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Effect of diet textural characteristics on the temporal rhythms of feeding in rats

Elise Mok

School of Dietetics and Human Nutrition

McGill University, Montreal

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ABSTRACT

Dietary selection involves the process of relating the postingestional consequences of eating a food to its sensory characteristics. Diet texture, the most plausible sensory characteristic affecting ingestion, may play an important role in the control of food selection. In this study, we compared the circadian rhythmicity of protein- and carbohydrate-rich diet ingestion of adult male Wistar rats presented with diets in different textural forms [high-protein powder and high-carbohydrate granular (HPP-HCG) diets vs. high-protein granular and high-carbohydrate powder (HPG-HCP) diets] during 15 days. Rats fed HPP-HCG diets selected significantly less protein (kcal) vs. rats fed HPG-HCP diets, during the 24 h, 12 h dark phase and the 4 h early and late dark phases. Carbohydrate intakes of the two dietary groups were not significantly different. Total caloric intake for HPG-HCP group was significantly higher than that of HPP-HCG group during the 24 h and 12 h dark phase. In conclusion, macronutrient-rich diets presented in different textural forms alter the circadian rhythmicity of protein-rich diet ingestion and total energy intake.

RESUME

La sélection alimentaire suppose l'établissement d'un lien entre les conséquences métaboliques de l'ingestion d'un aliment et les caractéristiques sensorielles de celui-ci. La texture, qui est la caractéristique sensorielle la plus plausible d'avoir un effet sur l'ingestion, jouerait un rôle important dans la régulation de la sélection des aliments. Cette étude a comparé le rythme circadien de l'ingestion de diètes riches en protéines et en hydrates de carbone offertes simultanément sous différentes formes [diète riche en protéines, poudreuse et diète riche en hydrates de carbone, granuleuse (HPP-HCG) vs. diète riche en protéines, granuleuse et diète riche en hydrates de carbone, poudreuse (HPG-HCP)] à des rats mâles Wistar d'âge adulte pendant 15 jours. Au cours de la période de 24 h, la phase nocturne de 12 h ainsi que durant les 4 h du début et de la fin de la phase nocturne significativement moins de protéines (kcal) ont été sélectionnées par les rats auxquels ont été offertes les diètes HPP-HCG comparativement auxquels ont été offertes les diètes HPG-HCP. Cependant, aucune différence significative n'a été observée pour l'ingestion des diètes riches en hydrates de carbone entre les deux groupes. Les prises caloriques totales de 24 h et de la phase nocturne etaient significativement supérieures chez le groupe HPG-HCP. En conclusion, cette étude a révélé que la texture de diètes riches en macronutriments modifie la rythmicité circadienne des ingestions protéique et énergétique.

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RELATIVE CONTRIBUTIONS OF EACH AUTHOR TO THE MANUSCRIPT

The manuscript was written by the first author, under the guidance of the second author (thesis supervisor). It was revised by the second author, who gave constructive and helpful suggestions in improving both the format and contents of the manuscript which have led the manuscript to the final form. The second author also provided all the material, supplies and facilities that were necessary to carry out the experiment. This research was supported by a grant from Natural Sciences and Engineering Research Council of Canada held by the second author.

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LIST OF ABBREVIATIONS

ANOVA: analysis of variance

$CaCl_2$: calcium chloride

cal : calorie

CPIR: cephalic phase of insulin release

cm^3: cubic centimetre

cc: cubic centimetre

dL: decilitre

DLAM: Diet Scan Lab Animal Monitoring System Software

EDTA: ethylenediaminetetraacetate

e.g.: for example

Fig.: figure

GABA: gamma-amino-butyric acid

g: gram

HK: hexokinase

HPP-HCG: high-protein powder and high-carbohydrate granular dietary group

HPP-HCG-SL: high-protein powder and high-carbohydrate granular-slow learners

HPP-HCG-FL: high-protein powder and high-carbohydrate granular-fast learners

HPG-HCP: high-protein granular and high-carbohydrate powder dietary group

h: hour

8-OH-DPAT: 8-hydroxy-2-(di-n-propylaminotetralin)

5-HIAA: 5-hydroxylindoleacetic acid

5-HT: 5-hydroxytryptamine, serotonin

5-HT_{1A}: $5\text{-hydroxytryptamine}_{1A}$, serotonin_{1A}

i.e.: that is

Inc.: incorporated

ip: intraperitoneal

kcal: kilocalorie

kg: kilogram

LSM: least square mean

ug: microgram

mg: milligram

min: minute

ml: millilitre

mm: millimetre

mmol/L: millimole per litre

$MgCl_2$: magnesium chloride

M: molar

ng: nanogram

PCPA: p-chlorophenylalanine

pmol/L: picomole per litre

KCl: potassium chloride

PIR: preprandial insulin response

RIA: radioimmunoassay

RPM: revolutions per minute

NaCl: sodium chloride

SEM: standard error

SCN: suprachiasmatic nucleus

vs.: versus

v/v: volume by volume

H_2O: water

w/v: weight by volume

Chapter 1
INTRODUCTION

Sensory properties of foods, palatability and postingestive consequences are three distinct parameters that affect the ingestion of food (Ramirez et al. 1989). The sensory effects of a food are the effects that the food has on the sensory receptors (taste, smell and touch). Food palatability is determined by the result of the integration of orosensory and postingestive stimuli, and consequently it depends on the interaction of food and the organism (Rogers, 1990). The palatability of a food was described by Booth (1990) as "its momentary sensory facilitation of the disposition to ingest in a specified context". And postingestive consequences entail the effects of the food after it has entered the digestive tract.

Dietary selection is the result of the organization of the information derived from both sensory properties and metabolic signals of the food (Ashley, 1985). Omnivores (such as rats and humans) are faced with a wide range of potential foods and accordingly their dietary selection may depend on learned influences (Rogers and Blundell, 1991). Learning is a change in the organization of an individual's behaviour so that this organization represents the environment better (Booth, 1987). Furthermore, all rational dietary selection involves the process of relating the postingestional consequences of eating a food to its sensory characteristics (Blundell, 1983).

Among food sensory properties, taste and odour have been given much attention. Texture, however has not been addressed to the same extent and is likely to be more important in the control of food selection (Booth, 1987). For example, when offered a choice of casein-free and casein-rich powdered diets, some rats fail to consume protein, which may be due to their inability to learn about the metabolic properties of the foods (Leathwood and Ashley, 1983). However, in the same study all rats offered a choice of the same diets in granulated form learned to choose sufficient protein intake more rapidly, thus promoting growth and survival of the animal.

Biological rhythms have been observed in all living organisms. Rat studies have shown a bimodal distribution of feeding during the active nocturnal cycle, demonstrating peaks during the early and late dark periods (Tempel et al. 1989). In

addition, specific rhythms in macronutrient intake have been displayed in both rats (Shor-Posner et al. 1991) and humans (DeCastro, 1987) throughout their active feeding cycle. Furthermore, sensory factors (e.g. textural factors) may contribute as much as metabolic factors to the circadian pattern of macronutrient intake. For example, rats given a two-way choice between a 60% casein and a casein-free powder diet demonstrated a circadian variation of protein intake, with protein concentration decreasing from light to dark meals (Johnson et al., 1979). However, when rats were given the same diets presented as pellets, the proportion of calories consumed as protein peaked at the end of the night (Leathwood and Arimanana, 1984).

Thus, the central hypothesis of the present study was that the circadian rhythmicity of carbohydrate-rich and protein-rich diet ingestion can be altered by the use of different textural characteristics of macronutrient-rich diets, independently from their macronutrient content.

This hypothesis was tested by presenting adult male Wistar rats with a choice between a protein-rich and a carbohydrate-rich diet in different textural forms. One group chose between a high-protein powder and a high-carbohydrate granular diet and the other group received a high-protein granular and a high-carbohydrate powder diet. The objectives of the present study were to measure each minute the distribution of dietary selection in order to: (1) calculate total intake (g, kcal) and intakes (g, kcal) from protein-rich and carbohydrate-rich diets and absolute intakes (g, kcal) from protein and carbohydrate, (2) compare the above parameters according to different textures (powder vs. granular) and circadian phase (24 h, 12 h light and 12 h dark phases, 4 h early, 4 h middle and 4 h late dark phases) over the 15-day experimental period, and (3) compare circadian variation (24 h, 12 h light and 12 h dark) in meal patterns [number of meals, meal duration, meal size (g), protein and carbohydrate composition (g) of meals and intermeal interval] for each experimental group over the 15-day experimental period. Additionally, daily body weight measurements were compared between the two dietary groups and plasma concentrations of glucose and insulin on day-16 immediately before the active dark period were also compared between the two dietary groups.

Chapter 2
LITERATURE REVIEW

The literature review covers four main areas: diet texture and feeding, protein and carbohydrate selection, circadian rhythms and cephalic phase insulin release. The first section provides a broad perspective of the influence of diet texture on feeding. The second section examines food preferences, specifically protein and carbohydrate selection. The third section addresses circadian rhythms and their importance in relation to feeding. And the last section reviews the cephalic phase insulin release. These four areas should essentially provide a thorough background for the present research.

1. Diet Texture and Feeding

1.1 Oral Perception of Food Texture

Each food has a distinct texture that contributes to its palatability. Tactile sensations and preferences are sensed by the touch- and pressure-sensitive mechanoreceptors in the oral mucosa and periodontium and from stretch and other receptors in the masticatory muscles (which include the muscle spindle and the golgi tendon organ), and temporomandibular joints (Morimoto and Takada, 1993).

Oral mechanoreceptors also discriminate among food materials. Tactile and kinaesthetic sensations are critical for the accurate identification of the size, shape, hardness, softness and other textural characteristics of solid and liquid foods in the mouth. The textural characteristics of the diets may serve to determine whether these material are beneficial or harmful to ingest. Furthermore, tactile sensations are essential for the control of jaw movements, tongue and hyoid during chewing and swallowing and for salivary secretion (Morimoto and Takada, 1993).

In addition to the fingertips, the lips and tongue are the most sensitive areas in the body, for example, the tongue has a threshold of two-point discrimination of less than 1 mm (Sherrington, 1900). Although the teeth have no sensory receptors on their surface, there are sensitive receptors in the periodontal ligaments. In addition, extraoral receptors include the masticatory musculature and temporomandibular joints

(Morimoto and Takada, 1993).

The total effect of these stimuli is to supply the brain with a texture perception of the food. The trigeminal (fifth cranial) nerve transmits the impulses to the brain, and oral mechanoreception and motor control are mediated in the brainstem (Morimoto and Takada, 1993). Furthermore, it is a well known fact that a well-developed trigeminal system is characteristic of all vertebrates from fish to primates (Zeigler et al. 1985).

1.2 Influence of Diet Form

The physical form in which a diet is presented can influence a rat's feeding responses. Previous studies have demonstrated the effect of diet form on feeding by using carbohydrate-rich, fat-rich and mixed diets.

1.2.1 Carbohydrate-Rich Diets

Rats fed sugar or polysaccharide diets tend to overeat and become obese, which is due to the physical form of the diet; that is liquid or gel (Sclafani, 1987a). In 1984, Sclafani and Xenakis investigated the importance of diet form (liquid versus powder) in adult female Sprague-Dawley rats fed chow only, or chow plus the polysaccharide Polycose presented as a 32% solution, as a powder, or as a powder mixed into the chow diet. In the 30-day test, rats fed Polycose solution (but not Polycose powder or mixed diet) overate and gained three times as much weight as did controls. The solution-fed rats ingested more Polycose than did the powder-fed rats. The authors concluded that diet form has a major impact on the rat's feeding and body weight responses to polysaccharide diets.

Sclafani (1987b) also examined the effects of saccharide type, form and taste in adult female Sprague-Dawley rats fed in addition to chow, a carbohydrate source that differed in type (glucose, sucrose, Polycose or maltodextrin), form (32% solution, powder or 32% gel) or taste (very sweet, minimally sweet or bitter). The gel was prepared by adding 1% agar to hot water and then adding Polycose (32 g/100 ml). The gel was allowed to solidify in a refrigerator overnight before use. Over a 40-day experiment, regardless of carbohydrate type rats fed carbohydrate as a solution all

overate and gained more weight versus controls. However, no differences in intake or weight gain were apparent among the different types of carbohydrate presented in solution form. Regardless of carbohydrate type, the groups fed carbohydrate in powder form ate less carbohydrate and total calories and gained less weight than did groups fed carbohydrate in solution form. Rats fed Polycose in solution form or in gel form were similar in their carbohydrate and total caloric intake and weight gain. Groups fed Polycose solution that were minimally sweet, sweet or bitter did not differ in carbohydrate and total caloric intake and weight gain. It was concluded that saccharide form is more important than saccharide type or taste in promoting hyperphagia and weight gain. However, rats fed Polycose in solid gel form consumed similar amounts of carbohydrate and total calories and had similar weight gain as did those fed Polycose as solution. Thus, indicating that it was the water of hydration, not liquidity that was responsible for the hyperphagia-inducing effect of carbohydrate solutions. It has been shown that the water content of a mixed carbohydrate diet has a greater effect on growth than texture (Ramirez, 1987) and that tactile sensitivity does not play a large role in the perception of dilute starch suspensions (Ramirez, 1993).

