High Fructose Corn Syrup (HFCS) in Beverages: Impact on Appetite & Food Intake

Reviewing The Science, Understanding the Controversies

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His work includes research on diet and chronic disease (with emphasis on sugars and proteins) and food selection and intake regulation.

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High Fructose Corn Syrup (HFCS) Basics

- A caloric sweetener derived from corn
- Two forms used in foods and beverages: HFCS 42 & HFCS 55
- Classified based on the fructose content:
  - **HFCS 42**: ~42% fructose and ~53% glucose
  - **HFCS 55**: ~55% fructose and ~42% glucose
- Uses:
  - HFCS 42 is used in canned fruits, condiments and other mild sweetness processed foods
  - HFCS 55 is used in soft drinks, ice cream and frozen desserts

Composition of Common Sweeteners

	Corn Syrup	HFCS 42	HFCS 55	Sucrose	Honey
Fructose (%)	0	42	55	50	49
Glucose (%)	100	53	42	50	43
Others (%)		5	3	0	5

The Fructose & Glucose content of HFCS is similar to Sucrose and Honey

HFCS: Proposed Adverse Effects

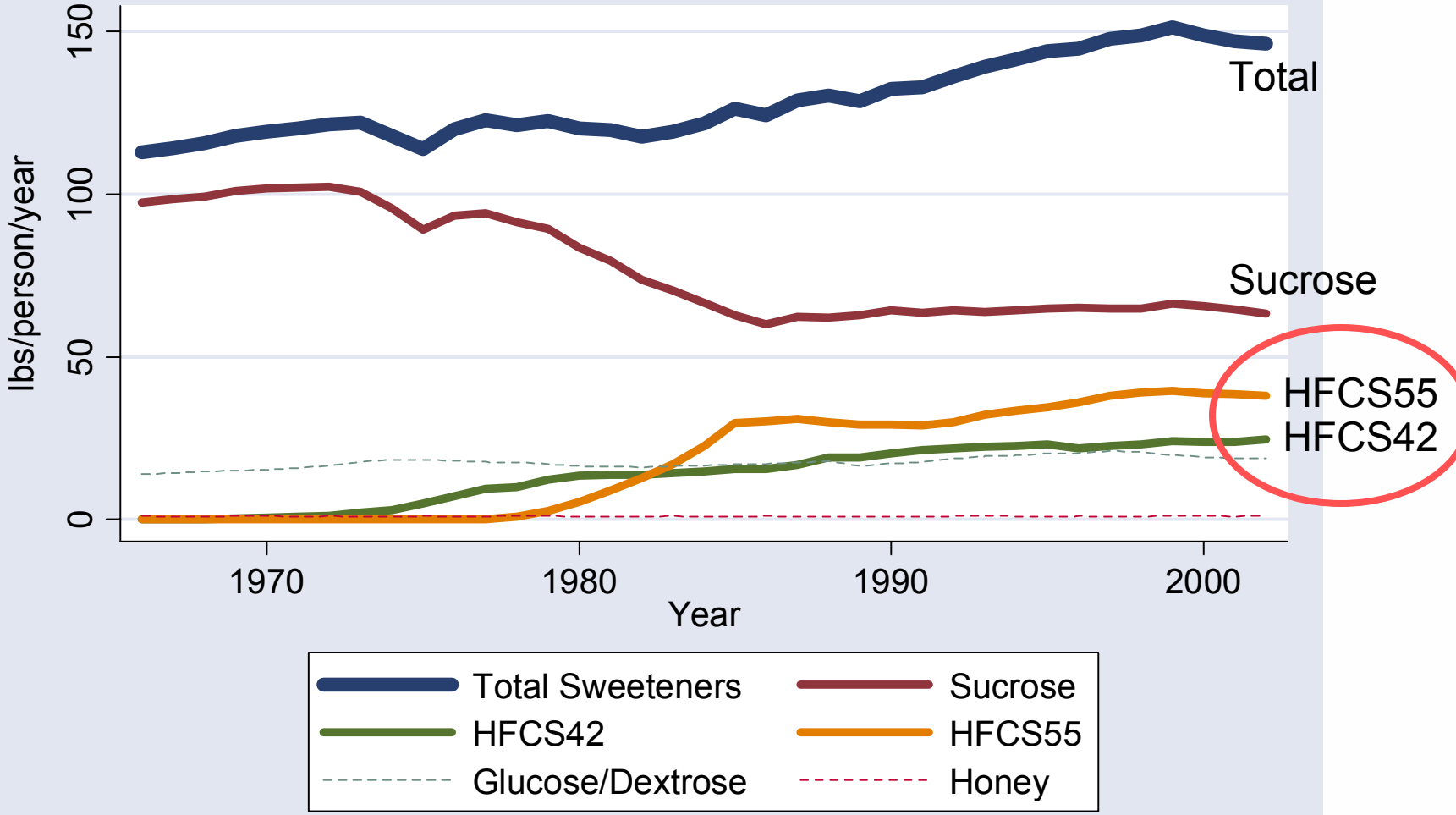
- Sugars availability in the food supply has increased more than other energy components of the diet. **[False]**
- Proportion of fructose in diet has increased due to HFCS. **[False]**
- High fructose consumption has an adverse affect on blood lipids, uric acid. **[True]**
- Sugars in solution do not stimulate satiety, reduce food intake. **[False]**
- HFCS replacing sucrose in beverages has increased obesity. **[False]**

HFCS: Proposed Adverse Effects

Let's look at the evidence for these statements.

