DENISE MACHADO MOURÃO

INFLUÊNCIA DE ALIMENTOS LÍQUIDOS E SÓLIDOS NA SACIAÇÃO E NA SACIEDADE

Tese apresentada a Universidade Federal de Viçosa, como parte do Programa de Pós-graduação em Ciência e Tecnologia de Alimentos, para a obtenção do titulo de *Doctor Scientiae*

VIÇOSA
MINAS GERAIS – BRASIL
2006

DENISE MACHADO MOURÃO

INFLUÊNCIA DE ALIMENTOS LÍQUIDOS E SÓLIDOS NA SACIAÇÃO E NA SACIEDADE

Tese apresentada a Universidade Federal de Viçosa, como parte do Programa de Pós-graduação em Ciência e Tecnologia de Alimentos, para a obtenção do titulo de *Doctor Scientiae*

Aprovada: 16 de março de 2006

Prof[a] Valeria P R Minim
(conselheira)

Prof[a] Cristina M. G Chaves Dias
(conselheira)

Prof[a] Rita C G Alfenas

Prof[a] Elizabethe Adriana Esteves

Prof[a] Josefina Bressan
(Orientadora)

A Deus,
Ao Marcelo,
e as minhas filhas Clara e Julia

AGRADECIMENTOS

Na elaboração deste trabalho quero lembrar de todos que de alguma forma contribuíram para a realização e conclusão do mesmo. Assim agradeço:

Ao meu marido Marcelo Ehlers Loureiro, que me acompanhou e ajudou todo tempo de trabalho principalmente no exterior;

Aos meus pais, em especial minha mãe Arlete A. Machado Mourão e amigos pessoais que mesmo de longe sofreram e torceram pelo meu trabalho;

Ao Prof. Richard Mattes e todo o grupo de pesquisa que proporcionaram a realização da coleta de dados na Universidade de Purdue;

À minha orientadora aqui no Brasil, Josefina Bressan, pelo esforço de ajuda para que este trabalho fosse realizado em Purdue, como era a minha vontade;

Às conselheiras e todos os membros da banca pelas correções e sugestões;

Ao CNPq e CAPES pelo auxilio financeiro.

ÍNDICE

RESUMO

MOURAO, Denise Machado, D. S, Universidade Federal de Viçosa, marco de 2006. **Influência de Alimentos Sólidos e Líquidos na Saciação e na Saciedade.** Orientadora: Josefina Bressan. Conselheiros: Cristina M. Ganns Chaves Dias e Valeria Paula Rodrigues Minim.

Os alimentos podem ser classificados segundo suas diferenças sensoriais, propriedades físicas e químicas. Dentre as propriedades físicas dos alimentos, a consistência tem um papel importante na saciedade. O alto consumo de bebidas, especialmente refrigerantes, tem sido apontado como um dos possíveis fatores responsáveis pelo ganho de peso. Alguns autores observaram que alimentos sólidos suprimem o apetite por um período de tempo maior do que alimentos líquidos, ao passo que outros encontraram uma associação inversa. Porém, os dados encontrados na literatura ainda não são conclusivos a respeito do assunto, bem como dos possíveis mecanismos que estariam relacionados. Por isso, o presente trabalho objetivou verificar a influência de alimentos líquidos e sólidos na ingestão alimentar de indivíduos com peso normal e obesos, controlando os principais fatores que poderiam afetar a interpretação dos resultados. O método de registro alimentar, juntamente com o questionário de apetite aplicado na forma de um sistema eletrônico (Eletronic Appetite Rating System – EARS), foram utilizados para verificar a saciação e saciedade dos participantes (n=98), em três estudos com alimentos sólidos e líquidos, contendo um macronutriente predominante. O tamanho amostral foi de quarenta participantes para os estudos de proteína e carboidrato, e de dezoito para o de lipídio. Verificou-se nos três

estudos que os alimentos líquidos utilizados levaram os indivíduos a ter um maior consumo calórico durante o almoço, e também ao logo do dia. De uma forma geral, a saciação foi menor com líquidos no estudo com carboidrato, porém esta diferença foi mais evidente nos indivíduos obesos no estudo com proteína. Uma menor saciedade dos indivíduos foi verificada com o tratamento líquido no estudo com carboidrato. Observou-se ainda, esta mesma tendência para os estudos com proteína e lipídio. Desta maneira, o presente trabalho mostrou que alimentos líquidos têm uma fraca influência no controle do apetite, sendo assim importante, por conseguinte, controlar o consumo de alimentos líquidos, contendo calorias, na prevenção e tratamento da obesidade.

ABSTRACT

MOURAO, Denise Machado, D. S, Universidade Federal de Viçosa, March of 2006. **Influence of liquid and solid foods on satiation and satiety.** Adviser: Josefina Bressan. Committee Members: Cristina M. Ganns Chaves Dias and Valeria Paula Rodrigues Minim.

Foods can be classified according their sensory differences, and physical and chemical structure. Among their physical characteristics, the consistence may play a role on satiety. The increased consumption of energy-yielding beverages, especially soft drinks, has been related to weight gain. Some studies have shown that solid foods seem to suppress appetite longer than liquids. On the other hand, others have shown the opposite. In fact, data from literature about this theme are not conclusive, likewise involved mechanisms in this area have not been clearly defined. Thus, the main aim of this study was to verify the influence of liquid and solid foods on energy intake, controlling the potentially confounding factors seen in previous studies. In this way, Electronic Appetite Rating System (EARS) was used to record participants' appetite sensations in three different macronutrient load experiments (n=98), each one using a matched solid and liquid sample. Food records were used to evaluate later energy intake. Sample size was n=40 for the protein and carbohydrate experiments, and n=18 for the fat. Participants had a tendency of higher energy intake during lunch and during the day when received liquid load, compared to solid, in the three experiments. Satiation was clearly smaller for the obese participants, with the liquid load, in the protein experiment. Further more, satiety was smaller with the liquid load in the

carbohydrate experiment. This study shown liquid foods have a weaker influence on appetite control, especially in a short term, compared to solid ones. Therefore, the consumption of caloric liquid foods must be limited in the prevention and treatment of obesity.

INTRODUÇÃO GERAL

Em nossa sociedade, cada vez mais industrializada, tem-se verificado a redução da atividade física dos indivíduos e o aumento da ingestão de alimentos de fácil e rápido consumo. Muitos pesquisadores têm atribuído o crescimento da obesidade a estes fatores (Nicklas *et al.*, 2001; Cutler *et al.*, 2003; Chou *et al.*, 2004; Drewnowski & Specter, 2004; Drewnowski & Darmon, 2005; Foster *et al.*, 2005). Por conseguinte, tem sido feita uma grande revisão dos mecanismos envolvidos no alarmante crescimento da obesidade, objetivando-se, entre outros, reduzir as graves conseqüências médicas relacionadas à obesidade e sua sobrecarga nos sistemas de saúde mundiais (Bray, 2005; Gregg *et al.*, 2005).

O alto consumo de bebidas, especialmente refrigerantes, tem sido relacionado ao ganho de peso (De Castro, 1993; Mattes, 1996; Johnson & Frary, 2001; Almiron-Roig *et al.*, 2003; WHO, 2003; Jurgens *et al.*, 2005; Mattes *et al.*, 2005). Existe uma hipótese de que as calorias provenientes de líquidos favorecem uma compensação dietética fraca, quando comparadas às de alimentos sólidos. Acrescenta-se que a adição de energia à dieta proveniente dos líquidos poderia aumentar a ingestão energética total. Isto foi demonstrado para café, bebidas alcoólicas, refrigerante, suco de fruta e leite (De Castro, 1993; Mattes, 1996).

Diante da existência de alguns trabalhos que apontam para a possibilidade de que alimentos sólidos provoquem maior saciedade que líquidos, embora não de forma clara e/ou conclusiva, e da existência de outros que contradizem esta hipótese, foi proposta a realização de três estudos para verificar a influência de alimentos líquidos e sólidos na ingestão alimentar de indivíduos de peso normal e obesos; controlando os potencias fatores que poderiam afetar e/ou influenciar a interpretação dos resultados.

Esta tese foi, então, dividida em duas partes: uma revisão de literatura, apontando os principais fatores relacionados aos possíveis mecanismos que poderiam interferir na ingestão de alimentos sólidos e líquidos, e suas implicações na saciedade; e uma descrição de todo o trabalho realizado na Universidade de Purdue, EUA, e dos principais resultados encontrados, na forma de artigo.

REFERÊNCIAS

Almiron-Roig E, Chen Y & Drewnowski A (2003) Liquid calories and the failure of satiety: how good is the evidence? *Obes Rev* **4**, 201-212.

Bray GA (2005) Medical consequences of Obesity. *The Journal of Clinical Endocrinology & Metabolism* **89**, 2583-2589.

Chou SY, Grossman M & Saffer H (2004) An economic analysis of adult obesity: results from the Behavioral Risk Factor Surveillance System. *J Health Econ* **23**, 565-587.

Cutler DM, Glaeser EL & Shapiro JM (2003) Why have americans become more obese? *Journal of Economic Perspectives* **17**, 93-118.

De Castro JM (1993) The effects of the spontaneous ingestion of particular foods or beverages on the meal pattern and overall nutrient intake of humans. *Physiol Behav* **53**, 1133-1144.

Drewnowski A & Darmon N (2005) The economics of obesity: dietary energy density and energy cost. *Am J Clin Nutr* **82**, 265S-273S.

Drewnowski A & Specter SE (2004) Poverty and obesity: the role of energy density and energy costs. *Am J Clin Nutr* **79**, 6-16.

Foster GD, Makris AP & Bailer BA (2005) Behavioral treatment of obesity. *Am J Clin Nutr* **82**, 230S-235S.

Gregg EW, Cheng YJ, Cadwell BL, Imperatore G, Williams DE, Flegal KM, Narayan KM & Williamson DF (2005) Secular trends in cardiovascular disease risk factors according to body mass index in US adults. *Jama* **293**, 1868-1874.

Johnson RK & Frary C (2001) Choose beverages and foods to moderate your intake of sugars: the 2000 dietary guidelines for Americans--what's all the fuss about? *J Nutr* **131**, 2766S-2771S.

Jurgens H, Haass W, Castaneda TR, Schurmann A, Koebnick C, Dombrowski F, Otto B, Nawrocki AR, Scherer PE, Spranger J, Ristow M, Joost HG, Havel PJ & Tschop MH (2005) Consuming fructose-sweetened beverages increases body adiposity in mice. *Obes Res* **13**, 1146-1156.

Mattes RD (1996) Dietary compensation by humans for supplemental energy provided as ethanol or carbohydrate in fluids. *Physiol Behav* **59**, 179-187.

Mattes RD, Hollis J, Hayes D & Stunkard AJ (2005) Appetite: measurement and manipulation misgivings. *J Am Diet Assoc* **105**, S87-97.

Nicklas TA, Baranowski T, Cullen KW & Berenson G (2001) Eating patterns, dietary quality and obesity. *J Am Coll Nutr* **20**, 599-608.

WHO (2003) Diet, nutrition and the prevention of chronic diseases. *World Health Organ Tech Rep Ser* **916**, i-viii, 1-149, backcover.

ARTIGO I - REVISÃO DE LITERATURA

A crescente incidência da obesidade vem cada vez mais preocupando as autoridades ligadas à área da saúde e a população mundial. Nos últimos anos, alguns trabalhos tentaram mostrar a relação o estado em que o alimento é ingerido e o ganho de peso corporal (Crapo & Henry, 1988; DiMeglio & Mattes, 2000).