Presenting the carbohydrate as a solution or a gel is more effective in promoting hyperphagia and weight gain versus presenting it as a powder or as part of a composite diet. The differential response to hydrated and dehydrated foods may occur because carbohydrates are absorbed at a faster rate in hydrated form as opposed to dehydrated forms, and hydrated carbohydrates may enhance appetite and food intake more rapidly compared to dehydrated carbohydrates (Sclafani, 1987a). Although rats are initially attracted to the orosensory properties of polysaccharide solutions (Sclafani and Nissenbaum, 1987), overeating and overweight induced by liquid diets cannot be attributed solely to their high palatability (Ramirez, 1988). The postingestive effects of carbohydrates also modulate preference for the sensory properties of carbohydrates in long term tests (Sclafani and Vigorito, 1987; Sclafani et al. 1987).

1.2.2 Fat-Rich Diets

It has been suggested that palatability of fat comes from its texture (Capaldi and Vandenbos, 1991). Oral stimulation produced by ingestion of sweet and oily fluids

stimulates food intake in adult male Sprague-Dawley rats (Tordoff and Reed, 1991). In two separate experiments, intake of chow (measured for 2 h) was greater after rats were sham-fed either 32% sucrose solution or a 15% corn oil emulsion than after tests when no fluid was available. Similarly, Sprague-Dawley rat pups of both sexes that were food deprived for 1 h responded more to both nutritive (10% corn oil) and non-nutritive (30% mineral oil) oil emulsions than they did to water (Ackroff et al. 1990). In the same study, corn oil and mineral oil emulsions were found equally acceptable to non-deprived adult female Sprague-Dawley rats, as measured by 3-min and 30-min one bottle tests. Food deprivation overnight increased the intake of both oil emulsions in one-bottle tests. In two-bottle tests, non-deprived rats displayed a slight preference for corn oil, but developed a strong preference for corn oil when they were food deprived. The authors concluded that rats have an unlearned attraction to the orosensory qualities of emulsified oils and they learn to prefer corn oil based on its postingestive consequences.

In 1969, Carlisle and Stellar demonstrated that adult male albino rats that were either hyperphagic (from hypothalamic lesions), aphagic or normal preferred greasy-textured diets to chow pellets regardless of the caloric density of the diet (i.e. although the mineral oil-powder chow mixture was calorically less dense than pellets, it was nevertheless preferred over pellets by all groups in a choice situation). However, Coscina et al. (1989) suggested that the hyperphagic response to greasy foods relatively low in calories and digestible fats by rats with hypothalamic lesions is a function of prior experience with the sensory and/or metabolic consequences of having first eaten high-calorie fatty foods. In their study, hypothalamic-lesioned adult female Wistar rats elicited hyperphagia on a mineral oil diet (21.4 ml mineral oil, 13.6 ml corn oil, 68 g powder chow) only when they had been previously exposed to a high-fat diet (33% vegetable shortening, 67% powder chow) for four weeks. Also it has been suggested in previous studies (Lucas et al. 1989; Naim et al. 1987) that long term fat selection and hyperphagia are influenced primarily by postingestive factors and not orosensory properties.

1.2.3 Mixed Diets

Variety and high palatability are sufficient factors to overcome postingestional regulatory mechanisms. It was demonstrated in adult male Wistar rats that the daily presentation of a new choice of highly palatable foods with a similar well-balanced composition, but varying in taste, smell and texture, that is the isocafeteria diet composed of chow modified with aspartame, Vaseline or chocolate flavor induced hyperphagia and overweight over a 10-day experimental period (Louis-Syvestre et al. 1984).

The contribution of texture to high palatability was demonstrated by Naim et al. (1986). In the study, weanling male Sprague-Dawley rats were used in order to determine the preference for nutritionally controlled semi-purified complete flavored diets prepared in three forms: powder and pellets of two sizes. Intake was monitored after 1 h and for each 24 h period, over a 5-day period. Rats displayed a strong preference for pelleted texture compared to the same diet in powdered form.

The effect of physical state of food on subsequent intake was also studied in humans (Tournier and Louis-Sylvestre, 1991). Two food meals having the same composition (cooked white beans, ham, green peas and maltodextrins) but different forms (liquid or solid) were offered at lunchtime 1 week apart. The 24-h caloric intake following the liquid lunch was higher than the solid. The authors suggested that the difference may have been attributed to the cognitive cues from the form of the food or the lack of masticatory movements. In order to test the hypothesis, a subsequent experiment was performed in which the test meals appeared absolutely identical to the senses and were composed of a liquid and solid item, however the major part of the calories was in the liquid or solid portion. The subsequent total caloric intake was higher when most calories had to be drunk in liquid form, versus eaten in solid form. Hence, the authors concluded that calories ingested in liquid form are not well accounted for and may induce subsequent overconsumption, at least until satiety was conditioned to the fluid.

In summary, diet form has a major impact on the rat's feeding responses to polysaccharide and mixed diets.

1.3 Effect of Drugs

Various drugs are used in the control of food intake. For example, chlordiazepoxide, which facilitates GABA receptor transmission; amphetamine, a dopamine agonist and fenfluramine, the serotonin (5-HT) agonist and the 5-HT_{1A} receptor agonists 8-OH-DPAT and gepirone. Diet texture, however has been shown to influence the feeding responses induced by these drugs.

The effects of acute and chronic administration of chlordiazepoxide (which acts on GABA receptors and facilitates receptor transmission) on feeding parameters using complete diets of 2 food textures (powder versus pellets) were studied in adult male Sprague-Dawley rats (Cooper and Francis, 1979a). Although, neither food texture nor drug administration had any effect on total food intake, food texture affected both feeding duration and feeding rate. Rats spent more time eating powdered food than pellets and the effect was constant over the range of drug doses (5-15 mg/kg) and for controls (0 mg/kg). However the effects of the drug did not significantly interact with the effects of food texture.

In another study by the same authors (1979b), feeding parameters with powdered and pelleted food textures were again examined after chlordiazepoxide (5-10 mg/kg) administration, alone or in combination with d-amphetamine (0.25 mg/kg) or fenfluramine (1 mg/kg). Food texture affected feeding behaviour: adult male Sprague-Dawley rats consumed standard diet in pellet form faster than powdered form, and meal duration was longer for powdered form. No significant interaction between textural differences and the changes in feeding responses induced by the 3 drugs was found. However, the latency to eat was significantly prolonged after d-amphetamine or fenfluramine injection when pellets were given.

It has previously been demonstrated that 5-HT_{1A} receptor agonists, for example, 8-OH-DPAT and gepirone cause hyperphagia. However, the specificity of 8-OH-DPAT induced feeding has been questioned due to difficulties in demonstrating consistent increases in the intake of liquid diets (Fletcher, 1987; Montgomery et al. 1988; Dourish et al. 1988a; 1988b). The increased intake of solid but not liquid food elicited by 8-OH-DPAT was concluded to be incidental to drug-induced gnawing or

chewing, which was directed towards food pellets.

The influence of textural factors on the feeding responses induced by 8-OH-DPAT and gepirone were examined by Fletcher et al. (1991). The drugs were administered subcutaneously to adult male Sprague-Dawley rats fully adapted to eating either standard pelleted chow or the same food presented in powdered form. Sixty and 100 ug/kg 8-OH-DPAT increased intake of both food textures equally, but at 500 ug/kg, rats consumed more of the pelleted food. Similarly, gepirone (1 and 2.5 mg/kg) increased pelleted food intake. The authors concluded that food texture may play a significant role in the capacity to induce feeding after high doses of 5-HT $_{1A}$ receptor agonists.

In a similar study, young and adult male Wistar rats were used to investigate the hyperphagic responses to 8-OH-DPAT when fed either powdered or pelleted diets (Chaouloff et al. 1988). During the 2 h following drug administration, 8-OH-DPAT (500 ug/kg) increased intake of the pelleted but not the powdered diet in young rats. In contrast, 8-OH-DPAT did not promote hyperphagia in adult rats fed either powdered diet or pellets. The authors suggested that gnawing may be an important parameter in food consumption that is induced by a high dose of 8-OH-DPAT.

2. Protein and Carbohydrate Selection

2.1 Control of Ingestion

Dietary selection is the result of the organization of the information derived from sensory properties of the food, and the visceral and metabolic signals it elicits. In classic experiments, Richter et al. (1943) offered rats (strain, sex and age not mentioned) separate macronutrient sources, such as sucrose, casein, yeast, olive oil, cod liver oil and wheat germ oil, along with various micronutrients (3% sodium chloride, 1% potassium chloride, 2.4% calcium lactate, 8% dibasic sodium phosphate and water). When given the choice, these rats selected nutritionally adequate diets and thus grew normally and showed no signs of nutritional deficiencies. Furthermore, rats made appropriate modifications in nutrient selection following manipulations of physiological parameters. For instance, Richter et al. (1943) observed that rats made

diabetic by subtotal pancreatectomy and offered carbohydrate, fat and protein in separate containers, had higher fat and protein consumption and lower carbohydrate intake relative to non-diabetic controls. These modifications in diet selection were associated with the improvement of many of the diabetic symptoms. Also when an animal is sodium deficient, it develops an immediate and compelling preference for the taste of sodium salt (Abraham et al. 1975).

Schutz and Pilgrim (1954) examined the changes in the self-selection pattern from separate nutrients (casein, mineral salts, sucrose and hydrogenated vegetable oil) in adult male Sprague-Dawley rats after food deprivation. It was found that after two-days starvation, the caloric consumption over two days from the hydrogenated vegetable oil increased over a 12-day period. In the same study, 21 out of 43 animals given the same four-way choice selected inadequate amounts of casein and were subsequently placed on a restricted diet that consisted of only 1 g each of hydrogenated vegetable oil and sucrose, while casein and salts were offered *ad libitum* at 2-day intervals over 18 days. All rats fed the restricted diet ate protein and grew normally, thus the need for calories caused rats to eat a non-preferred food (e.g. casein), and after 18 days on the restricted diet some animals even continued to eat casein when subsequently placed on the initial four-way self-selection regimen.

Although the majority of laboratory animals select balanced diets on self-selection regimens, some animals fail to maintain adequate nutritional intakes. Young Wistar rats of both sexes adapted to eat a stock ration for 1 week were allowed to chose among caseinogen (86.5% protein), sucrose and a mineral salt mixture (Kon, 1931). The average protein intake for the first 7 weeks was 6.5% of the total food intake. Furthermore, changing the carbohydrate source to rice starch did not affect protein intake, and in the course of the 10-week experimental period two of the four rats died after 54 and 61 days. Similarly, in a study by Scott (1946) both male and female albino rats of mixed strain (21-25 days old) were adapted for three weeks to a four-way choice (sucrose, casein, hydrogenated fat and mineral salts). Animals could be separated into two groups according to their intake of casein. Thirty-four of the 87 rats consumed an average of 1.3 g casein, failed to grow and lost an average of 21 g

in body weight over the three weeks. The second group consisted of the 53 remaining rats. This group ate adequate amounts of protein, that is an average of 60.1 g over the 3-week experimental period and grew well. Thus the rats' intakes showed no apparent relation to physiological need. Scott (1948) offered the same four-way choice to albino rats of both sexes weaned at 21 days and to 6-week or 12-week old rats adapted to a standard diet (24% casein, 62% sucrose, 10% hydrogenated fat and 4% mineral salt) for 3 weeks and 9 weeks, respectively. Over the 54-week experimental period, only 9 out of 31 rats (21 days old) selected 25.5% of total calories from casein and grew normally, the other 22 rats failed to grow and died at the average age of 58 days. On the other hand, approximately 60% of the 6-week and 12-week old rats selected 27.4% and 25.8% of total calories from casein, respectively and gained weight. In a similar study by Pilgrim and Patton (1947), male weanling Sprague-Dawley rats were given 4 days to adapt to a four-way choice (casein, salts, sucrose and hydrogenated vegetable oil) and their intakes were measured over the following 10 days. About one-third of the animals grew at subnormal rates, that is, gained less than 2.8 g/day, due to inadequate casein consumption, that is, consumed less than 1.45 g/day of casein. It was concluded that intakes for dietary components are not always determined by nutritional or physiological requirements.

Several studies, however, have shown that protein intake appears to be precisely controlled. Rats maintain a constant protein intake when allowed to select from diets varying in protein content (Musten et al. 1974). In response to dilution of a protein diet, rats increase the intake from that diet (Rozin, 1968). The amino acid content of the diet, that is the protein quality of the diet may also influence protein selection (Musten et al. 1974). Furthermore, the composition of recently ingested food and previous dietary adaptation may contribute to the short term control of protein intake (Li and Anderson, 1982). The following provides a more detailed account of the studies that demonstrate the precise control of protein intake.