- Sugars availability in the food supply has increased.
- Proportion of fructose in diet has increased due to HFCS.
- Sugars availability in the food supply has increased. more than other energy components of the diet

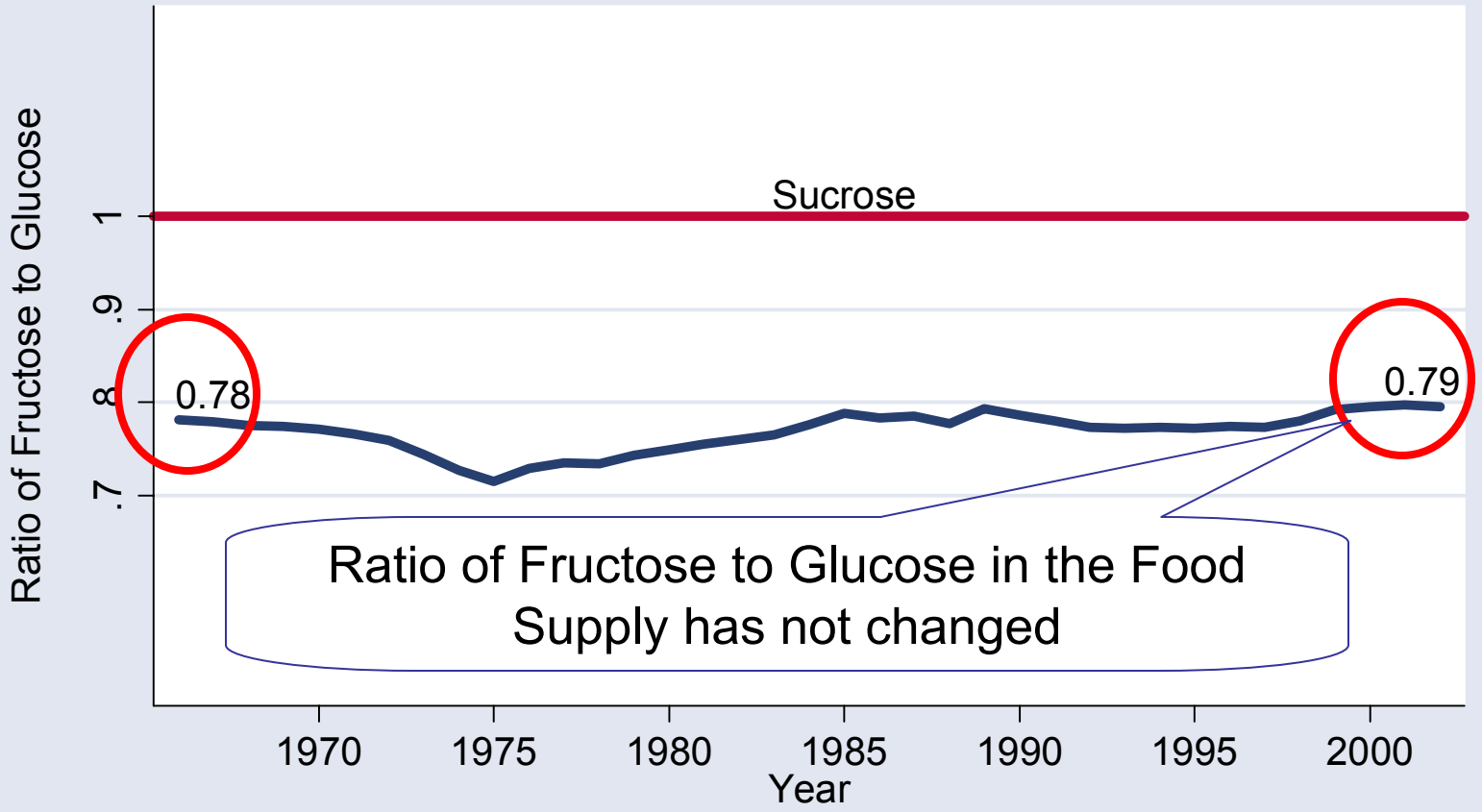
Sweetener Availability in the U.S. Food Supply, 1966-2002



Availability data from USDA Economic Research Service

Critical Reviews in Food Science and Nutrition, 2007; 47:561-582.

Relative Availability of Fructose and Glucose in the U.S. Food Supply, 1966-2002



Availability data from USDA Economic Research Service
Fructose and glucose composition from Hanover & White
Sucrose is the reference line for the fructose:glucose ratio if all sweeteners were sucrose