Os alimentos podem ser classificados segundo suas diferenças sensoriais, propriedades físicas e químicas, as quais contribuem para a regulação do comportamento alimentar, e também para regulação do metabolismo energético. Dentre as propriedades físicas dos alimentos, a consistência parece tem papel importante na saciedade (Santangelo *et al.*, 1998), e no gasto energético (Habas & Macdonald, 1998).

Segundo a Organização Mundial de Saúde, os alimentos líquidos levam a um maior ganho de peso corporal (WHO, 2003). Alguns autores observaram que a ingestão de alimentos sólidos parece suprimir o apetite por um período de tempo maior do que alimentos líquidos (Bolton *et al.*, 1981; Tournier & Louis-Sylvestre, 1991; Hulshof *et al.*), ao passo que outros encontraram uma associação inversa (Kissileff, 1984; Kissileff, 1985; Rolls *et al.*, 1990). Porém, os estudos que apontam para esta hipótese ainda não são conclusivos, bem como os possíveis mecanismos que estariam relacionados a ela.

O alto consumo de bebidas, especialmente refrigerantes, tem sido apontado por pesquisadores como um dos possíveis fatores que leva ao ganho de peso. A tendência de que um alto consumo de bebidas seja uma importante preocupação de saúde pública justifica-se pela hipótese de que as calorias contidas nas bebidas favoreceriam um consumo calórico maior, em relação aos alimentos sólidos. Esta hipótese pôde ser verificada após a manipulação da composição de energia em alimentos com diferentes estruturas físicas, tendo havido uma compensação calórica (redução no consumo) maior após o consumo de alimentos sólidos, seguido de alimentos semi-sólidos e líquidos. Assim, acrescenta-se que a adição de calorias à dieta proveniente dos líquidos possa aumentar a ingestão energética total. Isto foi demonstrado para café, bebidas alcoólicas, refrigerante, suco de fruta e leite (De Castro, 1993; Mattes, 1996).

Outros fatores relacionados às características do alimento, como viscosidade, também foram relacionados com alterações na ingestão alimentar. Uma maior viscosidade retardaria o esvaziamento gástrico, aumentando, assim, o tempo de saciedade (Marciani *et al.*, 2000).

A ausência da mastigação, que ocorre quando ingerimos alimentos líquidos, também tem sido apontada como um fator que contribuiria para a menor saciedade. O tempo de exposição aos receptores orofaríngeos, intimamente ligados ao controle dos centros da fome a da saciedade, para os alimentos sólidos é muito maior do que para líquidos. Em ratos, verificou-se que o ato mecânico da mastigação promove a saciedade, especialmente em animais magros, quando comparados aos obesos (Sakata, 1995; Fujise *et al.*, 1998). Mais recentemente verificou-se que a mastigação ativa a liberação de histamina, a qual suprime fisiologicamente a ingestão alimentar, pela ativação dos centros de saciedade no hipotálamo. Com isso, há uma redução tanto o volume, quanto da velocidade de alimento ingerido, e ainda, um aumento da lipólise, particularmente em adipócitos viscerais, e aumento da expressão gênica das proteínas desacopladoras, UCPs (Sakata, Yoshimatsu *et al.*, 2003).

Ainda são limitadas as informações que possibilitariam esclarecer a relação entre a taxa de esvaziamento gástrico e a secreção de hormônios gastrointestinais, mediados pelo efeito da consistência dos alimentos, relacionado a sinais de saciedade. O que já é conhecido é que a liberação de líquidos pelo estômago é mais rápida do que de sólidos (Read & Houghton, 1989). Entretanto, em refeições contendo quantidades normais de componentes sólidos e líquidos, há uma produção de solução viscosa na qual as partículas sólidas ficam suspensas, à medida que esses componentes são misturados na boca e no estômago. Um aumento da viscosidade do conteúdo gástrico reduz a sedimentação dos sólidos no líquido, e dificulta, assim, a habilidade preferencial que o antro tem em esvaziar-se mais rapidamente de líquidos do que de sólidos (Vincent *et al.*, 1995). Contudo, independentemente do tipo de alimento consumido, uma correlação negativa foi observada entre a taxa de esvaziamento gástrico e saciedade (Bergmann *et al.*, 1992).

Influências cognitivas também devem ser consideradas como um fator importante na regulação da ingestão alimentar. As áreas do cérebro onde o prazer ou valores afetivos relacionados ao cheiro e gosto estão intimamente relacionadas às áreas que envolvem as emoções (Rolls, 2005). Assim, ao longo dos anos, "aprendemos" que ao consumir uma bebida estamos satisfazendo a nossa sensação de sede, e não a de fome. Outro ponto a ser considerado aqui é o fato de que a ingestão de uma bebida geralmente ocorre junto com uma refeição, ou em intervalos ao longo do dia, e não em substituição a uma refeição principal. Desta forma, o fator cognitivo também pode influenciar fortemente a ingestão alimentar.

A palatabilidade, avaliação hedônica das propriedades sensoriais de um alimento (Yeomans & Symes, 1999), tem sido considerada um importante e determinante fator na seleção e ingestão de alimentos em humanos. Vários trabalhos mostraram uma menor ingestão de alimentos não palatáveis, quando comparados aos palatáveis (Kauffman *et al.*, 1995; Yeomans & Gray, 1996; Yeomans *et al.*, 1997; Yeomans & Symes, 1999; Sawaya *et al.*, 2001). Este último estudo ainda sugeriu que pessoas com sobrepeso são mais susceptíveis à escolha de um alimento palatável, que geralmente tem mais calorias, levando, possivelmente a um aumento do peso corporal. Ainda, estudos mostraram que dietas não palatáveis promovem um estímulo reduzido do sistema nervoso simpático (SNS), especialmente na fase inicial (cefálica) do processo de alimentação, podendo assim haver uma resposta diferenciada na termogênese (LeBlanc & Brondel, 1985).

Com relação ao gasto energético, poucos trabalhos foram desenvolvidos, associando esta variável e ao estado físico do alimento (Crapo & Henry, 1988; Robinson & York, 1988; Habas & Macdonald, 1998), sendo que nenhum deles conseguiu isolar completamente a variação do estado físico do alimento, sólido e líquido, investigando, assim, seu real efeito no metabolismo energético. Num dos primeiros estudos, em que foi verificado o efeito de alimentos sólidos e líquidos na termogênese, foi encontrada uma maior resposta no metabolismo de repouso, após a ingestão de alimento sólido. Contudo, esta dieta foi mais aceita que a fórmula líquida utilizada (Robinson & York, 1988). Posteriormente, Habas e Macdonald (1998) encontraram um maior gasto energético, glicose e insulina plasmática, após o consumo da dieta teste, na forma sólida. Entretanto, a dieta líquida usada neste estudo foi hipertônica, o que pode ter levado a um retardo no esvaziamento gástrico, confundindo assim o efeito principal a ser estudo do estado físico do alimento.

Uma das grandes dificuldades em se estudar este tema está relacionada à grande variedade de fatores que podem influenciar este tipo de estudo. Testar uma mesma formulação alimentícia ou uma composição de alimentos nas formas, líquida e sólida, de maneira que não haja uma diferença a ser considerada na densidade calórica, distribuição e perfil de macronutrientes, osmolalidade, volume, e outros, é uma tarefa difícil, e que ainda não foi realizada.

Deveríamos considerar, ainda, que mecanismos neurais, assim como a presença de produtos da digestão no duodeno, especialmente gordura e aminoácidos que estimulam a secreção de vários hormônios gastrointestinais, como a colecistocinina (CCK), têm demonstrado ter um importante papel na regulação da ingestão alimentar (Moran, 2000).

Um aumento no metabolismo basal, seguido à ingestão de glicose, está associado a uma elevação da concentração plasmática de adrenalina e noradrenalina, indicando um aumento na estimulação do sistema nervoso simpático (Welle *et al.*, 1981). Em 1998, alguns autores verificaram que a concentração plasmática de noradrenalina apresentou tendência em ficar mais elevada, após a ingestão de alimento sólido, em comparação aos líquidos; a concentração de adrenalina, ao contrário, tendeu a reduzir (Habas & Macdonald, 1998).

Alguns estudos consideram que a concentração plasmática de adrenalina, e não a de noradrenalina, está reduzida em indivíduos obesos, em repouso, após estimulação (Young & Macdonald, 1992). Entretanto, estudos com pré-obesos e pós-obesos indicaram que uma diminuição na estimulação da secreção de adrenalina, em pós-obesos, não está associada ao estado de obesidade, mas talvez já esteja presente em indivíduos pré-obesos (Zurlo *et al.*, 1990; Astrup *et al.*, 1994; Raben & Astrup, 1996).

A leptina também tem demonstrado possuir forte influência na ingestão alimentar. Ela promove o decréscimo do consumo, pela sinalização da saciedade no cérebro (Karhunen *et al.*, 1998). Em humanos, a leptina está associada ao peso corporal, índice de massa corporal (IMC), e percentual de gordura corporal (GCT), sendo que uma falha na produção de leptina ou uma resistência à sua ação pode resultar em aumento de peso corporal (Raben & Astrup, 2000). Assim, a leptina parece estar aumentada com o excesso de peso crônico, e reduzida em jejuns prolongados ou restrições calóricas. Dietas ricas em lipídios proporcionam um aumento significativo na concentração sérica de leptina, porém isso não ocorre com o aumento das calorias totais ingeridas, ou dietas hiperprotéicas (Ahren *et al.*, 1997; Cooling *et al.*, 1998).

A grelina, um peptídeo cérebro-intestinal, é outro exemplo de hormônio também importante na regulação tanto do metabolismo energético quanto da ingestão alimentar (Wang *et al.*, 2002). Em estudos onde a grelina foi administrada em ratos observou-se um aumento do quociente respiratório (RQ), sugerindo uma mudança em direção a glicólise, ao invés da oxidação de ácidos graxos, favorecendo assim a adiposidade e o ganho de peso (Tschop *et al.*, 2000). Outros efeitos da grelina foram demonstrados, como estimulação da motilidade gástrica e secreção ácida (Masuda *et al.*, 2000), estímulo do apetite (Wren *et al.*, 2000; Wren *et al.*, 2001), entre outros. Em humanos, os níveis plasmáticos de grelina parecem estar aumentados no jejum (Tschop *et al.*, 2000; Cummings *et al.*, 2001) e, ao contrário do que se esperava, reduzidos em obesos (Tschop *et al.*, 2001b). Uma possível explicação para este decréscimo na concentração plasmática de grelina em obesos seria de que este achado estaria refletindo uma adaptação fisiológica ao balanço energético positivo associado à obesidade (Tschop *et al.*, 2001b). Tem sido proposto, ainda, que a grelina é um hormônio que contribui para a iniciação de uma refeição, uma vez que seus níveis plasmáticos parecem estar aumentados, antes de uma refeição (Cummings *et al.*, 2001) e, diminuídos, logo após a ingestão (Tschop *et al.*, 2001a).

Assim, muitos fatores podem interferir na regulação da ingestão alimentar, com relação ao estado físico do alimento, e como ainda existem muitas controvérsias sobre este tema, verifica-se a necessidade do desenvolvimento de mais estudos sobre o assunto.

REFERÊNCIAS

Ahren B, Mansson S, Gingerich RL & Havel PJ (1997) Regulation of plasma leptin in mice: influence of age, high-fat diet, and fasting. *Am J Physiol* **273**, R113-120.

Astrup A, Buemann B, Christensen NJ & Toubro S (1994) Failure to increase lipid oxidation in response to increasing dietary fat content in formerly obese women. *Am J Physiol* **266**, E592-599.