When offered a choice among three solutions (35% sucrose in water, 1.4 cal/cc; 15% casein with 15% peptones in water, 1.2 cal/cc; 100% corn oil, 8.3 cal./cc), adult Sprague-Dawley rats of both sexes displayed compensatory increases of 2.32 and

3.22 fold in their intake of the protein solution when only the protein solution was diluted with water by 15% and 7.5%, respectively (Rozin, 1968). Also in a series of experiments by Musten et al. (1974) weanling Wistar male rats were allowed to select from pairs of isocaloric diets varying in protein content. When rats were given a choice between a 50% gluten diet (also containing 33.7% cornstarch and 10% corn oil) and a protein-free diet (83.7% cornstarch, 10% corn oil), they maintained a constant intake of protein even when gluten was diluted by 30% with non-nutritive material (cellulose) by increasing their protein intake. In the same series of experiments, five groups of rats were fed a choice between 0/50, 5/45, 15/55, 25/65, 40/70% casein diets and another six groups of rats were fed a choice between 0/50, 5/45, 15/55, 25/65, 10/60, 30/60% gluten diets. Rats selected 43.9% protein energy when poor quality gluten was fed versus 34.2% protein energy when high-quality casein was fed, suggesting that rats can compensate for protein quality by adjusting their protein intake in order to meet amino acid requirements.

Li and Anderson (1982) demonstrated that weanling male Wistar rats offered a protein-rich premeal that consisted of either 45% or 70% casein subsequently selected 21% and 22% casein, respectively during the next feeding session: when rats were allowed to select from 10 and 60% casein diets. However, rats given an isocaloric protein-free premeal (83.5% cornstarch) selected more protein (33% casein) during the next feeding session. The composition of recently ingested food and previous dietary adaptation may contribute to the short-term regulation of protein intake. Using adult male Sprague-Dawley rats, Holder and Huether (1990) found that prefeedings for 2 days with carbohydrate-rich (93.9% carbohydrate) or protein-rich (55.5% carbohydrate, 28.1% protein, 4.8% fat; sources not mentioned) pelleted diets decreased subsequent carbohydrate and protein intakes, respectively, when the same diets were presented in pellet form. However, prior access to carbohydrate solution (8%w/v sucrose in water) did not affect subsequent consumption when carbohydrate was offered as pellets. The decrease might be explained in terms of the oral sensory qualities of the foods and not their macronutrient content. This suggests that carbohydrate-specific selection does not exist, that is, specific to the carbohydrate character that the diets share.

Similarly, young male Sprague-Dawley rats, adapted for 7-10 days to a 15% casein diet and subsequently offered choices between pairs of diets in which the proportions of % casein were 5/65, 5/55, 5/45, 5/35 and 5/25 for 6-day intervals, ate randomly from the diet pairs and selected approximately 15-30% of total calories as casein (Tews et al. 1992). In the same study, rats adapted for 7-10 days to a 70% casein diet and subsequently offered choices between the same diet pairs for 6 days avoided eating the casein-rich diet, often within minutes and seldom chose more than 10% of their total caloric intake from casein.

Protein intake appears to vary among animals. For example, Leathwood and Ashley (1983) offered pairs of granular diets containing different levels of casein (0/20%, 0/40%, 0/60% or 10/40%) to weanling and adult male Sprague-Dawley rats for 14 days, after which diets were changed so that the first group received 10/40%, the second group 20/60%, the third group 10/40% and the fourth group received 0/60% casein diets over a subsequent 14 days. In both adult and weanling rats a large inter-individual variability in protein intake between animals was found. Also, weanling rats more rapidly selected adequate amounts of protein than did adults (4 days versus 10 days, respectively).

Musten et al. (1974) investigated the protein-specific appetite of weanling male Wistar rats given simultaneous access to two diets differing in protein content. Over a wide range of powdered dietary choices (0/50%, 5/45%, 15/55% or 25/65% casein), rats regulated their protein intake at a constant proportion (34.2%) of the dietary energy consumed. Similarly, adult male Sprague-Dawley rats given a two-way choice between granular diets varying in casein content (0/40%, 0/60% or 10/40% casein) chose relatively constant (30% of total energy from protein) amounts of protein (Leathwood and Ashley, 1983). On the other hand, Peters and Harper (1984) suggested that protein intake, particularly casein was not regulated at a constant proportion of total calories, but was controlled between a minimum level that will support rapid growth and a maximum that, if exceeded, would require the animal to undergo substantial metabolic adaptation. In their study, young male rats (strain not reported) were allowed to choose between either protein-free (45% glucose

monohydrate, 45% cornstarch) and 55% casein diets or 15% and 55% casein diets, throughout a 13-day experimental period. All diets were prepared in agar gel form. The average daily percentage of energy selected from protein for rats choosing between protein-free and 55% casein diets increased from 15-38% during the course of the study. In contrast, rats given a choice between diets containing 15% and 55% casein selected 18-22% of total energy from protein throughout the study.

Contrary to the case of protein, precise regulation of carbohydrate intake does not appear to occur. In a study by Rozin (1968), adult Sprague-Dawley rats of both sexes were offered a choice among three liquids (35% sucrose in water, 1.4 cal/cc; 15% casein with 15% peptones in water, 1.2 cal/cc; and 100% corn oil, 8.3 cal./cc). No evidence for compensation upon dilution of the carbohydrate solution with water by 17.5% and 8.75% was observed, nor after two days carbohydrate deprivation. Carbohydrate consumption may depend primarily on its relative palatability, for example, innate preference for sweet taste (Steiner, 1974) and the presence of other components in the diet. Indeed, carbohydrate intake has been related to the amount of thiamine in the diet (Yudkin, 1979). In the study by Yudkin (1979), adult hooded Hartwell rats of both sexes were fed two thiamine deficient diets: a carbohydrate free diet (71% casein, 13% arachis oil, 11% autoclaved yeast extract) and a sucrose-rich diet (13% casein, 18% arachis oil, 54% sucrose, 11% autoclaved yeast extract) offered separately. In the absence of dietary thiamine, 5-10 g of the sucrose-rich diet was ingested daily in the first 1 or 2 days, while intake of the carbohydrate-free diet decreased from 10-5 g. Thereafter sucrose intake was reduced to about 1 g per day and death due to thiamine deficiency followed at intervals that varied from 4 weeks to 12 months. Survival was shortest in animals that ate sucrose in the largest amounts and survival was longest in those that avoided sucrose for long periods, for example, one out of 26 animals ate between 1 and 10 g of sucrose weekly and survived for 12 months. Also, sex did not appear to affect survival.

Carbohydrate intake may also be related to the experimental situation. Four groups of male weanling Wistar rats were exposed to cold and fed a choice between a high-cornstarch diet (83.7% cornstarch, 10% corn oil) and an isocaloric high-casein

diet (70% casein, 13.7% cornstarch, 10% corn oil) over a 21-day experimental period. Through days 9-21, rats increased their energy intake from 908 kcal at room temperature to 1174 kcal at 8^{0}C, by eating more of the carbohydrate-rich diet (44 g at room temperature versus 109 g at 8^{0}C) (Musten, 1974). Also, following the induction of diabetes, upon administration of the beta-cell toxin streptozotocin (45 mg/kg), adult male Sprague-Dawley rats fully adapted to a three-way choice: carbohydrate (57% cornstarch, 27% dextrin, 10% sucrose), protein (94% casein) and fat (83% hydrogenated vegetable oil, 4% safflower oil) for 20 days, reduced their intake of carbohydrate while increasing their intake of fat and/or protein (Kanarek, 1984). Similarly, subdiaphragmatic vagotomy, a manipulation which impairs pancreatic secretion of both insulin and glucagon, was associated with a selective reduction in carbohydrate consumption, when adult female Wistar rats were given a three-way choice among 30% sucrose solution, 15% casein hydrolysate solution and olive oil (Fox, 1976).

The animal's prior experience can also affect carbohydrate intake. Wurtman et al. (1977) gave a single calorie-restricted ketogenic diet (30% casein, 37% vegetable shortening, 33% cellulose) or an isocaloric carbohydrate-rich control diet (60% dextrin, 30% casein, 10% vegetable shortening) to adult male Sprague-Dawley rats for three weeks. When subsequently given a choice between a pair of isocaloric, isonitrogenous diets containing 25 or 75% dextrin, ketotic rats ate a higher proportion of total calories as carbohydrate compared to controls (51% versus 37%, respectively) during the first 30 minutes exposure. Similar results were obtained when the same experiment was conducted with sucrose instead of dextrin. In the same study, rats given an isocaloric carbohydrate (1.4 g dextrose) premeal and subsequently allowed to choose between 25 and 75% dextrin diets ate 38% of total calories as carbohydrate. This was significantly lower than 58% of total calories as carbohydrate in rats given a mixed nutrients (0.25 g casein, 0.22 g dextrin, 0.45 g vegetable shortening) premeal. It was suggested that carbohydrate intake is influenced by prior nutrient consumption. Similarly, Thibault and Kensley (1996) reported that in adult male Sprague-Dawley rats previous adaptation for one week to a three-way choice that consisted of a sugar as

carbohydrate source (92.9% sucrose or fructose, 2% cellulose), protein (92.9% casein, 2% cellulose) and fat (20% soybean oil, 63.8% vegetable shortening, 2% cellulose) affected subsequent selection patterns. When rats were subsequently given a similar three-way choice with the sugars switched over a one week period, they decreased the intakes of the three macronutrients during the 12 h night and reduced 24 h carbohydrate intake, and diurnal intake rather than nocturnal intake was observed.

In summary, rats given simultaneous access to diets differing in protein content regulate their protein intake at a constant proportion of dietary energy consumed. On the other hand, it was suggested that protein intake (particularly casein) was not regulated at a constant proportion of total calories. Contrary to protein intake, carbohydrate-specific selection does not appear to exist.

2.2 Learning

Omnivores are faced with a wide range of foods and thus their diet selection may depend to a large extent on learned influences (Rozin, 1976). Learning is a change in the organization of an individual's behaviour so that this organization represents the environment better (Booth, 1987). Learning has powerful influences on food preference. All rational selection of dietary materials involves the process of relating the physiological consequences of eating a food to its sensory properties (taste, smell, texture, and appearance) (Blundell, 1983; Booth et al. 1989). Animals can detect distinctive physical and chemical properties in dietary materials. These properties are essential for the selective intake of a macronutrient. The distinctive sensory characteristics (taste, smell, texture and appearance) of a food serve as cues for the presence of a macronutrient. If these sensory cues do not recur in diets containing other macronutrients, they can predict the postingestional effects specific to the macronutrient.

Scott and Quint (1946) examined the self-selection of diet in male and female rats (21 to 25 days of age; strain not mentioned). When rats were offered for 3 weeks a four-way choice among sucrose, hydrogenated fat, salt mixture and protein (casein, lactalbumin, fibrin or egg albumin) diets, a similar proportion of animals refused to eat

protein (39 out of 87 rats, 9 out of 20 rats, or 7 out of 20 rats) if it was casein, lactalbumin or fibrin, respectively. If the protein was egg albumin many more refused (14 out of 20 animals). If these same four proteins were given simultaneously as choices, only 2 out of 22 animals refused to eat at least one of them. If the choices were offered as part of four mixed diets presented simultaneously each consisting of 24% protein (casein, lactalbumen, fibrin or egg albumen), 62% sucrose, 10% hydrogenated fat and 4% salts, most animals avoided the egg albumen diet but demonstrated similar preferences for the other three diets. In all the experiments, no sex differences were apparent. According to the authors "The different intakes of various protein sources found in some animals was based on simple preference, although it could be a learned appetite."

Baker et al. (1987) demonstrated a learned protein-specific appetite, using odour conditioning in adult male rats of a Sprague-Dawley hooded strain. Towards the end of the light period, rats were deprived of food for 4 h and subsequently infused with 10% calcium caseinate into their stomachs while they drank a distinctively flavoured non-nutritive fluid (benzyl acetate or eugenol dissolved 1:9 (v/v) in absolute ethanol) on two training days; on two alternate training days, the other odour was paired with a non-caloric intragastric control infusion. Each rat was subsequently presented with a choice between two tubes of non-caloric fluid: one tube with the odour associated with protein and one with the odour that was associated with non-caloric infusion. Odour preferences were calculated as the ratio of volume intake of the protein-paired odour to total volume drank over 30 minutes. On the first test day, after pre-infusion of non-nutritive diet, each rat demonstrated conditioned preference for the flavour alone, that is, each rat showed a protein-preference ratio greater than 0.5, the indifference value.

However, on the second test day when the same rats were pre-infused with 10% casein hydrosylate during the 4-h food deprivation and were subsequently subjected to the same procedure as in experiment 1, protein odour preference ratio was 0.5, at the level of complete indifference. On the third test when the same rats were infused with equicaloric carbohydrate (10% low-glucose maltodextrin) during a 4 h

food deprivation period and were subsequently subjected to the same procedure as the first two experiments, the preference ratio for the protein-paired odour was greater than 0.5.