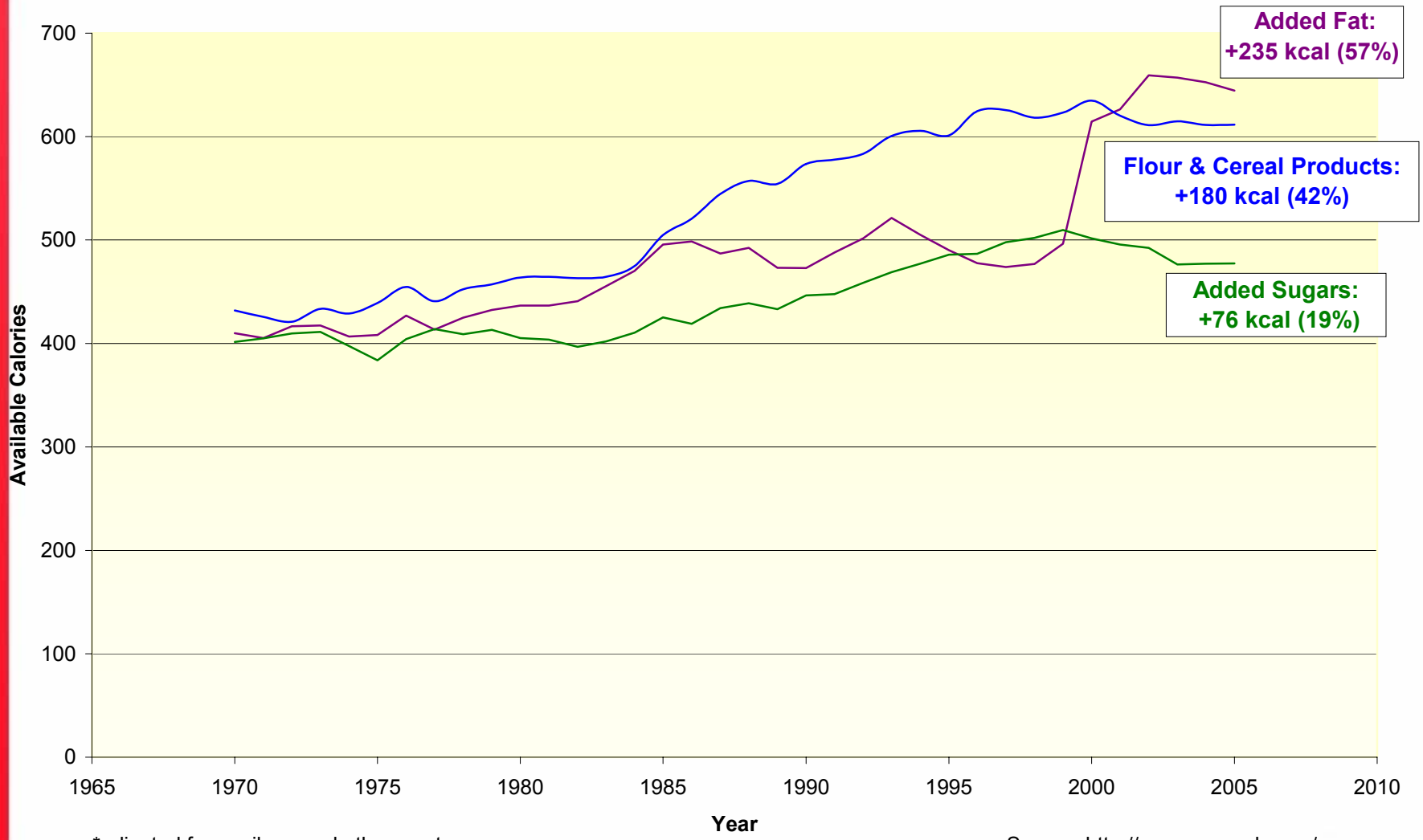
Energy (Kcal) Availability: 1970-74 to 2005

Dietary Component	Change in Available Energy (Kcal) from 1970-74 to 2000	Percent Change in Available Energy (Kcal) from 1970-74 to 2000
Total Energy	+523	24%
Flours and Cereals	+180	42%
Added Sugars	+76	19%
Added Fat	+235	57%

More energy (kcal) has become available in the food supply from increases in added fat than added sugars.

35-Year Change in Average Daily Per Capita Availability of Calories in the US Food Supply

[Change in Total Available Calories: + 523 kcal (24%)]



*adjusted for spoilage and other waste

Source: http://www.ers.usda.gov/

HFCS: Proposed Adverse Effects

Proportion of fructose in diet has increased due to HFCS. [False]

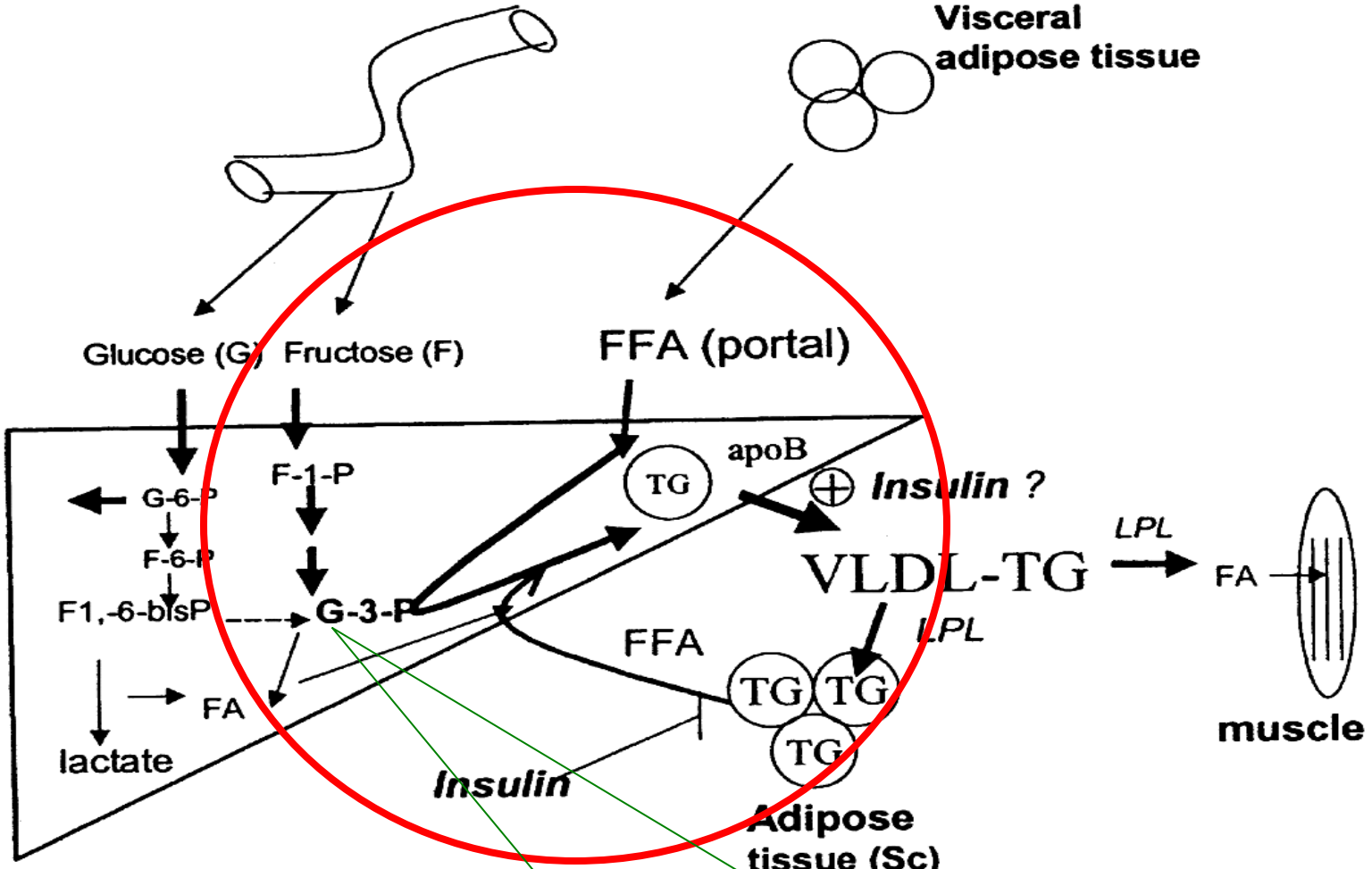
Availability of sugars in the food supply has increased more than other energy components of the diet. [False]