Bergmann JF, Chassany O, Petit A, Triki R, Caulin C & Segrestaa JM (1992) Correlation between echographic gastric emptying and appetite: influence of psyllium. *Gut* **33**, 1042-1043.

Bolton RP, Heaton KW & Burroughs LF (1981) The role of dietary fiber in satiety, glucose, and insulin: studies with fruit and fruit juice. *Am J Clin Nutr* **34**, 211-217.

Cooling J, Barth J & Blundell J (1998) The high-fat phenotype: is leptin involved in the adaptive response to a high fat (high energy) diet? *Int J Obes Relat Metab Disord* **22**, 1132-1135.

Crapo PA & Henry RR (1988) Postprandial metabolic responses to the influence of food form. *Am J Clin Nutr* **48**, 560-564.

Cummings DE, Purnell JQ, Frayo RS, Schmidova K, Wisse BE & Weigle DS (2001) A Preprandial Rise in Plasma Ghrelin Levels Suggests a Role in Meal Initiation in Humans. *Diabetes* **50**, 1714-1719.

De Castro J (1993) The effects of the spontaneous ingestion of particular foods or beverages on the meal pattern and overall nutrient intake of humans. *Physiol Behav* **53**, 1133-1144.

DiMeglio DP & Mattes RD (2000) Liquid versus solid carbohydrate: effects on food intake and body weight. *Int J Obes Relat Metab Disord* **24**, 794-800.

Fujise T, Yoshimatsu H, Kurokawa M, Oohara A, Kang M, Nakata M & Sakata T (1998) Satiation and masticatory function modulated by brain histamine in rats. *Proc Soc Exp Biol Med* **217**, 228-234.

Habas ME & Macdonald IA (1998) Metabolic and cardiovascular responses to liquid and solid test meals. *Br J Nutr* **79**, 241-247.

Hulshof T, De Graaf C & Weststrate JA (1993) The effects of preloads varying in physical state and fat content on satiety and energy intake. *Appetite* **21**, 273-286.

Karhunen LJ, Lappalainen RI, Haffner SM, Valve RH, Tuorila H, Miettinen H & Uusitupa MI (1998) Serum leptin, food intake and preferences for sugar and fat in obese women. *Int J Obes Relat Metab Disord* **22**, 819-821.

Kauffman NA, Herman CP & Polivy J (1995) Hunger-induced finickiness in humans. *Appetite* **24**, 203-218.

Kissileff HR (1984) Satiating efficiency and a strategy for conducting food loading experiments. *Neurosci Biobehav Rev* **8**, 129-135.

Kissileff HR (1985) Effects of physical state (liquid-solid) of foods on food intake: procedural and substantive contributions. *Am J Clin Nutr* **42**, 956-965.

LeBlanc J & Brondel L (1985) Role of palatability on meal-induced thermogenesis in human subjects. *Am J Physiol* **248**, E333-336.

Marciani L, Gowland PA, Spiller RC, Manoj P, Moore RJ, Young P, Al-Sahab S, Bush D, Wright J & Fillery-Travis AJ (2000) Gastric response to increased meal viscosity assessed by echo-planar magnetic resonance imaging in humans. *J Nutr* **130**, 122-127.

Masuda Y, Tanaka T, Inomata N, Ohnuma N, Tanaka S, Itoh Z, Hosoda H, Kojima M & Kangawa K (2000) Ghrelin stimulates gastric acid secretion and motility in rats. *Biochem Biophys Res Commun* **276**, 905-908.

Mattes RD (1996) Dietary compensation by humans for supplemental energy provided as ethanol or carbohydrate in fluids. *Physiol Behav* **59**, 179-187.

Moran TH (2000) Cholecystokinin and satiety: current perspectives. *Nutrition* **16**, 858-865.

Raben A & Astrup A (1996) Manipulating carbohydrate content and sources in obesity prone subjects: effect on energy expenditure and macronutrient balance. *Int J Obes Relat Metab Disord* **20 Suppl 2**, S24-30.

Raben A & Astrup A (2000) Leptin is influenced both by predisposition to obesity and diet composition. *Int J Obes Relat Metab Disord* **24**, 450-459.

Read NW & Houghton LA (1989) Physiology of gastric emptying and pathophysiology of gastroparesis. *Gastroenterol Clin North Am* **18**, 359-373.

Robinson SM & York DA (1988) Cigarette smoking and the thermic responses to isocaloric meals of varying composition and palatability. *Eur J Clin Nutr* **42**, 551-559.

Rolls BJ, Fedoroff IC, Guthrie JF & Laster LJ (1990) Foods with different satiating effects in humans. *Appetite* **15**, 115-126.

Rolls ET (2005) Taste, olfactory, and food texture processing in the brain, and the control of food intake. *Physiol Behav* **85**, 45-56.

Sakata T (1995) Histamine receptor and its regulation of energy metabolism. *Obes Res* **3 Suppl 4**, 541S-548S.

Sakata T, Yoshimatsu H, Masaki T & Tsuda K (2003) Anti-obesity actions of mastication driven by histamine neurons in rats. *Exp Biol Med (Maywood)* **228**, 1106-1110.

Santangelo A, Peracchi M, Conte D, Fraquelli M & Porrini M (1998) Physical state of meal affects gastric emptying, cholecystokinin release and satiety. *Br J Nutr* **80**, 521-527.

Sawaya AL, Fuss PJ, Dallal GE, Tsay R, McCrory MA, Young V & Roberts SB (2001) Meal palatability, substrate oxidation and blood glucose in young and older men. *Physiology & Behavior* **72**, 5-12.

Tournier A & Louis-Sylvestre J (1991) Effect of the physical state of a food on subsequent intake in human subjects. *Appetite* **16**, 17-24.

Tschop M, Smiley DL & Heiman ML (2000) Ghrelin induces adiposity in rodents. *Nature* **407**, 908-913.

Tschop M, Wawarta R, Riepl RL, Friedrich S, Bidlingmaier M, Landgraf R & Folwaczny C (2001a) Post-prandial decrease of circulating human ghrelin levels. *J Endocrinol Invest* **24**, RC19-21.

Tschop M, Weyer C, Tataranni PA, Devanarayan V, Ravussin E & Heiman ML (2001b) Circulating Ghrelin Levels Are Decreased in Human Obesity. *Diabetes* **50**, 707-709.

Vincent R, Roberts A, Frier M, Perkins AC, MacDonald IA & Spiller RC (1995) Effect of bran particle size on gastric emptying and small bowel transit in humans: a scintigraphic study. *Gut* **37**, 216-219.

Wang G, Lee HM, Englander E & Greeley GH, Jr. (2002) Ghrelin--not just another stomach hormone. *Regul Pept* **105**, 75-81.

Welle S, Lilavivate U & Campbell RG (1981) The effect of feeding in man: increased plasma norepinephrine levels following glucose but not protein or fat consumption. *Metabolism* **30**, 953-957.

WHO (2003) Diet, nutrition and the prevention of chronic diseases. *World Health Organ Tech Rep Ser* **916**, i-viii, 1-149, backcover.

Wren AM, Seal LJ, Cohen MA, Brynes AE, Frost GS, Murphy KG, Dhillo WS, Ghatei MA & Bloom SR (2001) Ghrelin enhances appetite and increases food intake in humans. *J Clin Endocrinol Metab* **86**, 5992.

Wren AM, Small CJ, Ward HL, Murphy KG, Dakin CL, Taheri S, Kennedy AR, Roberts GH, Morgan DG, Ghatei MA & Bloom SR (2000) The novel hypothalamic peptide ghrelin stimulates food intake and growth hormone secretion. *Endocrinology* **141**, 4325-4328.

Yeomans MR & Gray RW (1996) Selective effects of naltrexone on food pleasantness and intake. *Physiology & Behavior* **60**, 439-446.

Yeomans MR, Gray RW, Mitchell CJ & True S (1997) Independent effects of palatability and within-meal pauses on intake and appetite ratings in human volunteers. *Appetite* **29**, 61-76.

Yeomans MR & Symes T (1999) Individual differences in the use of pleasantness and palatability ratings. *Appetite* **32**, 383-394.

Young JB & Macdonald IA (1992) Sympathoadrenal activity in human obesity: heterogeneity of findings since 1980. *Int J Obes* **16**, 959-967.

Zurlo F, Lillioja S, Esposito-Del Puente A, Nyomba BL, Raz I, Saad MF, Swinburn BA, Knowler WC, Bogardus C & Ravussin E (1990) Low ratio of fat to carbohydrate oxidation as predictor of weight gain: study of 24-h RQ. *Am J Physiol* **259**, E650-657.

ARTIGO II - PAPER

INTRODUCTION

The prevalence of obesity is increasing at an alarming rate in almost all part of the world, and the researches about that have focused on the interaction between human physiology and the changing nature of the food environment supply (Drewnowski & Darmon, 2005).

Based in prior studies and accumulating evidence from literature, several data have indicated that energy-yielding fluids evoke weaker appetite and compensatory dietary responses than energy-matched challenges in solid form (Crapo & Henry, 1988; Tournier & Louis-Sylvestre, 1991; Hulshof *et al.*, 1993; DiMeglio & Mattes, 2000; Peracchi *et al.*, 2000; Mattes & Rothacker, 2001; Mattes, 2005).

Surveys increasingly document a positive association between beverage consumption and the increasing in body weight or BMI (Ludwig *et al.*, 2001; WHO, 2003; McConahy *et al.*, 2004), and intervention trials support the epidemiologic findings (DiMeglio & Mattes, 2000; James *et al.*, 2004). The mechanisms by which fluids escape appetite controls is not known, but may include cognitive, sensory, osmotic, gastrointestinal transit velocity, endocrine, and other processes (Mattes *et al.*, 2005).

Previous work have demonstrated that energy from fluids tends to add energy to the diet rather than substitute other forms of energy source (Tournier & Louis-Sylvestre, 1991; DiMeglio & Mattes, 2000). This may be manifest as larger meals, as fluids may lead to a weaker satiation, and/or more frequent meals, as they hold weak satiety properties.

Viscosity, which is defined as resistance of a substance to flow, may be one property of food that influences caloric compensation (Davidson & Swithers, 2005). The viscosity of beverages is reported to be inversely related to subsequent hunger ratings in humans (Mattes & Rothacker, 2001). Early signals of satiation may be induced through cephalic phase-responses related to the viscosity of liquid foods that may in turn be linked to soluble and insoluble fiber content. The absence of mastication preparatory to the swallowing of liquids may be another element responsible for diminished satiety.

Further, macronutrient-specific effects on satiety and satiation have been reported. While the principle source of energy in the US diet over the past two decades has derived from carbohydrate (Johnson & Frary, 2001), the increasing popularity of beverages with different primary sources, e. g., specialty coffees (high fat), performance enhancing beverages (high protein) requires assessment of each macronutrient's effects as well.

Some papers could not show differences in intake with solid and liquid foods (Pliner, 1973; Mustad *et al.*, 1999), however those studies had many no controlled factors (e. g., physical characteristics of the diets, fiber content, etc) that could confounded the interpretation of the data. On the other hand, many other studies ((Haber *et al.*, 1977; Wadden *et al.*, 1985; Tournier & Louis-Sylvestre, 1991; Hulshof *et al.*, 1993; de Graaf & Hulshof, 1996; DiMeglio & Mattes, 2000) agreed that solid are more satiating than liquids, however most of them could not show this hypothesis clearly, having the results just pointing a tendency, maybe because the design of the study, or because small sample size or lack of statistic power.