Heinrichs et al. (1990) demonstrated similar findings using adult male rats (Long-Evans and Sprague-Dawley strain). Rats fed either protein-free diet (70% cornstarch) or protein-containing diet (20% casein or peanut meal) over four days were subsequently offered an unflavoured carbohydrate diet (77% cornstarch, 20% sucrose) in two differently scented bins (one of seven protein odours and butter odour) during a 10 minute access period. According to the percentage preference for protein odours versus butter odour, rats fed the protein-free diet ate significantly more from the bin smelling of gluten (53%), ovalbumin (72%), yeast (68%) or fibrin (64%), but not significantly more from soy (40%), casein (40%) or lactalbumin (45%) than from the bin smelling of butter. On the other hand, rats fed the protein-containing diet ate significantly less from the bin smelling of gluten (24%), ovalbumin (44%), yeast (49%), fibrin (38%), soy (45%), casein (46%) and lactalbumin (34%) versus butter. The authors concluded that protein-deprived rats can use odour cues in making their selection of certain proteins and the increased preference for protein in protein-deprived rats was based on sensory properties of the diet and not its post-ingestional consequences.

In contrast, Deutsch et al. (1989) have demonstrated an innate or unlearned preference for protein in protein-deprived rats. Adult male Sprague-Dawley rats received a protein-free diet (56% cornstarch, 20% glucose, 12% fibre, 8% vegetable oil, 3.2% salt, 0.8% cod liver oil) for 2 h each day for 4 days and during the remaining 22 h of each day they received this diet along with normal rat pellets. In the first half hour of a test, rats were given a choice between a novel protein-rich diet (60% protein) and a novel carbohydrate-rich diet (70% amylose, 20% maltose). During this test period protein-depleted rats chose a significantly larger proportion of soybean (63.8%), gluten (52%), zein (55.7%), yeast torula (47.7%) and ovalbumin (64.7%) than protein-replete controls; this was not significant for casein (34.5%) and lactalbumin (36.1%). Moreover, the preference for the protein in protein-depleted rats manifested

itself from the first minute. In the same study, this preferential selection of protein-rich diets was also demonstrated in Sprague-Dawley dams in which protein need was induced by pregnancy. Thus, since rats have had no opportunity to learn such dietary preferences before the test (having been fed a protein-free diet and normal rat pellets) the existence of an innate specific appetite for protein was suggested.

Omnivores first learn about the sensory properties of various foods before making appropriate decisions on what to eat (Leathwood and Ashley, 1983). First choices are often based on taste, for example, the innate preference for sweet versus bitter foods. Newborn babies have the ability to detect sweetness and in a study using 3-day old infants, Mennella and Beauchamp (1994) demonstrated that newborns show facial reactions to tastes of sweet, sour, bitter and salt: sweet tastes caused the baby to open its mouth, both bitter and sour caused grimaces and salt produced indifference. These choices are metabolically safe but may not ensure that nutritionally adequate choices are made. For instance, Tews et al. (1992) demonstrated that when young male Sprague-Dawley rats adapted for 7-10 days to ingest a 70% casein diet were given a choice between 5 and 65% casein diets, they predominantly selected the 5% casein diet within the first 10 minutes rather than the 65% casein diet. The authors suggested that this rapidity in observed preference implies that this choice depended on external dietary characteristics (taste, smell and texture) and not on metabolic changes induced by low protein diet in plasma or tissue concentrations of amino acids or neurotransmitters.

It is well established that omnivores learn to avoid a food when its consumption is paired with an illness, particularly nausea or gastrointestinal upset (Garcia et al. 1974). In addition, Bernstein et al. (1984) demonstrated that adult male Long Evans rats fed a dietary self-selection regimen are more likely to develop conditioned aversions to the protein source (95% casein or 90% soybean meal) than to the carbohydrate source (90% cornstarch or 50% sucrose, 40%cornstarch) when their consumption is paired with a 40 mg/kg intraperitoneal injection of cyclophosphamide (a gastrointestinal toxic drug). This learning can be very rapid, it can happen over long delays and is very difficult to extinguish. In addition, it has been

assumed that preferences could also be established on the basis of the positive after-effects of food ingestion. It appears that both learned preferences and aversions are characterized by alterations in the hedonic evaluation of a food's palatability (taste, smell, and texture) (Booth, 1979; Rogers, 1990). This ability to modify a preference based on the benefit or otherwise derived from eating a food is advantageous, and it is likely that such conditioning of palatability plays an important role in the control of diet selection.

Appetite for specific nutrients may depend on early feeding experiences. LeProphon and Anderson (1980) demonstrated that the quantity of protein selected by young rats of both sexes was directly related to the protein concentration of the maternal diet. Wistar dams were fed single diets containing 10, 20, 30 or 40% casein throughout gestation and lactation. Pups from all groups were subsequently allowed to select from diets containing 10 or 60% casein. Protein selection in the weanling rat was found to correlate significantly with protein concentration in the maternal diet. Similarly, Morris and Anderson (1986) found that the level of protein selected by young rats of both sexes was positively correlated with the protein concentration of their first solid food. In their study, Wistar rats were prematurely weaned at 17 days of age to either 39% or 10% casein diets. When given a choice between 10 and 60% casein diets at 21 days of age, pups selected 37% of total calories as protein if weaned to a 39% casein diet as compared to 19% in pups weaned to a 10% casein diet. Therefore, previous familiarity with a 10% casein diet during premature weanling may have led to a preferential selection of that diet after weanling. Similarly, the 39% casein diet may have been more sensory similar to the 60% casein diet than the 10% casein diet was. The authors suggested that the effect of early dietary experience on subsequent protein selection may reflect the role of sensory factors, that is the level of protein selected after weanling may be influenced by the sensory similarity of the diets available during selection with those experienced at the time of first solid food consumption; that is weanling.

Reed et al. (1992) have shown in adult male Sprague-Dawley rats that experience with macronutrients can have a large, long-lasting and even detrimental

effect on subsequent food selection. During a 4-day pre-exposure period, rats received either commercial non-purified stock diet or a two-way choice between stock diet and a single macronutrient source: carbohydrate (56.7% cornstarch, 27.4% dextrin, 9.8% sucrose), protein (93.9% casein) or fat (82.9% hydrogenated vegetable oil, 44% safflower oil). When allowed to select among the three macronutrient sources rats selected more of the macronutrient of which they had been pre-exposed. These selection patterns continued for 12 days, until the test was ended due to low protein intakes and poor growth of rats pre-exposed to carbohydrate and fat sources. Similar patterns of selection were demonstrated after 34 days of recovery with only stock diet to eat and also when a 5-day interval was interposed between macronutrient pre-exposure and macronutrient selection.

In 1983, Leathwood and Ashley, examined the strategies of protein selection by weanling and adult male Sprague-Dawley rats. After a 3-day feeding with a granulated stock diet, four groups of animals were offered pairs of isocaloric granular diets containing either 0/20%, 0/40%, 0/60% or 10/40% casein (groups 1 to 4, respectively) over 14 days. Initially, groups 1-3 (both weanling and adult rats) preferred the 0% casein diet and those in group 4 preferred the 10% casein diet. Thus, the initial selection may have been based on palatability (taste, smell, and texture) rather than long-term protein needs. Within five days all weanling rats were eating adequate amounts of protein (greater than 12% of total energy ingested as protein). In adult rats, the percentage of total energy ingested as protein (% protein-energy) rose during the first eight to ten days, to reach a steady mean of 30%. After two weeks, the diets were changed so that different diet pairs of casein diets were given (10/40%, 20/60%, 10/40% and 0/60%) to groups 1, 2, 3 and 4, respectively. Significant shifts in the percentage of total energy consumed as protein were demonstrated in all weanling rats, for example, groups 1, 2, and 4 increased their selection of % protein-energy from 16-18 to 27%, 29 to 45%, and 22 to 44%, respectively, group 3 reduced their % protein-energy selection from 40 to 25%. On the other hand, most adults did not demonstrate shifts in the percentage of total energy consumed as protein, that is, mean % protein-energy remained stable at about 30%. Within each group there was a greater

variability in the range of protein intake between different animals than the day-to-day variation between individuals, for both young and adult rats. The authors concluded that protein intake in rats is regulated in the sense that all animals learned to consume sufficient protein to maintain growth and most animals ate a constant amount of protein each day. However, a neurobiological mechanism which precisely regulates protein intake was precluded.

In summary, all rational selection of dietary materials involves the process of relating the physiological consequences of eating a food to its sensory properties (taste, smell, texture, and appearance). A learned protein-specific appetite has been demonstrated in protein-deprived rats and protein intake in rats is regulated in the sense that animals learn to consume sufficient protein.

2.3 Trigeminal Orosensation and Ingestive Behaviour

2.3.1 Trigeminal Orosensation

The ingestive behaviour of the rat and other mammals involves a continuous flow of oral somatosensory input used to guide grasping, licking, biting, lapping, chewing and transport prior to swallowing. These perioral stimuli are conveyed by the trigeminal nerves (Zeigler et al. 1984).

In vertebrates, trigeminal orosensory deafferentation, which impairs oral somatosensory input (touch, temperature and pain) reduces responsiveness to food and causes a reduction in its intake and a decrease in the level of longterm body weight regulation (Jacquin and Zeigler, 1982; 1983; Zeigler, Jacquin and Miller, 1984). Deficits in food intake vary with the sensory properties of the diet and recovery takes place along a palatability gradient. Adult male Wistar rats were deafferented; that is their somatosensory input was impaired, and they subsequently received a 5-diet regimen (pablum mash, rat chow mash, moist cat chow, dry cat chow and rat chow pellets). Rats demonstrated a drastic reduction in food and water intake. Intake of the 2 mashes was first to recover, followed by bite size soft cat chow, with the 2 hard foods: rat and cat chow eaten last. Thus, the trigeminal system contributes to both the sensorimotor and motivational control of ingestive behaviour (Jacquin and Zeigler,

1983; Zeigler, Jacquin and Miller, 1984).

2.3.2 Dietary Self-Selection

The normal feeding behaviour of the rat involves two tasks. The first is food selection which is qualitative in nature, that is, what to eat. The second task, dietary self-selection, is quantitative, that is, how much to eat of a specific food. In order to achieve normal growth and maintain body weight, the rat must accomplish both tasks (Zeigler et al. 1985).

Numerous studies demonstrated that feeding directed at a specific food source is associated with its postingestional consequences, whether they be positive or negative (Zeigler et al. 1985). Thus, it is assumed that preference or aversion are controlled by a conditioning process that involves associating a food-related conditioning stimulus with a specific set of postingestional consequences (Booth, 1985).

There appears to exist mechanisms of dietary self-selection in the rat that mediate feeding behaviour in order to maintain a constant protein intake (Miller and Teates, 1984), in addition to meeting additional energy requirements by increasing carbohydrate intake (Musten, 1974).

Diet sensory cues are involved in the control of quantitative intake and thus should play a role in dietary self-selection. The sensory factors are thought to be associated with short term control, whereas long term control is mediated by metabolic factors (LeMagnen, 1971). Among the senses, the contribution of gustation and olfaction to the quantitative control of food intake in the rat is relatively minor in comparison to oral somatosensation (Miller and Teates, 1984; 1985; 1986; Miller, 1984). Taste and olfaction arise from the sensory characteristics of the diet, whereas somatosensory input is generated by the process of feeding itself (grasping, chewing, swallowing) and could therefore mediate the association of a given feeding pattern (meal size, frequency) with its metabolic consequences (Miller and Teates, 1984; 1986).

2.3.2.1 Learning

There is evidence that associations can be formed between orosensory inputs

from food intake and postingestive effects (Blundell, 1983). For example, rats learn to prefer foods that correct specific deficiencies (Booth and Simson, 1971). They also develop conditioned aversions to diets that are deficient in thiamine (Rozin, 1967) or amino acids (Simson and Booth, 1974). The basis for rejecting amino acid imbalanced diets was found to be a learned aversion rather than a direct mechanism for detecting the presence or absence of an amino acid (Simson and Booth, 1974). Rats also develop conditioned aversions to diets that are toxic. For example, malaise can condition avoidance of high viscosity fluids (Ramirez, 1992). Adult male CD rats given a single intraperitoneal injection of 1 ml 0.15 M lithium chloride after they had sampled a viscous fluid (0.5% xanthum gum, 2% methyl cellulose), subsequently showed a greater avoidance of that fluid than did controls and this avoidance was based on textural cues (Ramirez, 1992).

Miller and Teates (1985) studied the development of dietary choice behaviour in naive adult male Sprague-Dawley rats. When given a 2-way choice between isocaloric protein-rich (90% soybean meal, 5% corn oil) and carbohydrate-rich (90% dextrinized starch, 5% corn oil) mash diets, rats selected equal amounts of the two diets at first and over a 7-day period maintained a stable ratio of protein to total intake (g/g). To examine the contribution of oral somatosensation to the acquisition of dietary self-selection, the same experiment was performed in partially trigeminally deafferented rats (with impaired oral somatosensory input). The deafferented rats did not develop a stable selection pattern throughout the 37-day selection period; on the first day of exposure, they ate more of the carbohydrate-rich diet than the protein-rich diet, carbohydrate intake tended to decrease and protein intake increased after the first day. However, their protein intake ratio varied over the entire possible range (0-44%). The authors concluded that quantitative carbohydrate and protein selection requires an associative learning process in which somatosensory inputs from feeding activities and/or from the foods' sensory properties link dietary choice behaviour to later metabolic events. Using the same design, Miller (1984) examined the effects of trigeminal orosensory deafferentation on the retention of previously acquired self-selection behaviour in experienced rats. Protein intake was almost zero in the first

week after deafferentation, that is up to day-7, but resumed after 7 days. Carbohydrate intake was reduced up to week-5. When total intake had nearly recovered, the protein (g)/total intake (g) ratio remained impaired, and ranged from seemingly random selection to extreme preferences. In 5 of the 12 rats, the protein ratio fluctuated around the level of random selection (22%). Four rats developed extreme selection patterns; they either greatly increased their protein intake or eliminated it completely. Thus, trigeminal somatosensation plays a role in dietary selection through sensory stimuli which serve as the conditioned stimulus for establishing a particular feeding pattern or conditioned response for fine (quantitative) adjustment of intake from different diets appropriate for metabolic requirements, on a day-to-day basis.