HFCS: Proposed Adverse Effects

Let's look at the evidence for this statement.

High fructose consumption has an adverse affect on blood lipids, uric acid.

Fructose vs Glucose and Fat Synthesis



Dietary fructose is converted to G-3P, favoring esterification of unbound fatty acids.

Fried K.S. 2003. Am J Clin Nutr.

Metabolism: Fructose vs. Glucose

- Fructose bypasses two regulatory steps in glycolysis, and thus produces acetate for fatty acid synthesis more readily than glucose, and favors TG synthesis.
- Experimental Studies: High fructose diets (>20% of energy) increase blood lipids.

Peter Havel. Nutrition Reviews 2005;63:133-157

HFCS: Proposed Adverse Effects

High fructose consumption (>20% energy) has an adverse affect on blood lipids.
[True]

However: Put this in perspective
Population fructose intake = ~ 8% of energy.
(Highest fructose intake tertile is ~11% of energy)

HFCS: Proposed Adverse Effects

Let's look at the evidence for these statements.

Sugars in solution do not stimulate satiety, reduce food intake.

HFCS, by replacing sucrose in beverages, is the cause of obesity.

Two Recent Studies Address This Issue

- **Effects of glucose-to-fructose ratios in solutions on subjective satiety, food intake, and satiety hormones in young men.** Tina Akhavan and G Harvey Anderson. *Am J Clin Nutr* 2007;86:1354–63.

- **No differences in satiety or energy intake after high-fructose corn syrup, sucrose, or milk preloads.** S Soenen and MS Westerterp-Plantenga. *Am J Clin Nutr* 2007;86:1586 –94.

Effects of glucose-to-fructose ratios in solutions on subjective satiety, food intake, and satiety hormones in young men[1]

BACKGROUND: The greater prevalence of obesity and the metabolic syndrome in the past 35 y has been attributed to the replacement of sucrose in the food supply with high-fructose corn syrup (HFCS).

OBJECTIVE: Determine the effect of solutions containing 75 g (300 kcal) of sucrose, HFCS, or various ratios of glucose to fructose on men's:

- Subsequent food intake (Energy compensation)
- Appetite (Hunger ratings)
- Blood glucose, plasma insulin, ghrelin, and uric acid

[1]Tina Akhavan and G Harvey Anderson. *Am J Clin Nutr* 2007;86:1354–63.

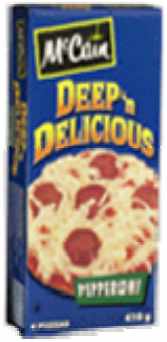
Supported in part by an unrestricted grant from the International Life Sciences Institute.

Satiety Study Design: Caloric Compensation

To what extent does the body compensate for the energy content of a test beverage by reducing intake at the next meal?

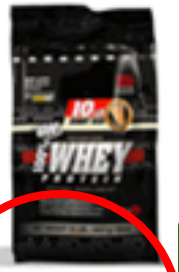
0 kcal Control
(Water or sucralose-sweetened beverage)

Defined time, e.g. 80 min



Measured Food Intake

e.g. 900 kcal



300 kcal
Test Drink

Defined time, e.g. 80 min

Measured Food Intake

??????

Example: If energy intake at the next meal is 300 kcal less than Control, Compensation is 100%.