Thus, the main purpose of this study was to investigate the effects of fluid and solid loads containing primarily carbohydrate, protein or fat on satiation and satiety; and also, see if there is any difference among them in lean and obese people. The potential confounded factors (e. g. dissimilar foods, small sample size, and lack of statistic power) were well controlled in this study.

METHODS

Participants

Ninety-eight individuals completed the study. Their anthropometric characteristics are shown in Table 1. They were recruited by public advertisements. Participants met eligibility criteria consisting of a BMI between 18-23 or 30-35 kg/m^2, 18-50 years of age, stable body weight $\leq$ 3 kg change within the past three months, not taking medication known to influence appetite, self-reported consumer of breakfast and lunch, non-restrained eater (score < 14 on the Three Factor Eating Questionnaire (Stunkard & Messick, 1985)), and non-smoker. They completed and signed an informed consent form approved by the Purdue University Institutional Review Board. Participants were divide in two groups, lean and obese, for all three experiments; protein (n=40, 20 lean and 20 obese), carbohydrate (n=40, 20 lean and 20 obese), and fat (n=18, 9 lean and 9 obese). To minimize the potential for biased response, they were informed that the intent of the study was to determine whether motor skills are affected by diet.

Meals

The participants were provided a meal consisting of chicken sandwiches, which were given in excess and were ingested *ad libidum*. However, only two sandwiches were visible at any time.

The samples were randomized and matched in a liquid and solid isocaloric form, and with one predominant macronutrient. For the protein experiment, a fat free, low carbohydrate milk (Carb Countdown Fat Free Dairy Beverage – Hood) and cheese were consumed (Kraft fat free Mozzarella plus whey). For the carbohydrate experiment watermelon fruit and watermelon juice were consumed. In the fat experiment was provided coconut milk (A Taste of Thai coconut milk) and coconut meat. Water (1:1) and sweetener (1 tsp of Equal) were used to prepare the coconut milk. To match the liquid and solid sample volumes, participants were required to drink additional water when consuming the samples of coconut meat and cheese (Appendix I). Two caloric loads, 125 and 225 kcal, were provided. Participants in the BMI range of 18 – 23 kg/m^2 received 125 kcal, and those between 30 – 35 kg/m^2 received 225 kcal. The characteristics of the meal and the samples are shown in Table 2.

The hardness and viscosity methodology used is described in details at the appendix II.

Table 1 – Means and standard deviation of anthropometric characteristic of the participants:

PTN EXP. (n=40)	HEIGHT (m)	WEIGHT (kg)	BMI (kg/m^2)	AGE (years)
FEMALE/LEAN	1.62±0.04^A	54.45±2.88^A	20.79±0.65^A	23.10±3.38^A
FEMALE/OBESE	1.68±0.06^A	89.10±7.00^B	31.69±1.16^B	24.60±4.64^A
MALE/LEAN	1.77±0.05^B	66.31±5.93^C	21.09±1.15^C	20.00±1.40^B
MALE/OBESE	1.77±0.07^B	97.23±8.30^D	31.15±1.19^D	25.20±3.88^B
CHO EXP. (n=40)				
FEMALE/LEAN	1.60±0.04^A	50.46±3.55^A	19.79±0.89^A	24.00±3.09^A
FEMALE/OBESE	1.62±0.04^A	84.57±5.25^B	32.09±1.90^B	30.90±8.64^A
MALE/LEAN	1.76±0.02^B	68.20±2.16^C	21.92±0.62^C	21.80±1.78^B
MALE/OBESE	1.80±0.02^B	101.23±4.69^D	31.26±1.04^D	24.70±4.95^B
FAT EXP. (n=18)				
FEMALE/LEAN	1.62±0.07^A	56.00±3.70^A	21.37±0.84^A	20.00±1.00^A
FEMALE/OBESE	1.59±1.60^A	79.45±1.60^B	31.34±1.12^B	31.11±11.00^A
MALE/LEAN	1.79±0.08^B	70.44±8.05^C	21.87±0.72^C	19.80±1.04^B
MALE/OBESE	1.80±0.02^B	101.76±7.30^D	31.21±1.54^D	28.00±6.80^B

Means ± SD, same letter at column are not significant different, for the same experiment, F test (P<0.05).

Table 2 – Nutritional composition of the foods used

	Chicken Sandwiches*	Milk		Cheese		Watermelon Juice		Watermelon Fruit		Coconut Milk		Coconut Meat	
Caloric Load (kcal)		125	225	125	225	125	225	125	225	125	225	125	225
Weight (g)	22	432	772	70	118	400	720	400	720	79	148	35	63
Volume (ml)	-	430	770	360[?]	650[?]	390	710	390	710	83[?]	150[?]	150[?]	240[?]
Energy Density (Kcal/g)	2.5	0.2	0.2	1.7	1.8	0.4	0.4	0.4	0.4	1.5	1.4	3.7	3.7
Carbohydrate (g)	4.5	5.4	9.6	4.7	10.3	**28.7**	**51.7**	**28.7**	**51.7**	2.1	3.75	5	9.1
Fat (g)	2.6	0	0	0	0	1.7	32	1.7	3.2	**11.4**	**20.6**	**11.7**	**21.1**
Protein (g)	3.05	**21.4**	**38.5**	**24.5**	**42.7**	2.5	4.5	2.5	4.5	1.04	1.9	1.16	2.1
Caloric Content (kcal)	54	107	192	117	213	140	254	140	254	115	208	130	235
Viscosity (cps)	-	26.27		-		263.9		-		171.35		-	
Hardness (g)	-	-		199.9		-		107.5		-		1125.6	

* a mixture 12 g of Tyson premium chunk chicken breast pouch with mayonnaise and an average of 10g of Iron Kids Crust less bread, a total of 22g per sandwich

[?] Volume of water consumed with the solid treatment in order to match the volume of the liquid.

[?] Coconut milk was diluted with water (1:1), being the final volume 166 and 300 ml respectively for the lean and obese group

Protocol

Participants were instructed to fast for 10 hours overnight, eat their typical breakfast (consisting of the same meal for each of the three test days), and fast again for at least a three hours before coming to the lunch appointment. Their visits were scheduled during their normal time for lunch. Upon arriving at the Laboratory, participants completed a motor skills test and an appetite questionnaire on a palm pilot. A finger stick glucose measurement checked the pre-test fast was maintained. Participants were then provided with a meal consisting of the chicken sandwiches and water, for the control session, and the sandwiches and a food sample on the two other test days. They were given around 20 minutes to complete the meal. In an attempt to minimize the influence of social interaction on the amount of food ingested, participants were placed in an isolation booth to consume their meal (de Castro & de Castro, 1989). The participants were given two sandwiches to begin and were permitted to reach behind a partition to obtain as many sandwiches as they needed to reach a level of comfortable fullness. They were unaware of how many sandwiches were behind the partition (Rolls *et al.*, 2002). Minimizing the risk of participants passing a level of comfortable fullness, the sample was divided in thirds. On the test days that the samples were provided, participants were instructed to eat the first two thirds of the sample, to evaluate their level of fullness, and then to decide if eating the sandwiches would interfere with finishing the sample and going beyond a comfortable level of fullness. Participants were instructed to take five minutes to consume each third of the sample. The written instruction for that part is presented in Appendix III. During the sessions they had samples to eat, it was asked them to rank how much they liked the sample. After finishing their lunch, participants again completed the motor skills test and the appetite questionnaire. Before leaving the lab, participants were instructed to keep a food record of each eating or drinking occasion until going to sleep for the night. They were instructed in portion size estimation using NASCO food models (Fort Atkinson, WI) and true-size pictures with a PowerPoint presentation. Additionally, the participants were requested to complete the appetite questionnaire on the palm pilot each hour and draw a single geometric form in the palm pilot notepad every other hour until going to sleep for the night.

Dietary Analyses and Appetite/Sensory Assessments (ratings)

Food records were analyzed using version 7.6 of the Food Processor nutrition database (ESHA, Research, Salem, Oregon). Satiation was estimated according the calories consumed at lunch. Satiety was estimated in two ways. One by calories, consumed after lunch, and the other by time (minutes between the participants completing their lunch with a comfortable level of fullness, until the next eating or drinking occasion greater than or equal to 150 kcal). Electronic Appetite Rating Systems (EARS) was used to record participants' hunger and fullness, before and after consuming lunch, and each hour after leaving the lab. Questions about appetite status, for example: "How hunger do you feel right now? How strong is your desire to eat right now?" Were anchored with "not at all hunger / very weak" at the beginning and "as hunger as I've ever felt / very strong" at the end of the scale. A schematically summary of the protocol is shown at Figure 1.

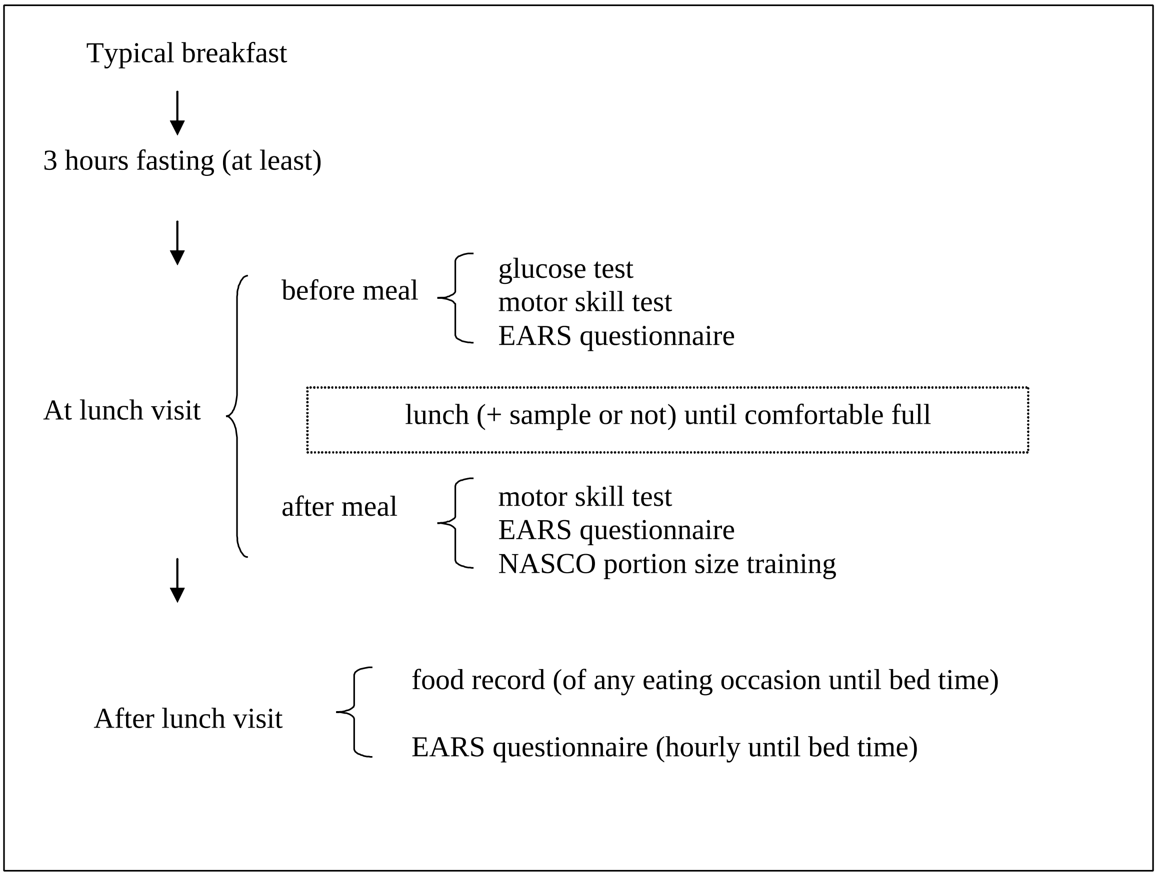


Figure 1- Schematically summary of the study protocol, for the three sessions (control, liquid or solid).

