

Post-ingestive effects of avocados in meals on satiety and gastric hormone blood levels

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INTRODUCTION

The inclusion of a whole food at a meal that is capable of prolonging satiety is very relevant for weight management among overweight adults. Satiety is a complex process that involves psychological and biological factors including the post-ingestive release of glucose, insulin and gastric hormones. Avocados are a nutrient dense whole food with characteristics that may impact the release of biological factors and favorably prolong appetite sensations. Hence, the objectives of this study were to evaluate if consumption of approximately one half of a Hass avocado by addition or inclusion to a lunch meal will influence self-reported post-ingestive satiety and specific biological factors among overweight adults.

Key words (English): Insulin, Ghrelin, Leptin, Gastric inhibitory peptide, Glucagon-like peptide-1, Peptide YY

MATERIALS AND METHODS

A randomized 3x3 crossover design was used in 26 healthy overweight subjects (mean \pm SD age 40.8 ± 11.0 years; and, BMI 28.1 ± 2.4 kg/m²). Subjects consumed lunch test meals on three 1-day study periods (scheduled 1 week apart): Control (C), avocado-free; Avocado Inclusive (AI), a meal containing avocado matched with the C meal for energy; and, Avocado Added (AA), the C meal plus avocado. Fasting blood samples were obtained before and at 0.5, 1, 2 and 3h following lunch for insulin, glucose, ghrelin, leptin, gastric inhibitory peptide (GIP), glucagon-like peptide-1 (GLP-1), and peptide YY (PYY). Visual analog scales (VAS) were administered to evaluate 5 appetite sensation measurements related to satiety before lunch and over 5 hours following the start of the lunch test meal. The area under the curve (AUC) was computed for the VAS and the biological factors using the linear trapezoidal rule at the aforementioned time points over 5 and 3 hours, respectively. Additionally, mixed models were used to evaluate the differences among the 3 lunch test meals for the 5 gastric hormones over 3 hours. All of the statistical analyses were performed using SAS version 9.3 (SAS Institute, Cary, NC, USA).

RESULTS

Figure 1 shows the blood glucose and insulin levels after consumption of the 3 lunch test meals (Wien *et al.*, 2013). The AUC(0-3h) for blood insulin was higher in the C and AA lunch test meals as compared to the AI lunch test meals ($P=0.04$ and $P=0.05$, respectively) in the context of equivalent changes in blood glucose (Wien *et al.*, 2013).

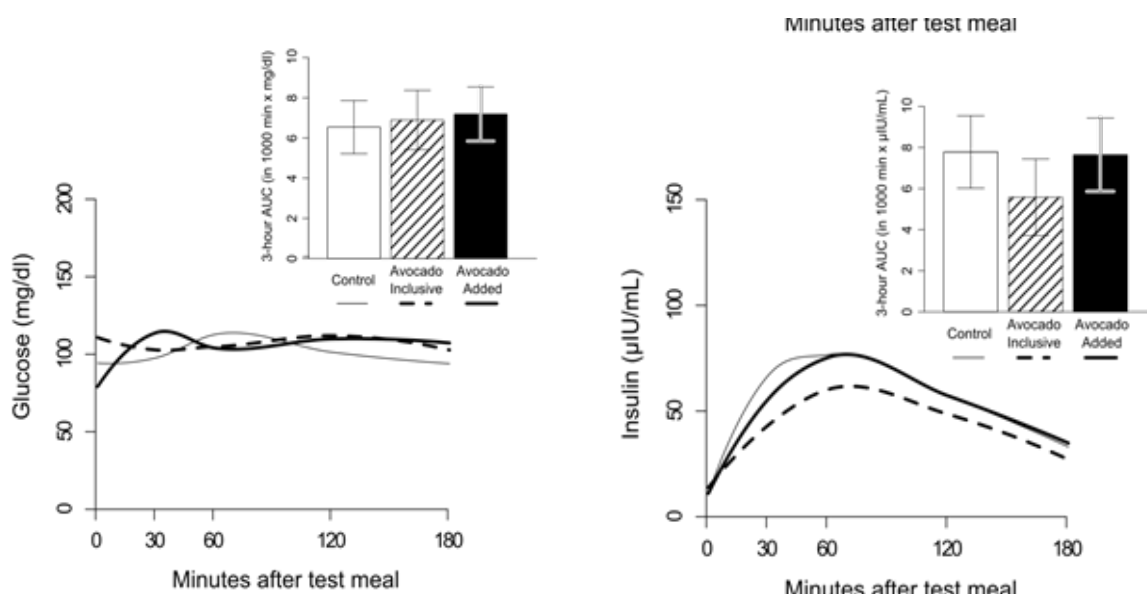


Figure 1. Blood glucose and insulin levels after consumption of the 3 lunch test meals.

RESULTS (CONT.)

Significant differences in self-reported feelings of satisfaction and desire to eat were found in the AUC mixed model analysis. Compared to the C lunch test meal, the AA lunch test meal increased satisfaction by 23% ($P=0.05$) and decreased the desire to eat by 28% ($P=0.04$) over 5 hours (Wien *et al.*, 2013). Further, the AA lunch test meal increased satisfaction by 26% ($P=0.02$) and decreased the desire to eat by 40% ($P=0.01$) over 3 hours as compared to the C lunch test meal (Wien *et al.*, 2013).