2.3.2.2 Control of Protein Intake

To study the role of oral somatosensory input in the ability of the rat to adjust protein selection to metabolic stress, Miller and Teates (1984) subjected trigeminally deafferented male Sprague-Dawley rats to either food deprivation or intragastric supplementation (protein and carbohydrate). Using the same two-way choice offered by Miller and Teates (1985), the deafferented rats that had recovered normal protein intake ratios under free-feeding conditions remained deficient in the regulation of both caloric and protein intake, following deprivation or nutrient supplementation. The authors suggested that recovery of protein ratio after deafferentation is incomplete and that the compensatory mechanisms or remaining sensory input (e.g. taste, odour) cannot fully replace the function of trigeminal somatosensory input. They also suggested that protein intake in the recovered trigeminal rat could be regulated for the most part by postingestional factors, that by nature can only act with delay after ingestion. However, trigeminal orosensory inputs could mediate the relatively rapid and fine adjustment of selection patterns to metabolic fluctuations. Trigeminal orosensation is generated in the act of eating and may be closely associated with maintaining a feeding pattern that determines the quantitative intake in accord with metabolic requirements.

These studies of dietary self-selection demonstrated that the deafferented rat (with impaired texture perception) is impaired in the regulation of both caloric and

protein intake. The rat is unable to acquire self-selection behaviour patterns that will maintain normal protein to total intake ratios, to retain these patterns once acquired, or to defend them against metabolic challenges (depletion or supplementation). Furthermore, the rats self-selection behaviour is highly variable and may fluctuate over a large range of protein intake ratios. Trigeminal orosensation may be important in mediating a rat's ability to adjust its feeding behaviour patterns rapidly and precisely to their metabolic consequences.

2.4 Effect of Diet Texture

The sensory characteristics of a diet influence the preference or liking for it. The structural characteristic of a diet or its texture is one aspect along with taste, of its sensory properties. Diets may be presented as liquids, semisolids (gels), or solids (powders, granules, chips, blocks), and rats do not find all these dietary forms equally acceptable (Blundell, 1983). Powders are difficult for rats to consume and appear to be least preferred and may be regarded as slightly aversive. Granules are more readily accepted, and blocks are probably most preferred by rats because of their natural tendency to grasp food materials with their forepaws and to nibble. Gels are accepted by rats but may be lower in nutrient concentration, since they include nutritional agar or similar substances (Blundell, 1983).

Modification in diet texture can alter macronutrient intake and selection. Lat (1967) observed that rats consumed twice as much casein when it was soaked in water than when it was given in dry form. The importance of food texture in determining choice was also demonstrated by Bise et al. (1983). Three groups of adult male Sprague-Dawley rats were given a two-way choice between carbohydrate-rich (87.5% cornstarch, 5% corn oil, 2% cellulose) and casein-rich (66% casein, 21.5% cornstarch, 5% corn oil, 2% cellulose) diets. Among the three groups of rats, the only difference was the texture (powder, granules or pellets) in which the diet was presented. Granulated diets were prepared by mixing portions of the powdered diets with water to form a dough, passing through a 2 mm sieve, freeze-drying then sieving again. A pill making machine was used to make hard 80 mg pellets. Texture did not affect food

intake: that is, mean daily energy intakes were 56.9, 54.4 and 63.6 kcal for rats given diets in powder, granular, pellet form, respectively. However, protein consumption and percentage energy selected from protein were higher with the granulated (5.9 g protein and 41.7% protein-energy) and pelleted (7.3 g protein and 45.6% protein-energy) diets, than with powdered (3.4 g protein and 23.1% protein-energy) diets. This effect may have been due to the difficulty rats had in eating finely powdered casein protein; and some rats who received powdered diets, failed to eat adequate protein and died. Which may have been due to their inability to associate the sensory characteristics of a casein-rich diet with its post-ingestive effects when in powdered form. The fact that some rats demonstrate an aversion to casein (Scott, 1946) poses a limitation to the study by Bise et al. (1983). According to Scott (1946), "rats either do or do not like casein; if they like it they eat an average of 3 g per day and grow well; if they do not, they eat less than 0.1 g per day, lose weight and die within a short period." In a pilot experiment, Leathwood and Ashley (1983) observed that some adult male Sprague-Dawley rats when offered a choice between casein-free (87.5% cornstarch, 5% corn oil, 2% cellulose) and casein-rich (66% casein, 21.5% cornstarch, 5% corn oil, 2% cellulose) powdered diets did not eat the casein-rich diet at all during the first two weeks of exposure, while all animals offered the diets in granulated form ate the casein-rich diet within five to six days.

In 1986, McArthur and Blundell examined the possibility that the texture of diets might alter dietary self-selection of protein and carbohydrate. Three groups of adult male Listar Hooded rats were given a two-way choice between isocaloric protein-rich (45% casein, 41% cornstarch, 10% corn oil) and carbohydrate-rich (81% cornstarch, 5% casein, 10% corn oil) diets. Among the three groups of rats, the only difference was the form (powder, gel or granular) in which the two diets were offered. The granular diet pair contained Animal Nutrition Research Council (ANRC) reference casein, whereas the finely milled powder and gelled diet pairs contained British Drug Houses (BDH) nutritional standard casein. Gel diets were prepared daily by addition of 35% agar solution to the dry BDH diet and then subsequently cooling for 1.5 h before being cut into blocks and given to the gel-diet group. Over a 21-day measurement

period, all three diet groups consumed similar amounts of mean daily energy. However, mean daily protein intake was significantly different. According to the mean daily diet selection over 21 days, groups fed the powder- and gel-diet, respectively consumed 41.0 and 74.5% less protein than groups fed the granular diet. This difference in protein intake was accounted for by differences in the selection of the protein-rich and carbohydrate-rich diets; while the group fed the granular diet selected its food mostly from the protein-rich diet, both the powder- and gel-diet fed groups selected food mostly from the carbohydrate-rich diet. The selection of particular diets and hence protein and carbohydrate intake was markedly altered by the diet texture. In this experiment, protein was the macronutrient that was most affected, which may have been due to an aversion for protein-rich diets presented as powder or gels. Furthermore, since casein was used as the protein source, the reduced protein intake may have been due to the aversion that some rats demonstrate for casein (Scott, 1946). This study (McArthur and Blundell, 1986) was limited by differences in absolute concentrations of protein between dry and wet diets; the granular and powder carbohydrate-rich diets contained 5.7% and 5.3% protein, respectively, whereas the carbohydrate-rich gel diet contained 2.8% protein. Also the percentage protein for the protein-rich granular and powder diets were 41.9% and 40.3%, respectively, whereas the protein-rich gel diet contained 21% protein. In addition, the casein (BDH nutritional standard) used for the preparation of the gel and powder diets was highly soluble in water and agar, whereas the casein (ANRC) used for the granular diet was not. Furthermore, gel diets were produced by the addition of a 35% agar solution in boiled water. Therefore differences in sources of casein and preparation methods, in addition to differences in texture, may have confounded the results. Principles that ensure that animals maintain adequate intake of required nutrients, may involve learned associations between diet sensory aspects and its post-ingestional metabolic consequences (Booth and Simonson, 1971; Miller, 1984).

Holder and DiBattista (1994) measured the effects of time-restricted access to protein-rich diets and of varying the oral-sensory properties of protein diets on protein intake and selection in adult male Sprague-Dawley rats. An initial 10-day adaptation

phase allowed each rat to become familiar with the carbohydrate-rich (47% sucrose, 47% cornstarch), fat-rich (94% vegetable shortening) and either soy-based (92%) or casein-based (92%) protein-rich diets. During the subsequent 9 days, rats were either deprived of protein for 23 h or they received the same initial protein diet (either the soy- or casein-based diet that was offered during adaptation) and food intake was measured during the following hour at the end of the light phase. Protein-deprived rats consumed greater than twice as much of the protein-rich diet than non-restricted rats, regardless of the protein source. For rats fed freely, those that received a different protein diet during the test periods ate 60% more of the protein-rich diet than did those that received the same protein diet. Thus, protein deprivation motivated rats to eat protein when rats were tested with two different protein sources. The authors concluded that increases in protein consumption following protein deprivation can be attributed at least in part to the novelty of the oral-sensory properties of diets and not necessarily to a specific protein appetite.

In summary, these studies demonstrate that the texture of the diets can alter the dietary self-selection of protein-rich and carbohydrate-rich diets.

2.5 Drugs and Diet Texture

It has been suggested that central serotonin (5-HT) synaptic activity is involved in animal and human dietary self-selection between protein and carbohydrate diets (Ashley et al. 1979). However, studies have shown conflicting results on the effects of dl-fenfluramine, a 5-HT agonist, on the intakes of protein-rich and carbohydrate-rich diets (Wurtman and Wurtman, 1977; Ashley et al. 1979; Orthen-Gambill and Kanarek, 1981; Peters et al. 1983). Wurtman and Wurtman (1977) reported that following intraperitoneal (ip) injection of dl-fenfluramine in doses of 2.5 or 5 mg/kg, young male rats (strain not mentioned) fully adapted to a two-way choice between a protein-rich (45% casein, 5% dextrin) diet and an isocaloric carbohydrate-rich (5% casein, 45% dextrin) diet, increased their kcal intake of the protein-rich diet relative to that of the carbohydrate-rich diet over the following 3-h period. Similarly, depletion of brain 5-HT with neurotoxins [300 mg/kg oral administration of p-chlorophenylalanine (PCPA)]

severely reduced the intake of a protein-rich diet over 2 weeks in young male Wistar rats given a choice between 15% and 55% casein diets (Ashley et al. 1979). Peters et al. (1983) observed in young male albino rats that ip injections of L-tryptophan (100 mg/kg) did not alter their choice between two diets differing in protein and carbohydrate content (15% casein, 37% cornstarch, 37% low glucose monohydrate and 55% casein, 17% cornstarch, 17% low glucose monohydrate), despite increases of 50% in brain concentrations of 5-HT and 5-hydroxy indoleacetic acid (5-HIAA; a 5-HT metabolite). Also, Orthen-Gambill and Kanarek (1981) allowed adult female Sprague-Dawley rats to choose between three isocaloric diets: carbohydrate (57% cornstarch, 27% dextrin, 10% sucrose), protein (94% casein) and fat (39% hydrogenated vegetable oil, 2% safflower oil, 52% alphacel). They found that ip injection of dl-fenfluramine at doses of 1.5, 3 and 6 mg/kg reduced the kcal intake of fat only over an 8-h feeding period. When the choice included a high caloric fat ration (83% hydrogenated vegetable fat, 4% safflower oil), the same doses of dl-fenfluramine caused a decrease in both fat and protein intakes (kcal) over a similar 8-h feeding period.

McArthur and Blundell (1986) examined the effects of 2.0 mg/kg fenfluramine, using adult male Listar Hooded rats, on the intake of protein and carbohydrate selected from pairs (5% and 45% casein) of three isocaloric diets in which physical form was varied. Fenfluramine reduced the percent of total energy selected from protein when powdered diets were fed, but left this parameter unaltered when either gel or granular diets were fed. These results suggest that the effect of fenfluramine is sensory-specific and not macronutrient-specific.

In 1990, Baker and Booth tested the effects of ip of 2.5 mg/kg dl-fenfluramine on selection between the textures of nutrient preparations. Adult male Hooded rats were presented with a choice between pairs of three sizes of chow crumb added with 45% dextrin, casein, maltodextrin or Ca caseinate. The three sizes of chow crumb were achieved by placing chow pellets in a paper bag and pounding with a pestle. Three grain sizes were separated and measured by sieving through three different utensils. Fine crumbs were passed through a Buchner filter funnel, medium crumbs through a gared sieve, and coarse crumbs through a domestic colander. Fenfluramine

reduced the intake preference over 6 h for a coarser over a finer crumb. However, the effect of the drug differed according to the preparation of carbohydrate or protein added to each crumb size. Furthermore, the preparations of carbohydrate and protein used had different textures, that is unlike casein and dextrin, Ca caseinate and maltodextrin are readily soluble. Thus, the effect of fenfluramine was not specific to macronutrient type, but to macronutrient texture.

In the brainstem the concentrations of 5-HT in the cranial motor nerve nuclei are higher than those in the sensory nuclei (Palkovits et al. 1974). Serotonin plays a role in both reflex and automatic swallowing (Hashim and Beiger, 1987) and has been shown to inhibit mastication at the moment of swallowing (Chandler et al. 1985). Thus, if fenfluramine disrupts the brainstem motor pattern generators mediating intake (Baker and Booth, 1990), this could reduce the relative ease with which the coarser crumb could be eaten.