Statistical analysis

Means, standard deviations, and correlations were used to describe distributions of all variables. Repeated measures analysis of variance with one within-subject factor (meal form – fluid versus solid) was used for all analyses, and also BMI (lean and obese) as between-subject factor were used to assess the all analyses for the protein and carbohydrate experiment, but not for the fat. The criterion for statistical significance was two-tailed $p<0.05$. Where appropriate, LSD test (pairwise comparisons) was used for post hoc analyses. The Statistical Package for the Social Science (SPSS) version 12.0 was used for all analyses. The dependent variables from participants food records were calories at lunch from the sandwiches consumed, total calories at lunch (sandwiches plus sample), after lunch calories, total calories, and satiety; and from the EARS were huger, fullness, desire to eat, preoccupation to eat, desire for salt food, for sweet, for fat, and thrust. Power calculation of 85% indicated a sample size of 20 participants per group (lean x obese), permitting detection of between-group treatment effects equal to a standardized of 1 at the 5% probability level.

RESULTS

The mean of hedonic ratings of the samples (how much participants like the food) is presented at Figure 2. There was no significant difference between the cheese and milk at the protein experiment, however there was difference between the samples for the carbohydrate (*P*<0.01) and fat (*P*<0.05) experiments.

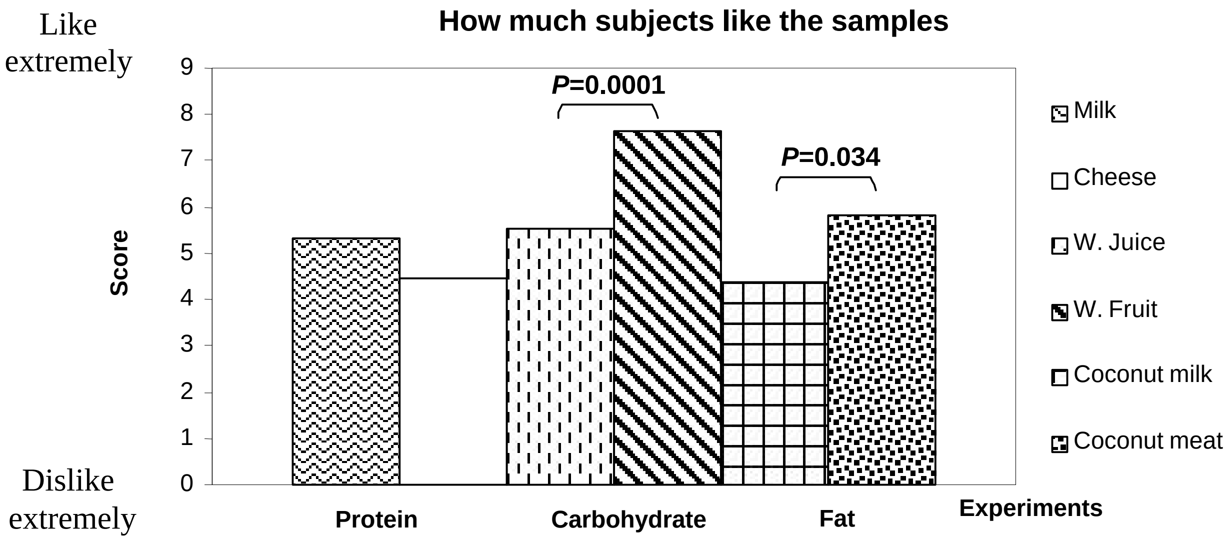


Figure 2 - Mean of hedonic ratings of the samples, paired *t*- test (*P*<0.05).

Energy Intake

- Protein experiment:

Calories consumed from sandwiches at lunch were higher when participants had the liquid load (*P*=0.001), compared to the solid. At the control session calories consumed from sandwiches didn't differ when participants had the liquid load, however, they were higher (*P*=0.0001) when they had the solid load.

There was a significant interaction among treatments and BMI for total calories consumed at lunch (*P*=0.037), sandwiches calories plus sample. Obese group ate more (577.3 kcal) than lean (435.6 kcal) with the liquid load (*P*=0.009), and also they ate more with the liquid load (577.3 kcal) compared to the solid (470.7 kcal), (*P*=0.031).

Calories consumed after lunch tended to be lower with the solid load (*P*=0.064), and also, for total calories (*P*=0.062) through the day. Satiety was not significant, and also neither BMI, for all parameters analyzed. Means and standard deviation (ME ± SD) of the protein experiment are presented at Table 3.

Table 3 - Means and standard deviation of calories consumed and satiety for the **protein** experiment:

Session	Calories from sandwiches at lunch (kcal)	Total lunch calories (kcal)	After lunch calories (kcal)	Total calories day (kcal)	Satiety (minutes)
Control	361.9±117.7^{A}		1457.1±516.8^{A}	1891.6±581.7^{A}	210.8±115.0^{A}
Liquid	**331.4±162.0^{A}**	TRTxBMI*	1408.1±765.3^{A}	1914.48±812.5^{A}	229.1±111.5^{A}
Solid	**264.6±129.3^{B}**		1225.7±585.1^{A}	1665.3±633.7^{A}	248.6±160.5^{A}

Means ± SD, same letter at column are not significant different, F test (*P*<0.05).
* Significant interaction among treatments and BMI (*P*=0.037).

- Carbohydrate experiment:

There was a significant interaction among treatments and BMI for calories consumed at lunch from sandwiches (*P*=0.006). Obese group ate less calories of sandwiches (199.9 kcal) than lean (394.4 kcal) with the liquid load (*P*=0.015).

No difference in total calories consumed at lunch was found when participants had liquid and solid loads, however when a potential outlier subject was removed of the analysis (n=39), total calories consumed at lunch was higher with the liquid load, compared to the solid (*P*=0.032). Also, during both liquid (*P*=0.001) and solid (*P*=0.009) sessions, total calories consumed at lunch was higher than control, either with or without this outlier subject.

Calories consumed after lunch (*P*=0.044) and also through the day (*P*=0.026) were higher after the liquid load compared to the solid. They did not differ between control and liquid, but they were higher with control (*P*=0.014) compared to solid. Because later consumption was different we proceeded the analysis with the profile of the nutrients from participants food records. Among the macronutrients, we found statistic significance only for carbohydrate, when after control its consumption was higher than after liquid (*P*=0.043), and solid (*P*=0.001) sessions. However, carbohydrate calories consumed after liquid and solid did not differ between them. For grams of food consumed later, control tended to be higher than liquid (*P*=0.086), however it was really higher just than solid (*P*=0.002). Also, for grams of food consumed after lunch, liquid and solid did not differ. Sugar consumption was higher after liquid load compared to solid (*P*=0.042), and also higher with control compared to solid (*P*=0.008). No difference was found among treatments for calories consumed after lunch from beverages, volume of beverages consumed, and water, and satiety (calculated by minutes) in this experiment. BMI was not significant for all parameters analyzed. Means and standard deviation (ME ± SD) are presented at Table 4.

Table 4 - Means and standard deviation of calories consumed and satiety for the **carbohydrate** experiment:

Variables	Control	Liquid	Solid
Calories from sandwiches at lunch (kcal)		TRTxBMI*	
Total calories at lunch (kcal) n=40	382.2+205.4^{A}	472.1+243.4^{B}	447.8+234.1^{B}
Total calories at lunch (kcal) **n=39**	379.6+207.4^{A}	**478.5+243.2^{B}**	**446.6+237.9^{C}**
After lunch calories (kcal)	1641.2+774.4^{A}	**1497.9+516.8^{A}**	**1304.6+579.5^{B}**
Total calories of the day (kcal)	2023.4+812.7^{A}	**1970.0+612.2^{A}**	**1752.5+614.2^{B}**
Satiety (minutes)	221.4+116.9^{A}	226.2+126.9^{A}	226.2+105.2^{A}
Protein after lunch (g)	59.2+38.6^{A}	56.7+27.9^{A}	47.4+18.5^{A}
Carbohydrate after lunch (g)	214.5+118.5^{A}	183.1+79.9^{B}	168.3+87.3^{B}
Fat after lunch (g)	74.7+91.1^{A}	58.9+34.5^{A}	49.2+26.1^{A}
Weight of food after lunch (g)	1917.9+814.0^{A}	1716.7+732.3^{AB}	1567.9+747.5^{B}
Sugar after lunch (g)	86.2+66.8^{A}	80.4+55.4^{A}	63.6+54.3^{B}
Calories from beverages after lunch (kcal)	217.5+206.4^{A}	260.7+354.0^{A}	185.0+201.0^{A}
Volume of beverages after lunch (ml)	1182.7+638.4^{A}	1086.7+729.5^{A}	1001.3+671.3^{A}
Water after lunch (ml)	1514.1+760.4^{A}	1360.5+690.5^{A}	1281.9+680.2^{A}

Means + SD, same letter at line are not significant different, F test (*P*<0.05).
* Significant interaction among treatments and BMI (*P*=0.006).

- Fat experiment:

No difference was found among treatments for calories from sandwiches at lunch, after lunch, and satiety. Total calories consumed at lunch were lower at control session, compared to liquid (*P*=0.0001), and solid (*P*=0.008), and tended to be higher for liquid compared to solid (*P* =0.055). Means and standard deviation (ME + SD) are presented at Table 5.

Table 5 – Means and standard deviation of calories consumed and satiety for the **fat** experiment:

Session	Calories from sandwiches at lunch (kcal)	Total lunch calories (kcal)	After lunch calories (kcal)	Total calories day (kcal)	Satiety (minutes)
Control	360.3+159.7^{A}	360.3+159.7^{A}	1935.1+1009.2^{A}	2295.5+1041.0^{A}	216.1+137.9^{A}
Liquid	363.3+231.6^{A}	538.3+237.9^{B}	1940.3+1054.0^{A}	2478.6+1175.2^{A}	215.1+127.9^{A}
Solid	306.1+176.9^{A}	481.1+187.6^{B}	1654.9+696.6^{A}	2136.1+729.1^{A}	239.4+109.5^{A}

Means + SD, same letter at column are not significant different, F test (*P*<0.05).

Appetite ratings

- Protein and carbohydrate experiment:

No significant effect among treatments and BMI was found for the average daily ratings of any appetite variables analyzed. Means and standard deviation (ME ± SD) are presented at Table 6 for the protein experiment and Table 7 for the carbohydrate one.

Table 6 – Means and standard deviation of appetite variables of the protein experiment:

Variables	Control	Liquid	Solid
Hunger	31.6±9.5[A]	33.0±9.4[A]	32.9±9.7[A]
Fullness	41.6±12.6[A]	41.1±12.2[A]	41.5±12.5[A]
Desire to eat	32.3±10.9[A]	31.5±10.9[A]	31.5±11.3[A]
Preoccupation to eat	27.1±12.9[A]	26.7±12.1[A]	27.5±12.2[A]
Desire for SALT food	17.9±12.0[A]	18.8±13.3[A]	17.6±12.3[A]
Desire for SWEET food	24.6±12.9[A]	22.7±14.7[A]	24.4±14.4[A]
Desire for FAT food	17.0±12.2[A]	17.1±13.5[A]	17.1±13.4[A]
Thrust	35.9±13.3[A]	37.5±10.8[A]	36.2±14.2[A]

Means ± SD same letter at line are not significant different, F test (*P*<0.05).