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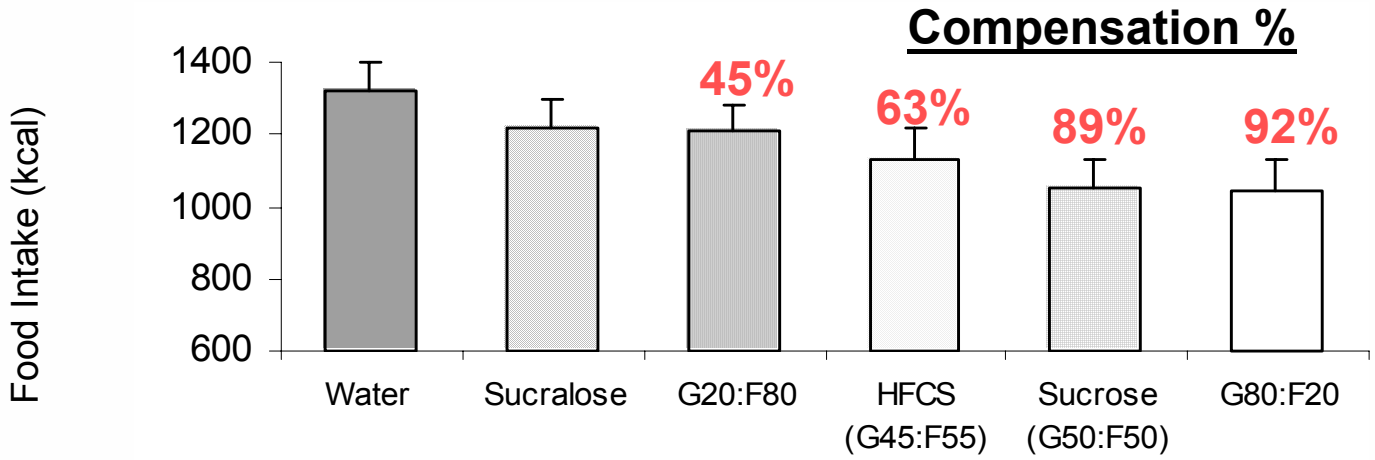
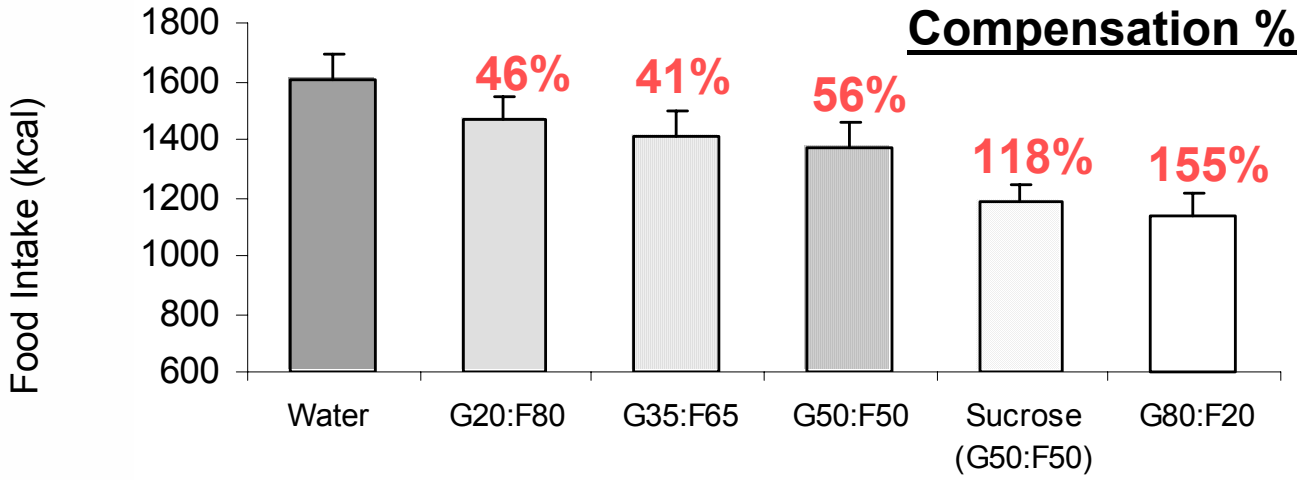
Effect of Sugars (75g, 300kcal) Solutions on Food Intake of Young Men 80 min Later