Booth and Baker (1990) also demonstrated that ip injection of fenfluramine (2.5 mg/kg) had no effect on texture-cued protein and carbohydrate selection in adult male rats (strain not mentioned). In their study, during training and testing, diets were presented between 1000 h and 1600 h (rats were food-deprived for the remaining 18 h). On two training days, one group (n=12) of rats were presented with a two-way choice between medium-sized crumb diet (55% chow crumb, 45% casein) and fine crumb diet (55% chow crumb, 45% dextrin), the other group (n=12) chose between medium-sized crumb diet (55% chow crumb, 45% dextrin) and fine crumb diet (55% chow crumb, 45% casein). Four rats in each group subsequently received 10 ml preloads of 10% casein hydrosylate, 4 received 10% maltodextrin and 4 received non-nutritive solution, 4 h prior to testing. At testing, rats were injected with dl-fenfluramine and subsequently presented with a two-way choice between fine crumb diet (55% chow crumb, 22.5% casein, 22.5% dextrin) and medium crumb diet (55% chow crumb, 22.5% casein, 22.5% dextrin). The ingestion of protein and carbohydrate conditioned a preference for one size of chow crumb, over another which was triggered by a nutrient-specific need. However, the state-dependent macronutrient-associated crumb preferences were not affected by fenfluramine. Thus the effects of

fenfluramine on differential intakes of dextrin- and casein-rich diets did not depend on nutrient specific dietary selection. In a similar study by Gibson and Booth (1988) using odour as a cue, adult male Sprague-Dawley derived Hooded rats were given 4 training days, two days with a nutrient, either protein (10% calcium caseinate) or carbohydrate (10% low glucose maltodextrin) diets, and two days with non-nutritive (0.3% cellulose gum and 0.02% saccharin, for protein and carbohydrate selection experiments, respectively) diets; nutrient and non-nutritive diets were each paired with an odour (almond or violet food-flavouring). On the test day, rats were deprived of food for 5 h (as during training) and received either saline or ip injection of fenfluramine in doses of 1.25 or 2.5 mg/kg for the protein selection experiment and in 2.5 mg/kg in the carbohydrate selection experiment. Following injection, rats subsequently received a choice between the two training odours in two separate tubes both containing a 1:1 mixture of the nutritive and non-nutritive training diets. For both the protein and carbohydrate selection experiments, no differences were found between preferences following fenfluramine administration and the preference shown by saline control. Thus, fenfluramine did not affect the selection of protein- or carbohydrate-paired odours by trained rats.

In summary, the effect of fenfluramine, a 5-HT agonist was not specific to macronutrient type, but to macronutrient texture.

3. Circadian Rhythms

Behavioral and physiologic rhythms are manifestations of self-sustained oscillators (biological clocks) endogenous to animals (Zucker, 1980). Under natural conditions, biological clocks are synchronized or entrained by periodically recurring environmental stimuli. Biological clocks enable living organisms to measure time and foresee changes of conditions in the programmed environment. The periodic factors in the environment no longer act as the immediate cause of the biological rhythm but only as synchronizing agents or *Zietgebers* ("time-givers"), that entrain the endogenous self-sustaining oscillation within living things (Aschoff, 1980).

The most powerful synchronizer is the light-dark cycle, and the most common

biological rhythms are circadian (from the Latin *circa*, about, and *dies*, day) to describe those with a period of 24 h. In isolation from fluctuations in the environment, biological clocks maintain spontaneous periodicities and "free-run" (Zucker, 1980). Circadian rhythms are maintained by endogenous mechanisms, since they free-run with a period of about 24 h in the absence of any obvious exogenous cues. These rhythms are thought to be generated autonomously by the suprachiasmatic nucleus (SCN) (Zucker, 1980). For instance, aperiodic behaviour has been demonstrated in rats after destruction of the SCN, that is, the rats were unable to entrain normally to a 12 h light/12 h dark cycle and under conditions of constant illumination they did not generate free-running rhythms (Zucker, 1980). Although the pacemaker system acts as a single oscillator, circadian oscillators are also located outside the SCN region (Connor Johnson, 1992). For instance, time of eating is one of the most effective synchronizers of many resultant circadian rhythms, such as certain enzyme levels or the levels of different tissue components. Also anticipatory feeding behaviors appear to be driven by an oscillator outside of the SCN that responds to periodic feeding cues (Moore Ede et al. 1982). For example, learned rhythms of food and water anticipation behavior were still present in SCN-lesioned rats (Clarke and Coleman, 1986). Finally, circadian rhythms have been identified in every organism studied, from single cell organisms to man and every function studied, whether physiologic function, an enzyme level, an endocrine system, the size of a cell or its histology (Aschoff, 1980).

There seems to exist two classes of circadian oscillators (Aschoff, 1980). One is the sleep-wakefulness cycle, which has a weak power for sustaining itself and readily deviates from the 24 h rhythm. The other class includes body temperature rhythms, urine excretion, hormonal secretion, enzyme synthesis and has strong self-sustaining power.

3.1 Natural Patterns of Feeding

The earth's rotation results in day and night and two classes of animals in terms of feeding. Diurnal animals, such as humans, are active during the day and rest at night. Nocturnal animals, such as rats, are active at night and sleep in the daytime.

Rats generally consume more than 70% of their daily food intake during the dark phase (Richter, 1927), and periodicity is an essential feature of feeding behaviour (Le Magnen, 1981). Furthermore, natural meal patterns and macronutrient intake display clear diurnal rhythms (Leibowitz, 1993).

3.1.1 Patterns of Macronutrient Selection and Regulation of Intake

Rat studies have shown a bimodal distribution of feeding during their active nocturnal cycle, demonstrating peaks during the early and late dark periods (Tempel et al. 1989; Shor-Posner et al. 1991). In dietary self-selection studies, in which adult male Sprague-Dawley rats were fully adapted to a three-way choice among carbohydrate-rich (28% dextrin, 28% cornstarch, 37% sucrose), protein-rich (93% casein) and fat-rich (86% lard) diets, carbohydrate intake peaks at the beginning of the natural feeding cycle, whereas a rise in preference for protein and fat develops near the end of the dark cycle (Tempel et al. 1989; Shor-Posner et al. 1991; 1994). Larue-Achagiotis et al. (1992) demonstrated similar findings in adult male Wistar rats offered a choice among carbohydrate-rich (85% cornstarch, 8% sucrose), protein-rich (93% casein) and fat-rich (91% lard, 2% sunflower oil) diets. Also, in female Sprague-Dawley rats adapted to a choice among high-carbohydrate (57% cornstarch, 27% dextrin, 10% sucrose), high-protein (94% casein) and high-fat (83% hydrogenated vegetable oil, 4% safflower oil) diets, approximately 70% of all first meals of the dark cycle were at least in part composed of carbohydrate and intake of most (56%) of their subsequent meals was from a single macronutrient source, namely, carbohydrate, protein or fat (Miller et al. 1994).

The specific needs of the rat seem to vary across the nocturnal cycle. It has been shown in rats that food ingested during the first half of the nocturnal cycle is used to supply immediate energy needs and to promote lipogenesis. In contrast, during the late dark period, nutrient and energy stores are replenished and feeding is anticipatory, geared toward storage and subsequent utilization of nutrients during the light period (Armstrong et al. 1978). Thus, the fluctuation in macronutrient intake over the active feeding cycle supports other findings demonstrating that feeding during different phases of the diurnal cycle may be differentially regulated (Le Magnen, 1981;

Strubbe et al. 1986). However, rats can be categorized into three subpopulations according to their 24 h and 12 h nocturnal pattern of nutrient intake : carbohydrate-, protein- and fat-preferrers (Shor-Posner et al. 1991), thus stressing the importance of individual differences of natural feeding patterns. In addition, the first meal of the feeding cycle has been identified as being the most distinctive in reflecting the individual dietary preferences, that is, rats' mostly consumed the specific nutrient that was generally preferred over the 24 h cycle during their first meal (Shor-Posner et al. 1994). Carbohydrate-preferrers consumed fewer total calories and relatively smaller, more frequent meals, compared with rats that preferred protein or fat. Moreover, regardless of dietary preference, rats exhibit a shift in meal composition from one meal to the next, with a specific macronutrient-rich meal, preceded as well as followed by meals with considerably lower amounts of this macronutrient. Greater satiating effects (longer post-meal interval relative to meal size) of meals taken in early dark versus late dark period are also demonstrated, independent of nutrient composition.

While numerous studies have demonstrated shifts in dietary selection from meal to meal, Rolls et al. (1984) have questioned whether this shift in preference may reflect the sensory rather than the nutritional properties of the diets. The notion of sensory specific satiety refers to the fact that the consumption of a particular food produces more satiety for foods of the same sensory properties than for other foods that have not been eaten (Rolls, 1986).

Johnson et al. (1979) examined the different diurnal rhythms of protein and non-protein energy intakes. Male weanling Wistar rats were given a two-way choice between isocaloric protein-rich (60% casein, 24% corn starch, 10% corn oil) and carbohydrate-rich (84% corn starch, 10% corn oil) powder diets. Although the amount of protein per meal remained constant, meal size increased from the mid light through the dark phase by a selective increase in carbohydrate intake. Hence meal composition selected by rats followed a diurnal rhythm with protein concentration decreasing from light to dark meals. Due to the consistency of these feeding rhythms, it was concluded that short-term regulation of protein and energy intakes exists. In a similar study by Leathwood and Arimanana (1984), adult male Sprague-Dawley rats given a two-way

choice between a 60% casein and a protein-free diet both in pelleted form, displayed stable selection patterns in terms of percentage of total energy selected as protein by the third day on the regimen. During the subsequent 4 to 10 days, the percentage of total energy selected as protein ranged from 12% during the latter part of the light period to 42% at the end of the dark period. Hence, the percentage of energy selected as protein increased from light to dark. Thus, sensory factors, such as textural factors may contribute as much as metabolic factors to the circadian pattern of macronutrient intake.

Human eating behaviour also displays specific rhythms on macronutrient intake; shifting from a high carbohydrate diet in the morning to a high fat diet and a high protein diet during the latter part of the day (de Castro, 1987). Thus, similar mechanisms regulating nutrient intake may be active in both humans and rats. In the same study it was also demonstrated that as the day progresses postmeal intervals, that is, the time from the termination from the current meal to the onset of the next meal, and satiety ratios decrease. This suggests that humans obtain less satiety from a given amount of food later in the day than earlier, thus anticipating the overnight fast. Also, Szczesniak and Kahn (1971) demonstrated that time of day has a significant effect on preferences for different textural characteristics, in humans. At breakfast, textures chosen were familiar and passive with the preferred textures being those that lubricate the mouth, moisture, those that could be swallowed and digested with ease and those that required little effort in manipulating in the mouth, such as softness. Dinner was a meal at which a wide range of textures, for example, tender, crisp, firm and chewy, were most appreciated and enjoyed; the preferred textures were those that required more energy for mastication.

In summary, circadian rhythms in macronutrient intake have been displayed in both rats and humans. Furthermore, time of day has a significant effect on preferences for different textural characteristics in humans. Also, sensory factors such as textural factors may contribute as much as metabolic factors to the circadian pattern of macronutrient intake.

3.1.2 Meal Patterns

Meal patterns provide a detailed description of the elements of ingestion and therefore theoretically serve as a more sensitive experimental manipulation than measurements of total food intake (Glendinning and Smith, 1994). Rats eat during discrete feeding episodes or meals, separated by definite non-eating intervals or intermeal intervals. Thus, overall intake is a product of two parameters of the meal pattern, meal size and meal frequency (Le Magnen, 1971). These parameters are affected by various manipulations such as the caloric density or palatability of the diet (Johnson et al. 1986; Sunday et al. 1983) or acute changes in light schedule (Plata Salaman and Oomura, 1987), thus suggesting control by separate physiological systems (Le Magnen, 1971). Clifton et al. (1984) reported that a direct reduction in the permitted feeding rate caused a reduction in meal size and an increase in meal frequency in rats. Also, manipulations, such as changes of food taste and texture, anorectic drugs, etc., affect the rate of food consumption.

In response to calorically dilute diets, rats maintain a constant daily caloric intake by increasing meal frequency and size (Johnson et al. 1986). Rats also demonstrate a circadian rhythm of food ingestion which entrains to the light-dark cycle and free runs under constant illumination and following blinding (Zucker, 1971; Rowland, 1976; Plata-Salaman and Oomura, 1987). Several studies have reported that both meal size and meal frequency increase during the dark phase of the light-dark cycle (Davies, 1977; De Castro, 1975). However, Glendinning and Smith (1994) concluded that rat strains can differ with respect to the consistency of meal patterning. In their study, each individual Sprague-Dawley rat demonstrated a highly consistent pattern of ingestive activity across 10 consecutive nights. However, feeding activity patterns in individual Fischer-344s were significantly less consistent over time. In terms of the distribution of feeding activity, Sprague-Dawley rats displayed lights-off and lights-on peaks of ingestive activity, whereas only a minority of Fischer-344s displayed a consistent lights-on peak of ingestive activity.