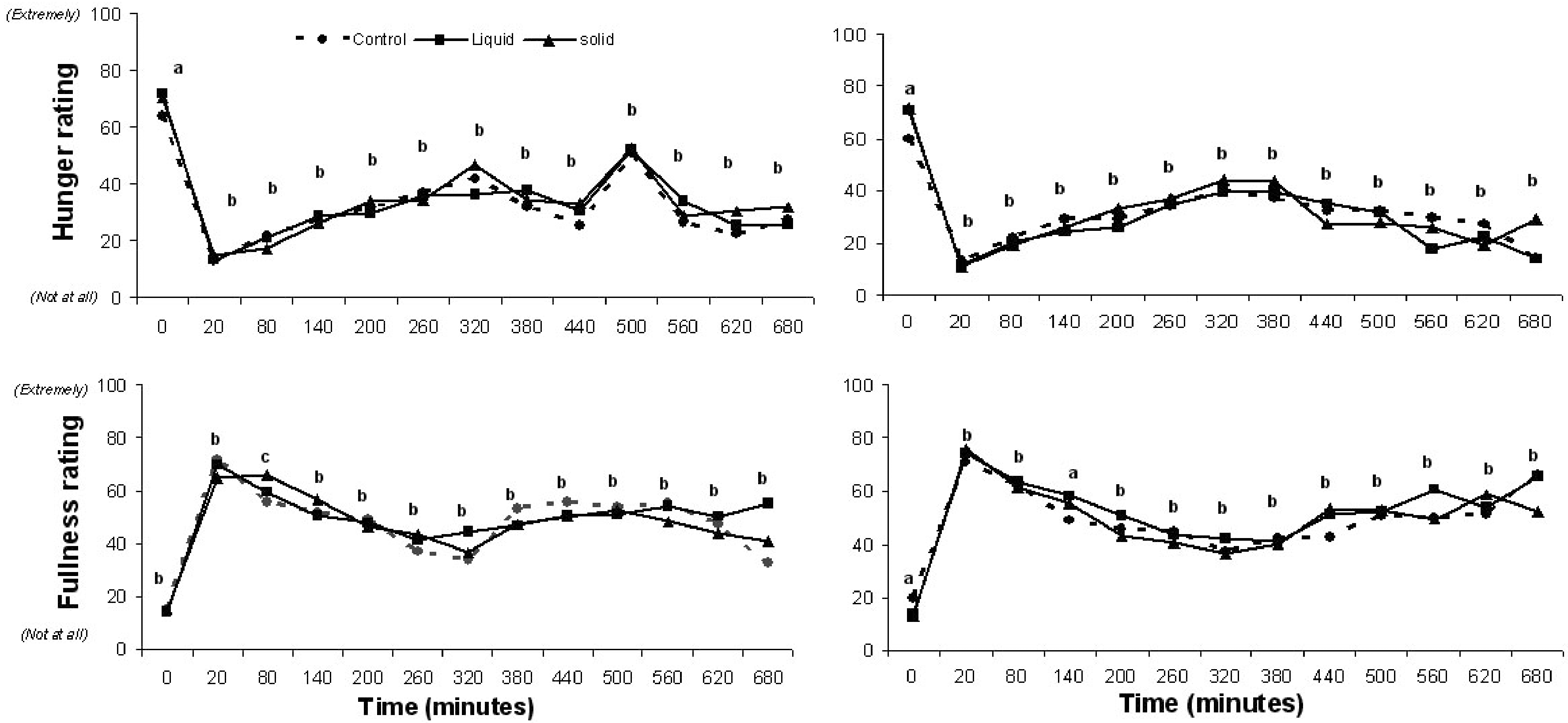
Table 7 – Means and standard deviation of appetite variables of the carbohydrate experiment:

Variables	Control	Liquid	Solid
Hunger	31.9±10.4[A]	31.3±9.5[A]	32.4±10.5[A]
Fullness	42.7±12.1[A]	42.6±13.6[A]	41.5±12.4[A]
Desire to eat	32.7±10.2[A]	31.2±11.8[A]	32.5±11.6[A]
Preoccupation to eat	27.0±11.3[A]	26.5±12.5[A]	28.1±11.5[A]
Desire for SALT food	21.5±12.0[A]	21.9±13.1[A]	23.0±12.3[A]
Desire for SWEET food	28.1±13.0[A]	23.8±11.4[A]	23.5±12.1[A]
Desire for FAT food	19.8±11.4[A]	18.4±10.5[A]	20.0±12.0[A]
Thrust	43.7±14.2[A]	41.8±15.3[A]	43.2±15.9[A]

Means ± SD same letter at line are not significant different, F test (*P*<0.05).

The variation of participant's hunger and fullness were also analyzed through the day, for the protein and carbohydrate experiments (Figure 3). The main differences found were for the protein experiment. Fullness was higher one hour later than solid load, at 80 minutes, compare to control and liquid (Figure 3).

Protein Experiment **Carbohydrate Experiment**



a = control different from liquid and solid
b = no difference among treatments
c = solid different from control and liquid
d = liquid different from control and solid

Figure 3. Means of hunger and fullness ratings of the control, liquid and solid sessions through the time for the protein and carbohydrate experiment.

- Fat experiment:

No significant effect among treatments was found for the average daily ratings of any appetite variables analyzed. Means and standard deviation (ME ± SD) are presented at Table 8.

Table 8 – Means and standard deviation of appetite variables of the fat experiment:

Variables	Control	Liquid	Solid
Hunger	29.9±9.2^A	33.1±8.5^A	34.4±12.1^A
Fullness	53.4±8.7^A	52.6±11.1^A	50.1±8.9^A
Desire to eat	33.0±10.1^A	32.9±9.7^A	33.5±12.7^A
Preoccupation to eat	25.4±7.1^A	28.6±12.4^A	28.5±11.6^A
Desire for SALT food	20.0±12.2^A	22.1±12.3^A	22.9±12.3^A
Desire for SWEET food	30.6±17.0^A	26.0±15.9^A	29.4±19.9^A
Desire for FAT food	18.1±10.5^A	20.1±14.2^A	20.4±14.6^A
Thrust	44.8±13.7^A	48.5±12.4^A	51.2±13.5^A

Means ± SD same letter at line are not significant different, F test (*P*<0.05).

DISCUSSION

The sensorial evaluation of the samples used in a study investigating satiation and satiety is essential to analyze the final results. Some studies do not measure that or they do not make any consideration about the differences found in the taste of the samples used in their final results. In this study, carbohydrate and fat liquid samples received lower taste scores than solid ones (Figure 2). However, a weak correlation between their taste scores and later calories consumption was verified (Appendix IV). In other words, there was no influence in later consumption of the participants by the lower taste score of those samples. We assumed that participants gave lower taste scores for the watermelon juice and the coconut milk because those samples are very rarely consumed by them. On the other hand, no difference in the taste scores was found for milk and cheese, which are foods often consumed by them.

The analyses of the energy intake at lunch and through the day could show some clear results about the use of liquid and solid foods. As it was said before, the main hypothesis addressed in this paper is that energy from fluids has a weaker influence in the control of satiety, compared to the same energy level presented by solid foods, leading many times in compensatory dietary responses (DiMeglio & Mattes, 2000).

In this study satiation was clearly lower with liquid load, compared to solid for the protein (Table 3) and carbohydrate (Table 4) experiments, and maybe it will be also with a bigger sample for the fat (Table 5). Calories consumed after lunch was significant higher after liquid load compared to solid in the carbohydrate experiment, and tended to be higher in the other two experiments, showing its weak power on satiety control, in other words, not leading to a caloric compensation later on.

However, many studies have shown opposite results (Jordan *et al.*, 1981; Rolls *et al.*, 1990; Spiegel *et al.*, 1994; Himaya & Louis-Sylvestre, 1998; Santangelo *et al.*, 1998; Rolls *et al.*, 1999). Most of these studies have used as food stimuli, yogurt, snacks and especially soup, consumed as a pre-load in a meal, or immediately before the test meal. The most common not controlled confounding factors in those studies were: macronutrient content, weight, temperature, volume, palatability, fiber content and structure, cognitive impression, and also the different design focus of each one. Soup is a very heterogeneous food category. It usually differs from beverages in nutrient content, temperature, and presentation form. It has a cognitive impression of a meal and not a snack. Thus, the studies that use soup as the liquid diet to be compared with solids have a complete different design, and should not be compared to those that use beverages as the liquid diet.

Mustad, Jonnalagadda et al. (1999) could not find any difference in hunger and satiety using a matched liquid-formula diet with a solid-formula diet in macronutrients; however other physical characteristics of the diets, especially fiber content, were different.

Mattes (2005) worked also with soup, however one of his macronutrients system, apples, had a juice version for comparison. In this case, it was shown that the beverage had the weakest satiety effect, compared to the soup and the fruit. But there were some points that could influence the results such as a large range of age (18-60 years) and BMI (18- 35 kg/m^2) of the participants, the different temperatures of the samples served, and the difference in volume in the protein and fat system.

Additionally to the physical attributes of foods that can affect satiation and satiety, hunger ratings and energy intake can also be affected by participants' age, gender and dietary restraint (Almiron-Roig *et al.*, 2003).

Contrasting the first group of studies cited, and agreeing with Mattes (2005), several other studies shown that solid pre-loads were more satiating than liquids. The earliest study, Haber, Heaton et al. (1977), shown greater reduction of hunger after ingestion of apples, compared to apple puree, and this one greater than apple juice. Nevertheless, other components such as weight, temperature, volume, palatability, fiber content and structure, cognitive impression, etc, were not controlled because the main focus was in food glycemia. Similarly, Bolton, Heaton et al. (1981) compared fruit with juice, oranges and grapes, finding that solids were stronger to decrease hunger, but with the same problems of the last study, and not including any energy intake measurement. Likewise, Tournier and Louis-Sylvestre (1991) shown that when most of the energy was ingested in liquid form, no compensation as observed. They controlled nutrient composition, weight, temperature and palatability, varying physical state with use of matodextrines and gelatin. Although hunger ratings did not differ after liquid and solid, total energy intake was higher when most of the pre-load energy was in liquid form. However, in this study, the freedom to drink water could influence the results.

Two other studies, Hulshof, De Graaf et al. (1993) and De Graaf & Hulshof (1996), found higher satiety after consumption of solid compared to liquid foods. But also, some conditions in those studies could mask the results, in particular no naturalist foods and conditions, such as thickening agent to prepare the solid diets, nose clips wore by subject, respectively (Hulshof *et al.*, 1993), likewise, differences in energy density and weight of the samples (de Graaf & Hulshof, 1996).

More recently, DiMeglio and Mattes (2000) contrasted liquid x solid carbohydrate using soda and candy. They found 118% of energy intake compensation during the use of the solid load, and no significance decrease in energy intake during the use of the liquid. Drawbacks that could influence these results were the freedom of time that participants had to eat the loads during the day, and under controlled laboratory conditions to measure food intake.

Two other studies, Mattes and Rothacker (2001) and Davidson and Swithers (2005), showed that differences in beverages viscosity can strongly affect hunger. They are inversely related. But the design of these studies was to compare liquids, more or less viscose, and not to contrast them with solid food.