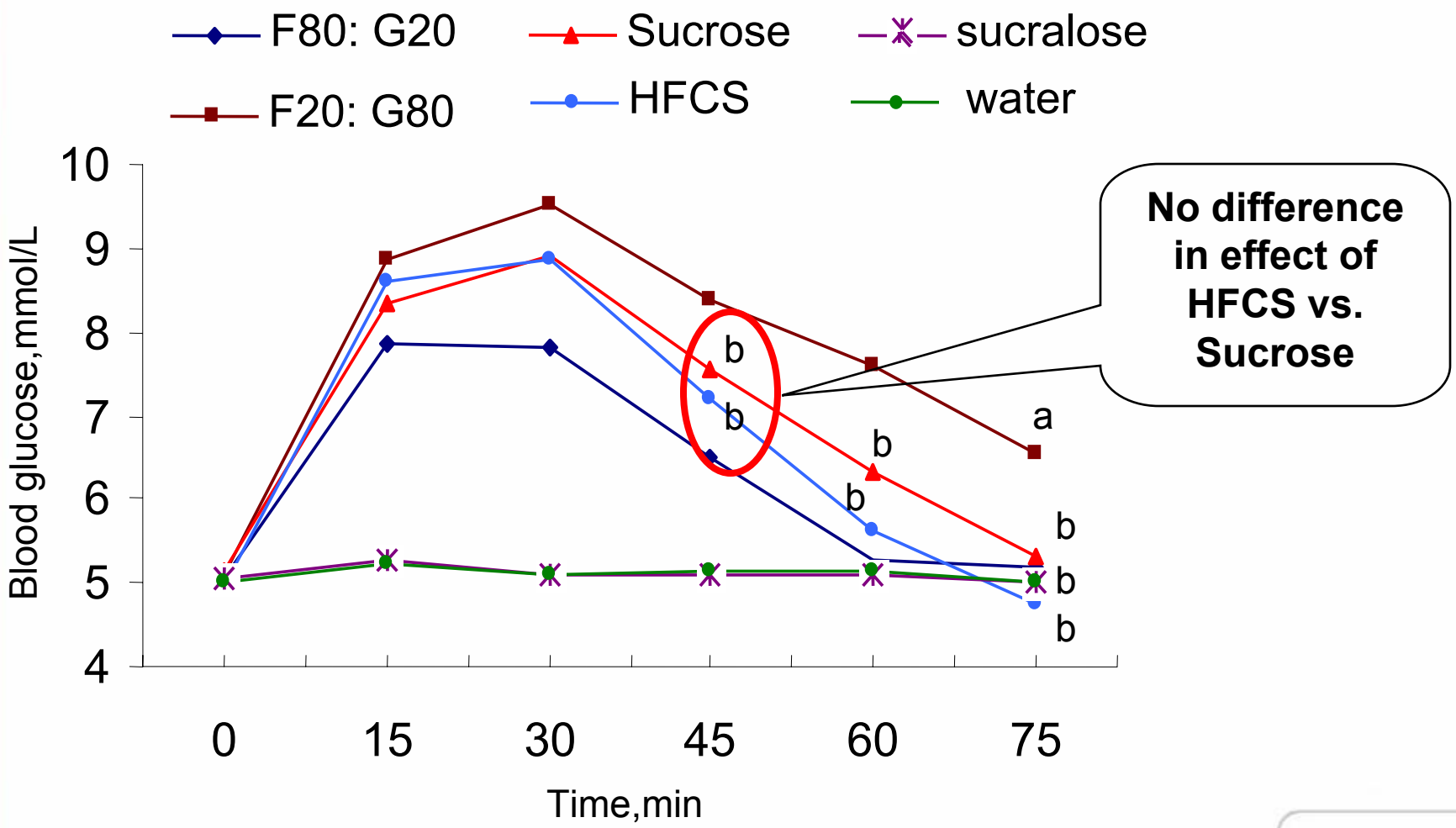


Experiment 1
n=12 F= 11.17
P<0.0001



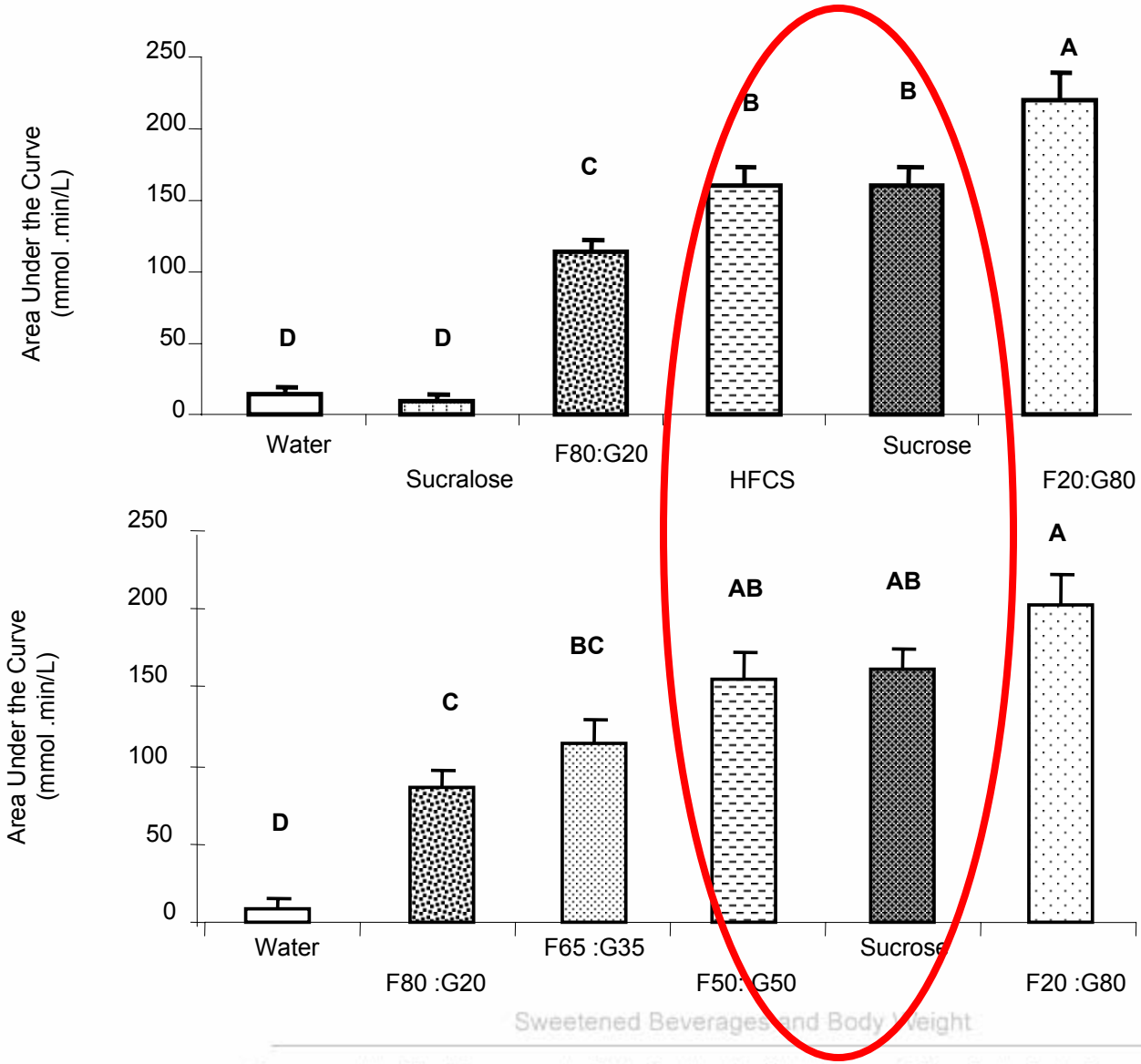
Experiment 2
n=19 F= 13.56
P<0.0001

Sugars Solutions and Blood Glucose



Values with different letters are significantly different ($p<0.05$;$n=12$)