While studies of the rat's meal patterns have demonstrated that meal size is positively correlated with the duration of the post-meal interval (De Castro, 1975; Le

Magnen, 1971), others have not replicated this finding (Panksepp, 1973; Castonguay et al. 1986). This postprandial correlation is believed to reflect the action of meal-initiated metabolic events on the induction and maintenance of intermeal satiety (Le Magnen, 1976). Rosenwasser et al. (1981) found that exposure to constant illumination resulted in attenuation of rhythms and an increase in postprandial correlations in adult male Hooded rats. The higher postprandial correlations resulted from changes in the temporal sequence of meal sizes and intermeal intervals across the day and were not accompanied by a decrease in the variability in meal size or intermeal interval. Thus, the authors suggested a competitive relationship between circadian rhythms and the short-term metabolic controls determining the rats meal pattern.

3.1.3 Palatability and Meal Patterns

In rats, mean meal size may reach up to 6 grams or more according to the sensory properties of the food (Le Magnen, 1981). The increase in meal size due to the presentation of a cafeteria diet, that is, a diet offered to experimental animals that is composed of a wide variety of highly palatable foods results from the fact that both the initial stimulating value and the satiating power of each food item is sensory-stimulus specific rather than nutrient specific.

It is fairly certain that palatability, a hedonic response which partly depends on the diet sensory characteristics, will affect feeding mainly during direct contact with food (Rogers and Blundell, 1984), thus meal size should increase when highly palatable foods are given. Increased enthusiasm for feeding might also be reflected in a faster eating rate. Also, it is likely that the tendency to initiate feeding (affecting meal frequency) would also be facilitated, since the action of sensory stimuli is not only limited to the moment of feeding.

The sensory qualities of the diet have been shown to affect the microstructure of feeding behaviour (Davis, 1989). Alterations in diet palatability can induce changes in the motivation to eat, which also influences meal size. Normal and hypothalamic hyperphagic adult female rats (CFE strain) take larger meals when diet palatability is increased by using a liquid diet consisting of 300 ml sweetened condensed milk with 600 ml water (Le Magnen, 1971; Sclafani, 1976), but meal number or day-night

distribution of feeding were left unaffected. Similarly, Rogers and Blundell (1984) demonstrated that palatability mainly influences meal size, whereas variety affects both meal size and intermeal interval. In addition, normal rats take smaller meals when palatability is decreased. For example, Levitsky (1970) found that adulterating a chow diet with quinine, led to reduced meal size and increased meal frequency in adult male Sprague-Dawley rats. Palatability also seems to be reflected in feeding rate. Rowland (1975) demonstrated that adult male Wistar rats receiving a palatable saccharin sweetened chow, increased their feeding rates. Similarly, in adult male Sprague-Dawley rats on a foraging paradigm, fed either cereal-based (21% protein, 57% carbohydrate, 4% fat) or casein-based (18% casein, 63% sucrose, 6% fat) pelleted diets, meal patterns were found to be sensitive to subtle differences in diets, for example, casein-based pellets tended to be hard and dustless compared to those that were cereal-based (Johnson et al. 1984). Lastly, in a study by Sunday et al. (1983) male Sprague-Dawley rats were simultaneously offered two differentially preferred, yet nutritionally equivalent diets. One diet was a cereal-based diet (40% soybean meal, 27% corn meal, 5% fish meal, 4% alfalfa meal, 5% celluflour, 8% cornstarch, 6% corn oil) and the other was a casein-based diet (a one to two mixture of the cereal-based diet and a nutritionally equivalent casein-based diet). The casein-based diet was known to be preferred seven to one in total daily intake over the cereal-based diet by weanling Sprague-Dawley rats in a free-choice preference test. Rats consumed the preferred casein-based diet more frequently, in larger meals, and at a faster rate than the less preferred cereal-based diet (Sunday et al. 1983). Also, in humans, eating rate is faster for isocaloric foods of identical composition (yogourt, apples, bananas, tofu and soy nuts) when offered in liquid versus solid form (Kissileff et al.1980).

In summary, palatability, a hedonic response which partly depends on the diet sensory characteristics, influences meal patterns.

3.2 Plasma Insulin and Glucose

Daily changes in plasma insulin might play an important role in regulating energy metabolism. In rats maintained on a 12:12 h light:dark cycle, with lights on

from 0800 to 2000 h, plasma insulin was lowest in the middle of the light period and highest in the middle of the dark period (Yamamoto, 1987). Plasma glucose stayed constant at a level slightly higher than the 100 mg/dL found throughout the light period. Changes in these parameters seemed to occur in close relation to food intake. However, even in fasting conditions there was a persistent increase in plasma insulin at the end of the light period from 1845 to 1945 h. Blood glucose, however was maintained almost constant. In fasting humans, plasma insulin is slightly higher in the morning than in the afternoon, and in fasting rats it increases at the end of the light period (see review by Nagai and Nakagawa, 1992). In addition, the response of insulin secretion to the same dose of glucose is higher in the light phase in humans and in the dark phase in rats (see review by Nagai and Nakagawa, 1992). Thus daily fluctuations in plasma insulin are driven by an endogenous oscillator and glucose regulation is homeostatically controlled.

4. Cephalic Phase Insulin Release

The cephalic phase of insulin release (CPIR) is the early rise in insulin secretion. It is triggered by the sensory characteristics of the diet; that is, the taste, smell and sight of food. CPIR is not triggered by the postingestional consequences of eating the food (Powley and Berthoud, 1985). CPIR has been demonstrated in mammals, for example rats and humans (Berthoud et al. 1981; Teff et al. 1991) and birds (Karmann et al. 1995). It can be elicited by carbohydrate-rich or carbohydrate-free foods, by noncaloric meals (Strubbe, 1975) by glucose or saccharin ingestion (Berthoud et al. 1980; Louis-Syvestre, 1976; Strubbe, 1978) and can be conditioned by arbitrary stimuli (Roozendaal et al. 1990). CPIR is a parasympathetic reflex mediated by the vagus nerve because it can be suppressed by atropine blockade (Sjostrom et al., 1980; Trimble et al. 1981; Strubbe, 1992), subdiaphragmatic vagotomy (Louis-Syvestre, 1976) or B-cell denervation (Berthoud et al. 1980; Trimble et al. 1981; Louis-Syvestre, 1978). The cephalic phase insulin response may be integrated at the brainstem/midbrain level and at least some gustatory-evoked secretory and ingestive behavioral responses are organized at the brainstem level (Berthoud, et al. 1981).

Furthermore, changes in hypothalamic monoamines, in particular 5-HT, norepinephrine and dopamine have been associated with the CPIR (Holmes et al. 1989). Lastly, the central amygdala is involved in the conditioned but not the meal-induced cephalic phase insulin response (Roozendaal et al.1990).

4.1 Palatability And The Cephalic Phase Insulin Response

4.1.1 Animal Studies

Using chronically jugular catheterized adult male Wistar rats, Berthoud et al. (1981) demonstrated that the sweet taste of 1 ml of a 0.15% non-nutritive sodium saccharin solution caused a 100% increase of insulinemia from baseline, peaking in the second or third post-stimulus minute in the absence of any significant change of glycemia. Using the same design, Powley and Berthoud (1985) studied the CPIR to ingestion of different volumes (0.1, 1.0 and 3.5-5.0 ml) of a 0.15% sodium saccharin solution and demonstrated a similar increase in plasma insulin levels over baseline, with no significant change in plasma glucose. Furthermore, the magnitude of the cephalic response was proportional to the volume of palatable solution consumed. Ionescu et al. (1988) studied the taste-induced changes in plasma insulin and glucose turnover in lean FA/FA and obese fa/fa adult male Zucker rats equipped with chronic catheters for blood sampling. In 6-h fasted lean and obese rats that were trained to drink 1 ml sodium saccharin (0.15%) or 1 ml glucose (70%), there was an increase in CPIR as early as 1-1.5 min poststimulus compared to baseline values. The amplitude of the CPIR induced by either saccharin or by glucose was higher in the obese rats (4 ng/ml x 2 min and 6 ng/ml x 2 min, respectively) than it was in the lean rats (0.5 ng/ml x 2 min and 1.2 ng/ml x 2 min, respectively). The plasma glucose levels remained stable, but showed a slight increase at 4 minutes poststimulus in the obese group. In 6-h fasted lean and obese rats, saccharin ingestion produced an increase in hepatic glucose production and in the rate of glucose disappearance compared with basal values. The increments in hepatic glucose production and rate of glucose disappearance were higher in the obese (13.4 mg/20 min and 10 mg/20 min, respectively) than in the lean (5.2 mg/20 min and 3.6 mg/20 min, respectively)

animals. The authors concluded that the taste of saccharin appears to elicit insulin release and increases hepatic glucose production in lean and obese rats and these taste-induced changes were exaggerated in the obese rats.

4.1.2 Human Studies

A reliable CPIR has been confirmed in normal weight male adults (Teff et al. 1991) challenged three times with the same food stimulus (an aspartame sweetened strawberry flavored gelatin dessert combined with dairy fat and served in the form of a mousse) over a 5-day period, that is, plasma insulin increased above baseline at 4 minutes postingestion on each of the three trials. However, Teff et al. (1995) found no increases in plasma insulin after normal weight men sipped and spit different sweet-tasting solutions (aspartame, saccharin and sucrose) each on a separate day.

In men and women who ingested food of high palatability (assortment of 3 foods: onion tart, tuna tart and quiche) and low palatability (the same 3 foods mixed to a homogenous paste with added spices and blue coloring), preprandial insulin responses (PIR) were more frequent when the food presented was highly palatable, that is, a significant PIR was observed in 2 out of 8 low palatability tests and in 8 out of 10 high palatability tests (Lucas et al. 1985). Similarly, in men and women presented with high and low-palatability sandwiches on 2 different occasions (hedonic ratings were obtained in a pretest session), Bellisle et al. (1985) reported that when high-palatability meals were ingested, the amplitude of the early mealtime insulin response, relative to premeal oscillations, was higher than in the low palatability situation. Furthermore, Simon et al. (1985) reported that olfactive and visual presentation of a standard palatable meal (raw carrots, fried chicken, spaghetti and cookies) produced an early blood insulin increment between the third and ninth minute after meal presentation, in both normal and overweight men and women.

Using a modified sham-feed, Teff et al. (1993) demonstrated that oral sensory stimulation, in which a peanut butter sandwich served as the food stimulus, can elicit CPIR (0-10 min poststimulus) in men, when compared with fasted values, with no change in blood glucose. Teff and Engelman (1996) used a similar design but reported no difference in the magnitude of CPIR between foods that were rated palatable and

unpalatable by normal weight women.

4.2 The Conditioned Cephalic Insulin Response

Insulin secretion can also be conditioned by association with arbitrary stimuli that reliably predict the presentation of food (Powley and Berthoud, 1985; Berthoud et al. 1981). For instance, insulin was elevated in meal-fed adult male rats (strain not mentioned) at the specific time of day associated with feeding (Woods et al. 1977). In the same study, after 21 days on a regimen in which rats received their food (19% casein, 12% corn oil, 70% glucose) between 1130-1330 h, insulin levels were increased at the time of day that they normally ate (1130 h) relative to both 6 h prior to (0530 h) or 6 h after (1730 h). Control rats who had continuous access to the diet throughout the experiment had higher insulin levels overall. Similarly, Strubbe (1992) habituated adult male Wistar rats to one of two feeding schedules to obtain a rapid conditioned cephalic phase of insulin secretion which was measured in blood sampled via cardiac catheter. Clock-activated opening of doors in front of a food hopper (containing chow pellets) imposed a feeding schedule of either 6 meals per day or 2 meals per day. Tests were performed in the mid light phase. In both conditions, insulin was increased during the first minute of feeding when the doors were opened, whereas the first rise in blood glucose occurred at 3 minutes after the start of the meal. When presented an empty food hopper immediately after door opening, only rats on the 2-meal per day condition demonstrated elevated insulin levels and not those receiving 6 meals per day. No change of blood glucose was found. It was suggested that rapid conditioned insulin secretion was evoked within one minute by a meal-associated stimulus and thus its occurrence was dependent on the nature of the feeding schedule. In a similar study, Roozendaal et al. (1990) habituated adult male Wistar rats to a feeding regimen in which chow was available twice daily (from 1045 to 1200 h and from 2245 to 0000 h) through clock-activated opening of doors. They demonstrated a conditioned increase in plasma insulin (in the first minute) and glucose (in the second minute) as compared to basal levels in blood sampled via cardiac catheter.

In summary, the cephalic phase of insulin release (CPIR) is the early rise in

insulin secretion. It is triggered by the sensory characteristics of the diet; that is, the taste, smell and texture of food. CPIR is not triggered by the postingestional consequences of eating the food. Also insulin secretion can be conditioned by association with arbitrary stimuli that reliably predict the presentation of food, such as time of day.

In summary, all rational dietary selection involves the process of relating the postingestional consequences of eating a food with its sensory characteristics; that is taste, texture and odour. Learning is a change in the organization of an individual's behaviour so that this organization represents the environment better. It has been suggested that protein-specific appetite can be learned. Among food sensory characteristics, diet texture, the most plausible sensory characteristic affecting ingestion, may play an important role in the control of food selection. It has been demonstrated that the texture of the diets can alter the self-selection of protein and carbohydrate intake.