No differences were found among the lunch test meals for ghrelin, GIP, GLP-1 and PYY. The repeated measures analysis showed that there was a lunch test meal x time interaction for leptin ($P=0.05$). Compared to the C lunch test meal, leptin levels were 22% and 52% higher for the AI lunch test meal at the 0.5 ($P=0.04$) and 3h ($P<0.0001$) time points, respectively.

Lastly, the mixed model AUC analysis showed a lunch test meal effect for GLP-1 ($P=0.04$) (Table 1). Compared to the C lunch test meal, the estimated AUC (0-3h) above baseline levels for GLP-1 was found to be equivalent for the AI lunch test meal ($P=0.92$) and lower in the AA lunch test meal ($P=0.03$).

Table 1. Estimated 3h AUC above baseline (minute x log of each measurement)

	Control (C)		Avocado Inclusive (AI)		Avocado Added (AA)		P-value ^b	P-value ^c	P-value ^c
	LSMd	SE	LSM	SE	LSM	SE			
Ghrelin	-29.70	15.15	-25.83	15.91	1.80	15.46	0.30	0.86	0.15
Leptin	-11.63	11.19	-11.52	12.76	-11.09	11.17	0.99	0.99	0.97
GIP	196.99	18.85	203.64	21.60	227.60	19.60	0.33	0.78	0.16
GLP-1	37.14	24.11	39.07	24.56	-7.32	24.28	0.04	0.92	0.03
PYY	47.37	12.64	38.32	13.54	37.35	12.90	0.80	0.59	0.54

m Measurements were log-transformed and the AUC(0-3h) in log scale was calculated above the baseline value. The mixed model included test meal and study day visit as fixed-effects. Subjects were nested in sequences as random-effects, and values were adjusted for fasting levels and BMI.

bP- value for lunch test meal effect (mixed model)

cP- value comparing AUC to the C (Tukey-Kramer post-hoc tests)

dLSM, least squares mean

DISCUSSION

The inclusion of $\approx\frac{1}{2}$ of a Hass avocado at a lunch meal produced a significant reduction in blood insulin levels over a 3h post-ingestive period compared to the C and AA lunch test meals in the context of equivalent changes in blood glucose (Wien *et al.*, 2013). A unique seven-carbon sugar (D-manno-heptulose) that does not contribute energy is present in avocados, which some believe may support glycemic control and weight management by reducing glycolysis via hexokinase inhibition (Roth *et al.*, 2009). The addition of $\approx\frac{1}{2}$ of a Hass avocado at a lunch meal also favorably increased satisfaction and reduced the desire to eat over a post-ingestive 3h and 5h timeframe (Wien *et al.*, 2013).

The increase in leptin levels that were noted over 3h is inconsistent with the findings of others that have explored changes in leptin levels in the context of high fat versus low fat meals over 24h in normal weight females (Havel *et al.*, 1999), high fat meals with variable levels of saturated fat (SFA) vs. unsaturated fat in lean males (Poppitt *et al.*, 2006) or high fat meals with variable levels of SFA vs. monounsaturated fat in healthy males (Cooper *et al.*, 2010). To our knowledge, this is the first study that has evaluated the effect of Hass avocados in overweight adults, and our findings are in contrast with those who found either a decrease in circulating leptin levels (Havel *et al.*, 1999) or null findings (Poppitt *et al.*, 2006; Cooper *et al.*, 2010) among their respective normal weight subject populations. Thus, there may be differential responses to avocado consumption across the spectrum of BMI categories.

The decrease in GLP-1 levels that we observed in the AA lunch test meal are consistent with the findings of Wikarek *et al.* (2014) who found that the intake of a high fat test meal compared to a high carbohydrate and high protein test meal significantly decreased GLP-1 levels over 6h in 11 obese adults in contrast to null findings among 9 normal weight adults in the same cohort. It is worth noting that we observed an acute initial increase in GLP-1 levels over 1h followed by a significant decline over the subsequent 2h. Duca *et al.* (2012) have observed that compared to obesity resistant rats, obesity prone rats that are fed a high energy/high fat diet yields a downregulation of GLP-1 mRNA in the vagal nodose ganglia. The AA lunch test meal contained an additional 6% of daily energy compared to the C and AI lunch test meals (3% and 2% more fat, respectively), which may have contributed to the decrease in GLP-1 levels that were observed from 1 to 3h after the AA meal in this current study.

CONCLUSIONS

The addition of $\approx\frac{1}{2}$ of a Hass avocado to a lunch meal favorably increased self-reported satisfaction and reduced the desire to eat over a subsequent 3h and 5h period in overweight adults. The favorable biological changes in insulin levels observed over 3h after consumption of the avocado inclusive lunch test meal is worthy of future exploration in a long-term feeding study among persons with insulin resistance and type 2 diabetes to determine if avocado intake can favorably influence measures of glucose homeostasis and gastric hormone release. The increase in post-ingestive leptin levels that we observed also deserves further investigation to provide additional insight into the role of avocado intake in energy balance and weight management.

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