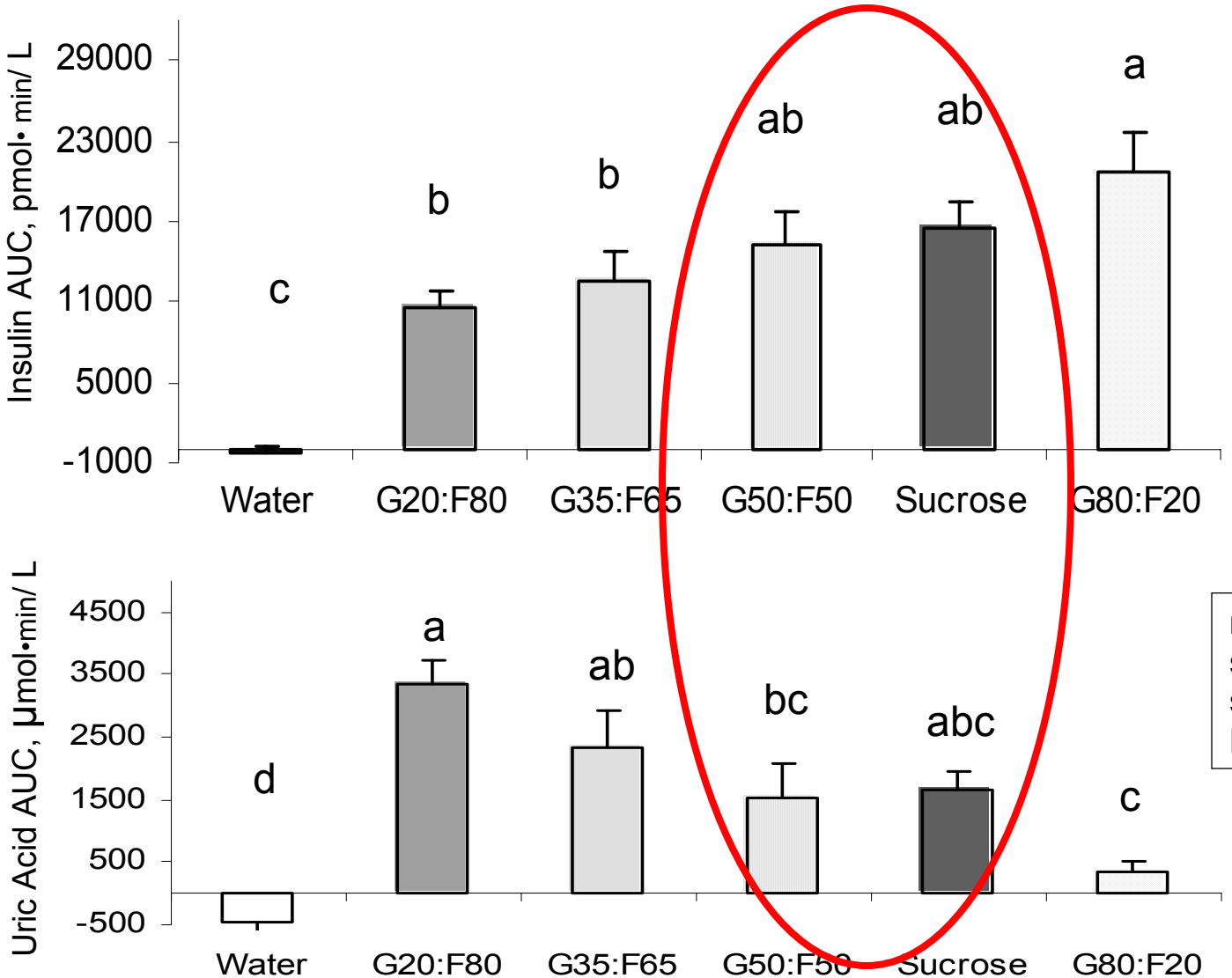
Blood Glucose Net AUC: Change from Baseline



