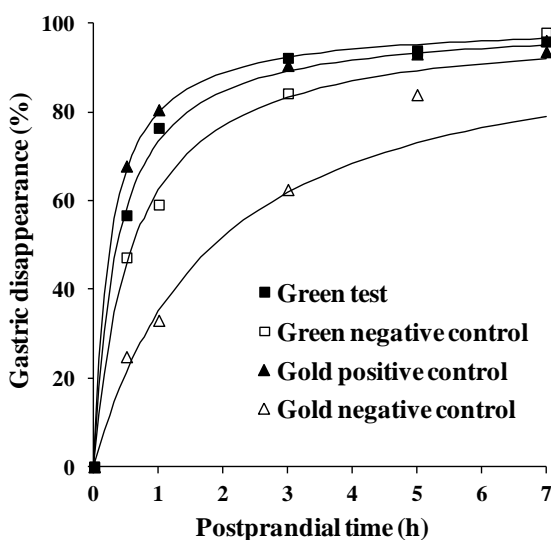
Figure 1



Relative gastric Al concentration (i.e. dry matter stomach retention) of growing rat gavaged a meat diet with or without actinidin; pooled-SEM = 3.64 [7].

The pig study showed an increased stomach emptying rate (for dry matter and for total N) and a greater rate of gastric protein hydrolysis (based on free amino groups) in the presence of actinidin (e.g. at 3 h postprandial the degree of gastric protein hydrolysis increased from 14 to 24%) [8]. SDS-PAGE showed enhanced gastric digestion of most meat proteins in the presence of actinidin [8] (Figure 2). Both a higher stomach emptying rate and gastric protein digestion rate suggest an enhanced rate of protein digested released into the small intestine, which may also result in more rapid uptake of amino acids from the small intestine (e.g. at the medial jejunum the true serine digestibility increased from 69 to 94% when actinidin was present in the meat diet) (Montoya et al., unpublished).

Figure 2.



Fitted curves for disappearance of myosin heavy chain for pigs fed a meat diet and green kiwifruit (■); gold kiwifruit (Δ); gold kiwifruit plus actinidin (▲) and heat-treated green kiwifruit (□); pooled-SEM= 4.99 [8].

IV. CONCLUSION

Consumption of green kiwifruit enhances digestion of myofibrillar proteins of meat in *in vitro* systems, in rats and in growing pigs. It is likely that it will also improve gastric and small intestinal digestion of meat in humans.

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