No macronutrient-specific response was found at the carbohydrate experiment, but sugar consumption was higher after liquid load, even though participants did not show any difference for the desire to eat sweet foods with the EARS among the three sessions. Those findings are probably related to the common participants underreport food intake assessed by food records, plus the free-living condition that can greatly affect some data in short investigations. This result agrees with Gatenby, Aaron et al. (1997) that also did not find any macronutrient compensation in a long-term study with free-living subjects using modified foods.

The present study tried to get a more complete picture of these controversies, by the use of more controlled conditions and less variability in food composition, in its solid and liquid forms.

About the possible mechanisms of action involved with satiation and satiety, fiber content was controlled in this study, however its structure was different for the carbohydrate experiment after blended the watermelon to obtain the juice. The liquid sample probably had a weaker contribution of fibers on satiety and satiation than the solid, by the breakdown of the fibers. This could be another explanation for the higher consumption with liquid at that experiment.

Lack of mastication also could have contributed for the greater values of calories consumed with the liquid load. This potential mechanism related also to the control of the appetite cascade seems to affect more satiation than satiety, in the case of the protein experiment; but it seems to affect both for the carbohydrate one. The absence of chewing might result in decreased pancreatic exocrine and endocrine responses when compared to solids (Brand *et al.*, 1982). Also, in general, liquids are emptied from the stomach at a much higher rate than solids and they may induce weak signals in the gastrointestinal tract that would otherwise lead to further energy intake (Spiegel *et al.*, 1994; Spiegel *et al.*, 1997; Almiron-Roig *et al.*, 2003; Almiron-Roig & Drewnowski, 2003).

Almiron-Roig, Chen et al. (2003) have pointed in their review that solids may exert their impact on satiety primarily through energy content, rather than volume (Kirkmeyer & Mattes, 2000), whereas beverages show a stronger effect of volume and weaker effect of energy (Rolls *et al.*, 1990). Also, they mentioned that solids can appear to be more satiating than liquids when there is a long time delay between pre-load and the meal, but liquids can appear to be more satiating than solids when pre-load volume is high and the time delay is short (Almiron-Roig *et al.*, 2003). If that is true, those two considerations could be another reason for such controversies about this theme in the literature.

Body weight related to physical state of the food was another main focus of this paper. Few studies compared solid and liquid foods in lean and obese people. Pliner (1973) failed to show differences in eating behavior between normal weight and obese subjects. His work just showed a tendency of the leans to eat less after the liquid pre-load than solid. However, the pre-loads, flavored milk and an angel food cake plus jam differed in many physical attributes and macronutrients composition.

In the three experiments we could see more clearly that body weight influences calories consumed especially in the protein one, when the obese group ate more calories at lunch, with the liquid load, than the leans (577.3 *vs* 435.6 kcal). Even receiving a bigger load of milk than the lean ones, 100 kcal difference, they did not show any compensation. Also, obese ones ate more calories at lunch with the liquid load compared with the solid (577.3 *vs* 470.7 kcal). These data shown that obese people seems to have a weaker control of calories consumed with liquids, especially at short term (Drewnowski *et al.*, 1994), compared to lean ones. Protein is the strongest macronutrient in the satiety cascade and also is very powerful to release cholecystokinin, CCK, hence that is why these differences and others, illustrated at figure 3, were detected more clearly for this experiment.

In the carbohydrate experiment, the obese group ate less calories at lunch (from sandwiches), with the liquid load, than the leans (199.9 *vs* 394.4 kcal), which was *ad libitum*. Two possible explanations for that are gastric empty and insulin action that may be differentiated in obese people. Glasbrenner, Pieramico et al. (1993) verified a significant short lag phase for the emptying of solids and a trend to slowed liquid emptying in obese subjects compared to lean, using a orange juice and an egg ham sandwich. Also, it has been shown that the increase of body weight contributes to insulin resistance (Jenkins *et al.*, 2000; McLaughlin *et al.*, 2004; Reaven, 2005). Both, liquid samples, the orange juice used in Glasbrenner, Pieramico et al. (1993) study, and the watermelon juice used in this study are examples of high glycemic index foods. Then, in a normal pathway, they should decrease satiety by the fast release of insulin, therefore stimulating food intake (Ludwig, 2000; Roberts, 2000). It did not happen at the carbohydrate experiment, suggesting that obese participants probably had a dysfunction of this system.

Thus, the mechanisms by which fluids escape appetite controls have not been sufficiently characterized, but we strongly believed that cognitive, sensory, osmotic, gastrointestinal transit, endocrine, and other processes are involved.

In conclusion, our data shown liquid foods leaded to higher calories consumption in a short term, satiation, but also it has some influence at long term, satiety, compared to solids. Therefore, the control of liquid caloric foods, especially as beverages combined in a meal or as a snack, must be limited in the prevention and treatment of obesity.

ACKNOWLEDGMENTS

I would like to thank Dr. Mattes for all coordination and help with the project, and his entire lab group, especially Amy Devitt, Christy Wood and Judy George. Also, I appreciated all statistic assistance by Nilupa Gunaratna, and the contributions of the initial design of the study by John Potter. This work was supported by CNPq, Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES), Brasília/Brazil.

REFERENCES

Almiron-Roig E, Chen Y & Drewnowski A (2003) Liquid calories and the failure of satiety: how good is the evidence? *Obes Rev* **4**, 201-212.

Almiron-Roig E & Drewnowski A (2003) Hunger, thirst, and energy intakes following consumption of caloric beverages. *Physiol Behav* **79**, 767-773.

Bolton RP, Heaton KW & Burroughs LF (1981) The role of dietary fiber in satiety, glucose, and insulin: studies with fruit and fruit juice. *Am J Clin Nutr* **34**, 211-217.

Brand JG, Cagan RH & Naim M (1982) Chemical senses in the release of gastric and pancreatic secretions. *Annu Rev Nutr* **2**, 249-276.

Crapo PA & Henry RR (1988) Postprandial metabolic responses to the influence of food form. *Am J Clin Nutr* **48**, 560-564.

Davidson TL & Swithers SE (2005) Food viscosity influences caloric intake compensation and body weight in rats. *Obes Res* **13**, 537-544.

de Castro JM & de Castro ES (1989) Spontaneous meal patterns of humans: influence of the presence of other people. *Am J Clin Nutr* **50**, 237-247.

de Graaf C & Hulshof T (1996) Effects of weight and energy content of preloads on subsequent appetite and food intake. *Appetite* **26**, 139-151.

DiMeglio DP & Mattes RD (2000) Liquid versus solid carbohydrate: effects on food intake and body weight. *Int J Obes Relat Metab Disord* **24**, 794-800.

Drewnowski A & Darmon N (2005) The economics of obesity: dietary energy density and energy cost. *Am J Clin Nutr* **82**, 265S-273S.

Drewnowski A, Massien C, Louis-Sylvestre J, Fricker J, Chapelot D & Apfelbaum M (1994) The effects of aspartame versus sucrose on motivational ratings, taste preferences, and energy intakes in obese and lean women. *Int J Obes Relat Metab Disord* **18**, 570-578.

Gatenby SJ, Aaron JI, Jack VA & Mela DJ (1997) Extended use of foods modified in fat and sugar content: nutritional implications in a free-living female population. *Am J Clin Nutr* **65**, 1867-1873.

Glasbrenner B, Pieramico O, Brecht-Krauss D, Baur M & Malfertheiner P (1993) Gastric emptying of solids and liquids in obesity. *Clin Investig* **71**, 542-546.

Haber GB, Heaton KW, Murphy D & Burroughs LF (1977) Depletion and disruption of dietary fibre. Effects on satiety, plasma-glucose, and serum-insulin. *Lancet* **2**, 679-682.

Himaya A & Louis-Sylvestre J (1998) The effect of soup on satiation. *Appetite* **30**, 199-210.

Hulshof T, De Graaf C & Weststrate JA (1993) The effects of preloads varying in physical state and fat content on satiety and energy intake. *Appetite* **21**, 273-286.

James J, Thomas P, Cavan D & Kerr D (2004) Preventing childhood obesity by reducing consumption of carbonated drinks: cluster randomised controlled trial. *Bmj* **328**, 1237.

Jenkins DJ, Axelsen M, Kendall CW, Augustin LS, Vuksan V & Smith U (2000) Dietary fibre, lente carbohydrates and the insulin-resistant diseases. *Br J Nutr* **83 Suppl 1**, S157-163.

Johnson RK & Frary C (2001) Choose beverages and foods to moderate your intake of sugars: the 2000 dietary guidelines for Americans--what's all the fuss about? *J Nutr* **131**, 2766S-2771S.

Jordan HA, Levitz LS, Utgoff KL & Lee HL (1981) Role of food characteristics in behavioral change and weight loss. *J Am Diet Assoc* **79**, 24-29.

Kirkmeyer SV & Mattes RD (2000) Effects of food attributes on hunger and food intake. *Int J Obes Relat Metab Disord* **24**, 1167-1175.

Ludwig DS (2000) Dietary glycemic index and obesity. *J Nutr* **130**, 280S-283S.

Ludwig DS, Peterson KE & Gortmaker SL (2001) Relation between consumption of sugar-sweetened drinks and childhood obesity: a prospective, observational analysis. *Lancet* **357**, 505-508.

Mattes R (2005) Soup and satiety. *Physiol Behav* **83**, 739-747.

Mattes RD, Hollis J, Hayes D & Stunkard AJ (2005) Appetite: measurement and manipulation misgivings. *J Am Diet Assoc* **105**, S87-97.

Mattes RD & Rothacker D (2001) Beverage viscosity is inversely related to postprandial hunger in humans. *Physiol Behav* **74**, 551-557.

McConahy KL, Smiciklas-Wright H, Mitchell DC & Picciano MF (2004) Portion size of common foods predicts energy intake among preschool-aged children. *J Am Diet Assoc* **104**, 975-979.

McLaughlin T, Allison G, Abbasi F, Lamendola C & Reaven G (2004) Prevalence of insulin resistance and associated cardiovascular disease risk factors among normal weight, overweight, and obese individuals. *Metabolism* **53**, 495-499.

Mustad VA, Jonnalagadda SS, Smutko SA, Pelkman CL, Rolls BJ, Behr SR, Pearson TA & Kris-Etherton PM (1999) Comparative lipid and lipoprotein responses to solid-food diets and defined liquid-formula diets. *Am J Clin Nutr* **70**, 839-846.

Peracchi M, Santangelo A, Conte D, Fraquelli M, Tagliabue R, Gebbia C & Porrini M (2000) The physical state of a meal affects hormone release and postprandial thermogenesis. *Br J Nutr* **83**, 623-628.

Pliner PL (1973) Effect of liquid and solid preloads on eating behavior of obese and normal persons. *Physiol Behav* **11**, 285-290.

Reaven G (2005) All obese individuals are not created equal: insulin resistance is the major determinant of cardiovascular disease in overweight/obese individuals. *Diab Vasc Dis Res* **2**, 105-112.

Roberts SB (2000) High-glycemic index foods, hunger, and obesity: is there a connection? *Nutr Rev* **58**, 163-169.

Rolls BJ, Bell EA & Thorwart ML (1999) Water incorporated into a food but not served with a food decreases energy intake in lean women. *Am J Clin Nutr* **70**, 448-455.

Rolls BJ, Fedoroff IC, Guthrie JF & Laster LJ (1990) Foods with different satiating effects in humans. *Appetite* **15**, 115-126.

Rolls BJ, Morris EL & Roe LS (2002) Portion size of food affects energy intake in normal-weight and overweight men and women. *Am J Clin Nutr* **76**, 1207-1213.