Experiment 1, n=12
F= 84.92, P<0.0001

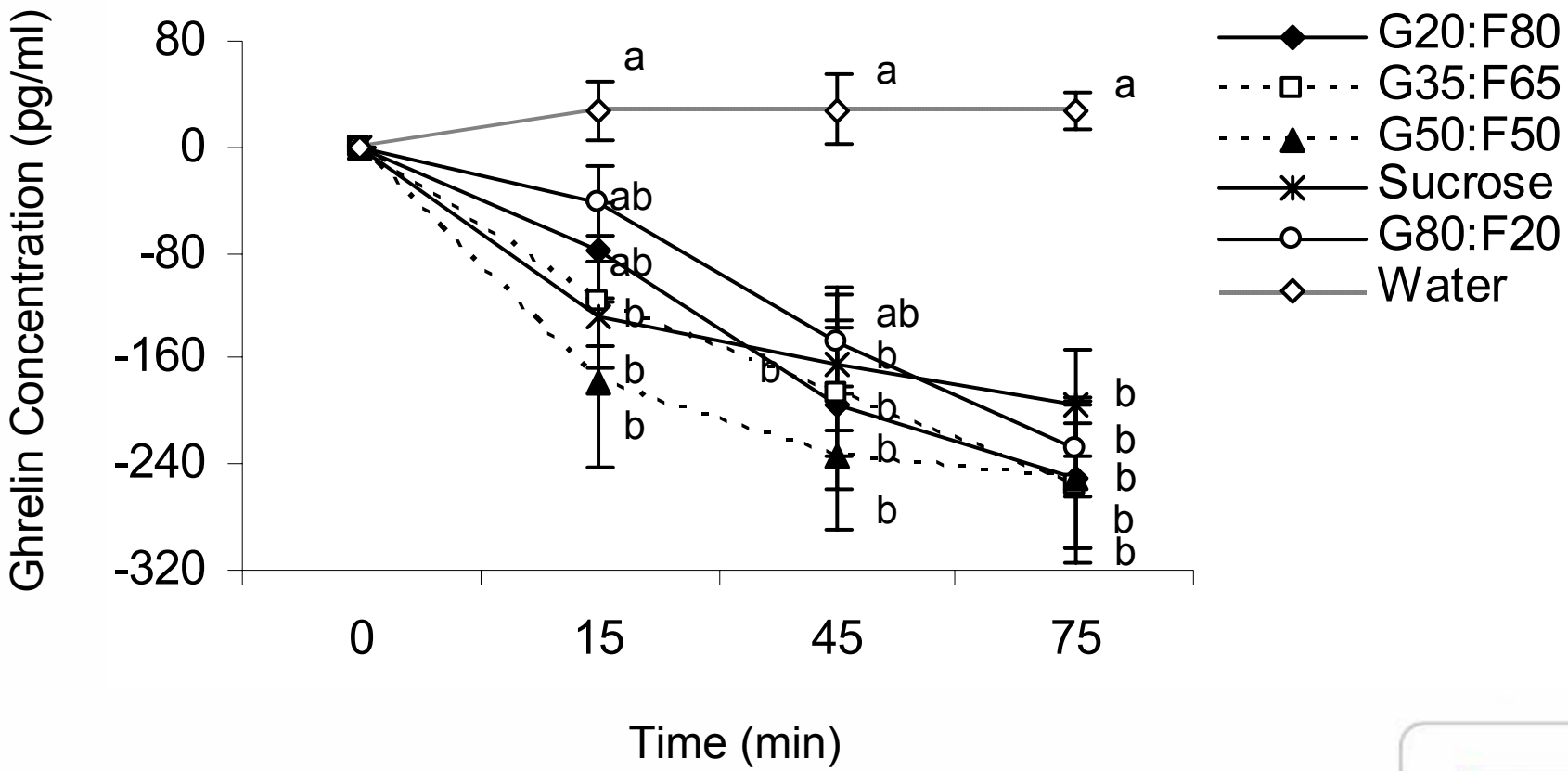
Experiment 2, n=12
F= 27.51, P<0.0001

Effect on Insulin and Uric Acid



n=7, Different superscripts are significantly different, P<0.0001

Effect on Ghrelin Concentrations



Means with the same letter are not significantly different at each time (n=7, p<0.001)

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Effects of glucose-to-fructose ratios in solutions on subjective satiety, food intake, and satiety hormones in young men[1]

Conclusion:

Sucrose, HFCS, and G50:F50 solutions do not differ significantly in their short-term effects on subjective and physiologic measures of satiety, uric acid, and food intake at a subsequent meal.

[1] Tina Akhavan and G Harvey Anderson. *Am J Clin Nutr* 2007;86:1354–63.

Supported in part by an unrestricted grant from the International Life Sciences Institute.

No differences in satiety or energy intake after high-fructose corn syrup, sucrose, or milk preloads[2]

BACKGROUND: It is unclear whether energy-containing drinks, especially those sweetened with high-fructose corn syrup (HFCS), promote positive energy balance and thereby play a role in the development of obesity.

OBJECTIVE: Examine the satiating effects of HFCS and sucrose in comparison with milk and a diet drink.

[2]S Soenen and MS Westerterp-Plantenga. *Am J Clin Nutr* 2007;86:1586 –94.

No differences in satiety or energy intake after high-fructose corn syrup, sucrose, or milk preloads

- **Test Beverages:** Two beverage compositions were tested against milk and a zero-calorie control: A HFCS beverage containing 59% Fructose (41% Glucose) and a Sucrose beverage containing 36% Fructose (63% Glucose)
- **Results:** Fifty minutes after consumption of the 360 kcal preloads (in 800ml), compensatory energy intake did not differ significantly between the 3 caloric preloads. No differences were observed over 120 min between the effects of the sucrose- and HFCS containing drinks on changes in VAS and on insulin, glucose, GLP-1 and ghrelin.
- **Conclusion:** Energy balance consequences of HFCS-sweetened soft drinks are not different from those of other isoenergetic drinks, eg, a sucrose-drink or milk.

Meal Energy Intake 50 min after 360 kcal Preloads

Preload Beverage	Gender	Meal Energy Intake
Sucrose	Women	417 +/- 175
	Men	564 +/- 190
HFCS	Women	448 +/- 208
	Men	559 +/- 189
Milk	Women	465 +/- 181
	Men	628 +/- 211
Diet #	Women	548 +/- 185
	Men	753 +/- 235

#significant difference between diet drink and all others (P<0.05)

S Soenen and MS Westerterp-Plantenga. *Am J Clin Nutr* 2007;86:1586 –94.

HFCS: Proposed Adverse Effects

Sugars in solution do not stimulate satiety, reduce food intake. [False]

HFCS, by replacing sucrose in beverages, is the cause of obesity. [False]

Sugars and HFCS: Hypotheses and Conclusions

- Sugars availability in the food supply has increased more than other energy components of the diet. NO
- Fructose content of the food supply has increased disproportionately due to HFCS. NO
- Compared with glucose, ↑ fructose consumption → ↑ blood lipids, uric acid . Yes, but not physiologically significant
- Sugars in solution do not stimulate satiety, reduce food intake. Wrong They do decrease!
- ↑ HFCS, by replacing sucrose in beverages, is the cause of obesity. NO

Why did the original hypothesis gain so much appeal? "Replacing sucrose with HFCS in beverages is a cause of obesity?"

"Had the hypothesis been phrased in the converse, namely that replacing HFCS with sucrose in beverages would be a solution for the obesity epidemic, its merit would have been seen more clearly. Put simply, a proposal that a return to sucrose containing beverages would be a credible solution to the obesity epidemic would have been met with outright dismissal."[3]

[3] Much ado about high-fructose corn syrup in beverages: the meat of the matter. Anderson GH *Am J Clin Nutr* 2007:86:1577)