Santangelo A, Peracchi M, Conte D, Fraquelli M & Porrini M (1998) Physical state of meal affects gastric emptying, cholecystokinin release and satiety. *Br J Nutr* **80**, 521-527.

Spiegel TA, Hubert CD, Fried H, Peikin SR, Siegel JA & Zeiger LS (1997) Contribution of gastric and postgastric feedback to satiation and satiety in women. *Physiol Behav* **62**, 1125-1136.

Spiegel TA, Kaplan JM, Alavi A, Kim PS & Tse KK (1994) Effects of soup preloads on gastric emptying and fullness ratings following an egg sandwich meal. *Physiol Behav* **56**, 571-575.

Stunkard AJ & Messick S (1985) The three-factor eating questionnaire to measure dietary restraint, disinhibition and hunger. *J Psychosom Res* **29**, 71-83.

Tournier A & Louis-Sylvestre J (1991) Effect of the physical state of a food on subsequent intake in human subjects. *Appetite* **16**, 17-24.

Wadden TA, Stunkard AJ, Brownell KD & Day SC (1985) A comparison of two very-low-calorie diets: protein-sparing-modified fast versus protein-formula-liquid diet. *Am J Clin Nutr* **41**, 533-539.

WHO (2003) Diet, nutrition and the prevention of chronic diseases. *World Health Organ Tech Rep Ser* **916**, i-viii, 1-149, backcover.

APPENDIX

APPENDIX I – Calculation of water volume given to participants to drink with the solid samples (Displacement technique):

Sample	Grams sample (g)	Water volume (ml)	Displacement (ml)	Water for dilution (ml)	Volume of water consumed with the solid sample (ml)
Coconut *					
(lean group)	35	100	32	83	**150**
(obese group)	63	150	61	150	**240**
Cheese					
(lean group)	63	430	60	-	**360**
(obese group)	112	770	110	-	**650**

* The matched liquid sample (coconut milk) was diluted.

In order to match the volume of the samples given to participates in the liquid and solid sessions, water as also consumed when they had cheese and coconut meat as samples.

APPENDIX II – Viscosity and Hardness measurements

Viscosity measurements were done for the liquid samples used in the study, using a Brookfield digital viscometer (Model RVDV-E Brookfield Engineering Laboratories, Stoughton, MA).

The sample foods used were: low carbohydrate milk (Carb Countdown Fat Free Dairy Beverage – Hood), watermelon blended (with a standard kitchen blender for 5 minutes), and coconut milk (A Taste of Thai coconut milk), prepared with 1:1 water dilution and 1 tsp of Equal sweetener.

All the measurements were taken after at least one hour the sample have been prepared and storage in the refrigerator, as the same temperature presented to be drunk by the participants, and previously re-homogenized with a spoon. Spindle number 1* was used for the three samples, and at least three different sets of rpm, with stable reading, were used.

Sample	Spindle	Speed (rpm)	Centipoises (cps)	%
Watermelon juice	1	3	637	19.1
		5	380	19
		10	217	21.7
		20	142	28.4
		50	109.4	54.5
		60	98	58.8
Mean			**263.90**	
Coconut milk	1	3	410	12.3
		5	234	11.7
		10	140	14
		20	94	18.8
		50	74.4	37.2
		60	75.7	45.3
			171.35	
Mean			**171.35**	
Milk	1	50	23.4	11.7
		60	25.3	15.2
		100	30.1	30.1
Mean			**26.27**	

* Smallest number of the spindle is used for thin liquids, lager for thicker ones.

Hardness measurements were done for the solid samples of the study, using a Texture analyzer (Stable Micro Systems Texture Analyzer, model TA.XT2 – Texture Technologies Corp., Scarsdale, NY).

The sample foods for the hardness measurements were: watermelon, coconut meat, cheese (Kraft fat free Mozzarella plus whey) with whey (9:1)

Cylinder and cone probes were used for the three samples.

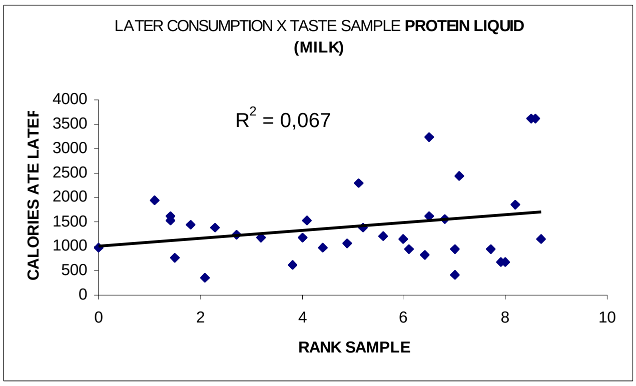
Sample	Probes			Force
Watermelon fruit	cone			137.6
				141.5
				69.6
				81.2
			mean	**107.5**
Coconut meat	cone	inside part		503.8
				431.8
				439
			mean	**458.2**
		outside part		1857.3
				1818.3
				1703.3
			mean	**1793.0**
			mean	**1125.6**
Cheese				206.7
				140.5
				161.3
				135.7
				355.3
			mean	**199.9**

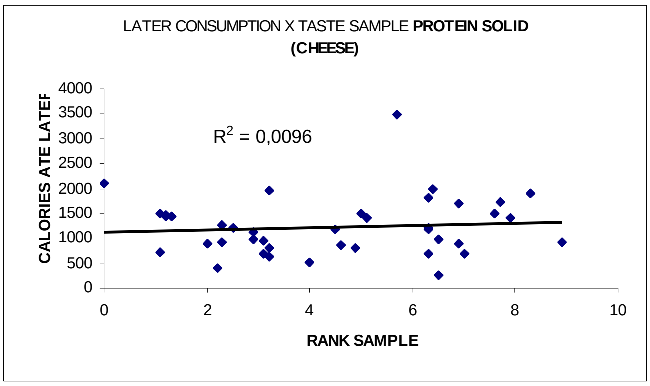
APPENDIX III – Written instructions for participants to eat the sample at the solid and liquid sessions.

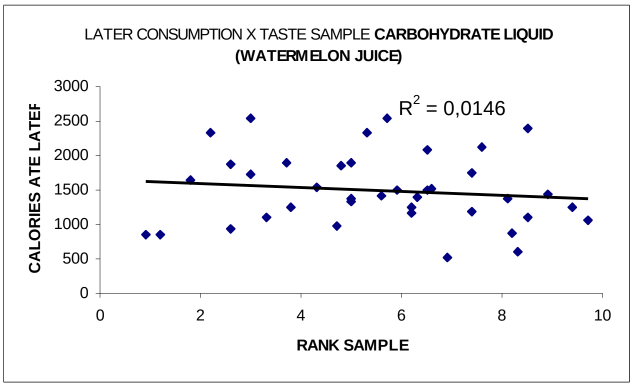
Instructions for today's session:

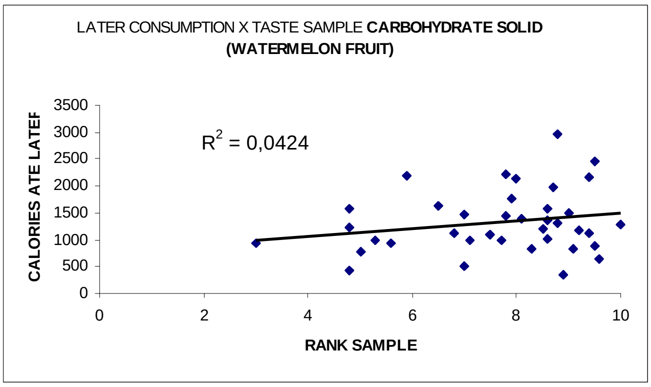
In addition to the sandwiches you were given during our first session, today you will also receive a randomly assigned sample. The sample will be in either a liquid or solid state and will be equally divided into thirds. As in the first session, we ask that you eat until you reach a "comfortable fullness", as indicated by the 3 on the 9-point scale. The second and third sessions differ in that you will have three 5-minute sections to complete the 1/3 samples. Please eat the sandwiches at your own pace, **but be aware that you must complete all three samples**. It may be best to take your time eating the sandwiches. We don't want you to eat too many too quickly.

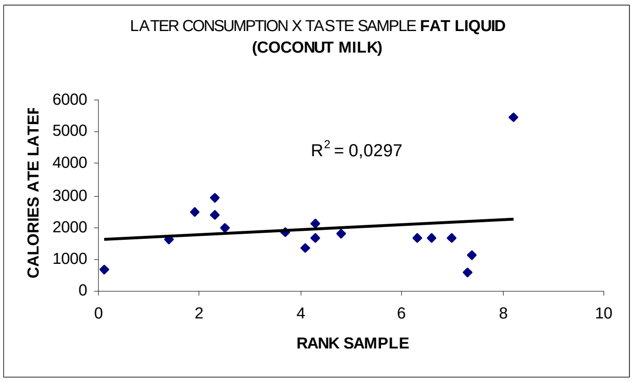
APPENDIX IV – Correlation between later consumption and score of the samples

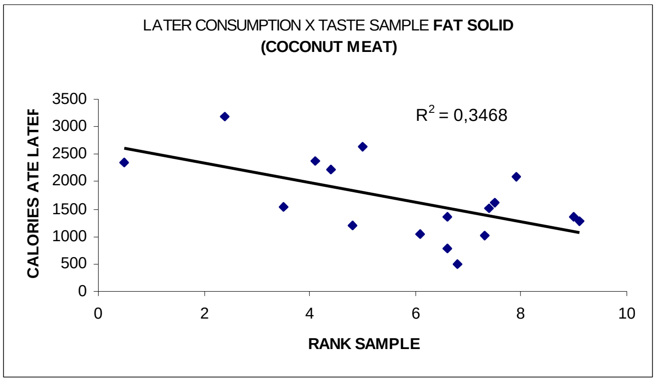












OBSERVAÇÃO:

FORMULÁRIOS UTILIZADOS NO ESTUDO E FOTOS PERTINENTES

CONSTAM SOMENTE NA TESE IMPRESSA NO EXEMPLAR LOCALIZADO NA BIBLIOTECA CENTRAL DA UFV

CONCLUSÃO GERAL

Pode-se verificar, pela análise dos resultados obtidos neste trabalho, que o estado físico do alimento tem grande influência nos níveis de fome e saciedade, especialmente em indivíduos obesos. No estudo com proteína, foi observado que o alimento líquido utilizado causou uma menor saciação nos indivíduos obesos, quando comparados aos de peso normal, e que estes indivíduos obesos consumiram mais calorias durante o almoço quando este foi oferecido juntamente com a sobrecarga líquida, quando comparada com a sobrecarga sólida. Este resultado corroborou a hipótese inicial, de que alimentos líquidos têm um fraco controle sobre o apetite, quando comparados a sólidos. Mostrou ainda, que isto ocorre, mais pronunciadamente, em pessoas com obesidade, quando se trata de uma sobrecarga de proteína. Em termos de saciedade, também se verificou um maior consumo calórico, ao longo do dia, quando se utilizou a carga líquida, para o estudo com carboidrato; porém, já para os estudos com proteína e lipídio foi observada apenas uma tendência. Apesar dos mecanismos envolvidos no fraco controle do apetite, pelo uso de alimentos líquidos não terem sido suficientemente caracterizados, acredita-se que os fatores cognitivos, sensoriais, osmóticos, endócrinos, entre outros, estejam fortemente envolvidos. Assim, é importante considerar a limitação do consumo de alimentos líquidos, contendo calorias, especialmente na forma de bebidas, na prevenção e tratamento da obesidade.