Circadian rhythms in macronutrient intake have been displayed in both rats and humans. In studies involving rats that display preferences for particular macronutrients across the 24 h cycle, it is not clear as to whether texture has an influence on their preferences. Also in humans, time of day has a significant effect on preferences for different textural characteristics. Furthermore, sensory factors, such as textural factors may contribute as much as metabolic factors to the circadian pattern of protein and carbohydrate intake in rats.

Chapter 3

MANUSCRIPT

Effect of Diet Textural Characteristics on the Temporal Rhythms of Feeding in Rats

Effect of Diet Textural Characteristics on the Temporal Rhythms of Feeding in Rats

Mok, E.[1] and Thibault, L.[1]

[1]School of Dietetics and Human Nutrition, McGill University, Canada, H9X 3V9

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Correspondence should be addressed to:

Louise Thibault, Ph.D.

Associate Professor

School of Dietetics and Human Nutrition

Macdonald Campus of McGill University

21,111 Lakeshore

Ste. Anne de Bellevue

QC, Canada H9X 3V9

Telephone: (514)-398-7848

Facsimile: (514)-398-7739

email: louise_thibault@maclan.mcgill.ca

ABSTRACT

MOK, E. AND L. THIBAULT. Effect of diet textural characteristics on the temporal rhythms of feeding in rats. PHYSIOL BEHAV To examine whether the circadian rhythmicity of protein-rich and carbohydrate-rich diet ingestion would be altered by presenting the diets in different textural forms, adult male Wistar rats were assigned to two dietary groups. One group received a two-way choice between high-protein powder and high-carbohydrate granular (HPP-HCG) diets. In the other group the textures were reversed [high-protein granular and high-carbohydrate powder (HPG-HCP) diets]. Rats fed HPP-HCG diets selected significantly less protein (kcal) vs. rats fed HPG-HCP diets, during the 24 h and 12 h dark phase and during the 4 h early and late dark phases. Carbohydrate intakes of the two dietary groups were not significantly different. Total caloric intake for the HPG-HCP dietary group was significantly higher than that of the HPP-HCG dietary group during the 24 h and 12 h dark phase. Body weight was significantly lower in rats fed HPP-HCG diets. Within the HPP-HCG dietary group two subgroups were identified (slow and fast learners) according to the different adaptation abilities to the HPP diet. The slow learners consumed significantly less protein (kcal) vs. the fast learners during the 24 h and 12 h light and dark phases and during the 4 h early, middle and late dark phases. In conclusion, macronutrient-rich diets presented in different textural forms alter the circadian rhythmicity of protein-rich and carbohydrate-rich diet ingestion and total energy intake.

Texture Protein Carbohydrate Circadian Rhythm Feeding Learning

INTRODUCTION

Dietary selection is the result of the organization of the information derived from both sensory properties and metabolic signals of the food (Ashley, 1985). Omnivores (such as rats and humans) are faced with a wide range of potential foods and accordingly their dietary selection may depend on learned influences (Rogers and Blundell, 1991). Learning is a change in the organization of an individual's behaviour so that this organization represents the environment better (Booth, 1987). Furthermore, all rational dietary selection involves the process of relating the postingestional consequences of eating a food to its sensory characteristics (Blundell, 1983).

Among food sensory properties, taste and odour have been given much attention. Texture is likely to be more important in the control of food selection (Booth, 1987), however it has not been addressed to the same extent. For example, when offered a choice of casein-free and casein-rich powdered diets, some rats fail to consume protein, which may be due to their inability to learn about the metabolic properties of the foods (Leathwood and Ashley, 1983). However, in the same study all rats offered a choice of the same diets in granulated form learned to choose sufficient protein intake more rapidly, thus promoting growth and survival of the animal.

Circadian rhythms in macronutrient intake have been displayed in both rats (Shor-Posner et al. 1991) and humans (DeCastro, 1987) throughout their active feeding cycle. Furthermore, sensory factors (e.g. textural factors) may contribute as much as metabolic factors to the circadian pattern of macronutrient intake. For example, rats given a two-way choice between a 60% casein and a casein-free powder diet demonstrated a circadian variation of protein intake, with protein concentration decreasing from light to dark meals (Johnson et al., 1979). However, when rats were given the same diets presented as pellets, the proportion of calories consumed as protein peaked at the end of the night (Leathwood and Arimanana, 1984).

These studies, however leave questions. For instance, can the circadian rhythmicity of carbohydrate-rich and protein-rich diet ingestion be altered by the use of different textural characteristics of the macronutrient-rich diets, independently from their macronutrient content. Secondly, can the circadian variation in meal patterns

differ according to the different textural forms in which the carbohydrate-rich and protein-rich diets are presented. Therefore, the objectives of the present study are to answer the above questions.

METHOD

Animals and Diets

Twenty-four male Wistar rats (Charles River Laboratory, Quebec, Canada), initially weighing 250-300 g were used. They were housed in individual cages, in a room with controlled temperature (24^{0}C), humidity, and a 12:12 h light-dark schedule (lights on at 0700 h). The animals were provided *ad libitum* with water and isocaloric carbohydrate-rich and protein-rich diets (Table 1), having different textures (powder versus granular) during a 15-day experimental period. One group (n=12) received a two-way choice between a high-protein powder and a high-carbohydrate granular (HPP-HCG) diet. In the other group (n=12) the textures were reversed [two-way choice between a high-protein granular and a high-carbohydrate powder (HPG-HCP) diet]. Granular diets were prepared fresh on alternate days, by adding a fixed amount of water to the powdered diets (50 ml water to 100 g high-protein diet and 30 ml water to 100 g high-carbohydrate diet) and stirring to obtain a granular consistency. Granular diets were left to dry overnight in order to evaporate added water. Weights of the granular diets were checked the following day to ensure that granular diet weights were similar to the weight of the powder diets before the addition of water. In addition, weights of carbohydrate- and protein-rich diets were similar. Diets were controlled for flavor by adding artificial flavor (Bush Boake Allen Americas-Natural & Artificial Peanut butter powder #25743, Chicago, Illinois). The experiment was conducted from February to May, 1996.

Experimental Design

After 3 days of adaptation to environmental conditions, in which commercial non-purified stock diet (Purina Rat Laboratory Chow) and water were available *ad libitum*, the animals were randomly divided into two groups and placed in a Diet Scan data acquisition system (AccuScan Instruments Inc., Columbus, OH). The animals were studied six at a time (three on HPP-HCG diets and three on HPG-HCP diets) over an experimental period of 15 days. Measurement intervals of 1 minute across 24 h were used. Body weight was measured daily. To ensure minimal disturbance to the animals during the active dark period, introduction of fresh food, body weight

measurements, cleaning of cages and resetting the Diet Scan system were scheduled at 0930 h. In order to measure the cephalic phase insulin response (CPIR) and plasma glucose levels, on day-16 blood was collected by cardiac puncture [B-D 5 cc Syringe #309603, Becton Dickinson, Franklin Lakes, NJ; Vacutainer brand blood collection tube #6457, EDTA (K3), Becton Dickinson, Franklin Lakes, NJ] at the end of the light phase (1800 h) and then centrifuged at 1500 RPM for 10 minutes at 4^{0}C (Sorvall RT6000B, Dupont, Montreal, QC). Plasma was stored at -80^{0}C for future analysis. Plasma insulin content was determined in duplicate by a radioimmunoassay (RIA) procedure (Immunocorp RIA Kit, KTSP-11001, Montreal, QC) and Gamma counter (1282 Compu Gama CS, Pharmacia, Turku, Finland). Duplicate measures of plasma glucose were determined using Glucose [HK] 20 Kit (Sigma Diagnostics, St Louis, MO) and Autoanalyzer (Abbott Laboratories Ltd, Mississauga, Ontario).

Diet Scan System

The Diet Scan system was designed to study food intake patterns of small animals continuously. Each Diet Scan cage was surrounded by electronic balances (Ohaus Port-O-Gram-C301P and A&D-EW300A). The scales were connected to an analyzer that was linked to an IBM PC computer. Each animal cage was made of clear acrylic frames (41.75 X 41.75 X 31.5 cm^3), with a stainless steel grid on the bottom. Square openings in the cage with tunnels permitted the animal access to the food trays. Each tray was placed on top of the scale plate and filled with a carbohydrate-rich or a protein-rich diet. Rats had access to water through a drinking hole that was connected to the drinking bottle which was held by a holder that stood on a scale plate. The data was collected using Diet Scan Lab Animal Monitoring System Software (DLAM). A Diet Scan custom made Template was used to compile the information into data files.

Statistical Analysis

Raw data were obtained as g/minute of intake from carbohydrate-rich and protein-rich diets. In order to express the effect of diet texture on the circadian rhythmicity of feeding during the 15-day experimental period, intakes from each macronutrient-rich diet were analyzed separately with Repeated Measures ANOVA. The following main effects were analyzed: texture (powder vs. granular) and phase (12

h light and dark; 4 h early, middle and late dark); the interaction between texture and phase was also tested. The dependent variables were intakes (g and kcal) from the protein-rich and carbohydrate-rich diets and the absolute macronutrient intakes (g and kcal of carbohydrate and protein) for the 24 h, 12 h light and dark phases and 4 h intakes from the early, middle and late part of the dark phase.

The circadian rhythmicity of total energy (g and kcal) was also analyzed with Repeated Measures ANOVA, using dietary group (HPP-HCG vs. HPG-HCP) and phase (12 h light and dark; 4 h early, middle and late dark) as factors; the interaction between dietary group and phase was also tested. The dependent variables were total g and kcal from each dietary group for the 24 h, 12 h light and dark phases and 4 h intakes from the early, middle and late part of the dark phase.

Meal patterns were also determined. A meal was defined as at least 3 consecutive minutes of eating separated from other meals by at least 5 minutes during the dark phase and at least 10 minutes during the light phase (Castonguay et al., 1986; Tempel et al., 1989). Meal patterns were analyzed with Repeated Measures ANOVA, using dietary group (HPP-HCG vs. HPG-HCP) and phase (12 h light and dark) as factors; the interaction between dietary group and phase was also tested. The dependent variables were the number of meals, meal duration (min), meal size (g), protein and carbohydrate composition (g) of meals and intermeal interval (min) from each dietary group for the 24 h, 12 h light and dark phases.

Due to the different adaptation abilities of the animals within the HPP-HCG group, this group was subsequently separated into two sub-groups [high-protein powder and high-carbohydrate granular slow learners (HPP-HCG-SL; n=7) vs. high-protein powder and high-carbohydrate granular fast learners HPP-HCG-FL; n=5). In order to be classified as a fast learner a minimum protein intake of 7.4 g was required after day-4 of the 15-day experimental period. The circadian rhythmicity of protein-rich and carbohydrate-rich diet ingestion (g and kcal) was analyzed with Repeated Measures ANOVA, using group (HPP-HCG-SL vs. HPP-HCG-FL) and phase (12 h light and dark; 4 h early, middle and late dark) as factors; the interaction between group and phase was also tested. Meal patterns were also analyzed with Repeated

Measures ANOVA, using group (HPP-HCG-SL vs. HPP-HCG-FL) and phase (12 h light and dark) as factors; the interaction between group and phase was also tested.

Body weights (g) were analyzed by two-way ANOVA, using dietary group (HPP-HCG and HPG-HCP) and day as factors. To separate the HPP-HCG-SL vs. HPP-HCG-FL, body weights were subsequently analyzed by two-way ANOVA using group (HPP-HCG-SL, HPP-HCG-FL and HPG-HCP) and day as factors. Plasma glucose (mmol/L) and insulin (pmol/L) concentrations between the HPP-HCG and HPG-HCP dietary groups were analyzed by Student's t-test and data were subsequently analyzed by one-way ANOVA using group (HPG-HCP, HPP-HCG-SL and HPP-HCG-FL) as the factor.

When the main effects were significant multiple comparisons were tested for significance by Tukey's test. Results are presented as Least Square Mean (LSM)$\pm$SEM intakes (g and kcal) of the macronutrient-rich diets and absolute macronutrient intake (carbohydrate and protein) and total food intake (g and kcal) each day of the 15-day experimental period. A probability of less than 5% was considered significant. Statistical analysis was carried out using SAS (version 6.10).

RESULTS

BODY WEIGHT

Daily body weight variations in groups of rats fed a choice between a high-protein powder and a high-carbohydrate granular diet (HPP-HCG) or a choice between a high-protein granular and a high-carbohydrate powder diet (HPG-HCP) are presented in Fig. 1. Throughout the experimental period body weight was significantly affected by dietary group, $F(1,330)=197.26$, $p<0.0001$. Body weight was significantly higher in the HPG-HCP dietary group compared to that of the HPP-HCG dietary group from day 2-15. Within the HPP-HCG dietary group, two subgroups were identified according to their variations in body weight, namely the slow learners (HPP-HCG-SL; n=7) and the fast learners (HPP-HCG-FL; n=5) (Fig. 1). The HPP-HCG-SL lost weight up to day-10 and subsequently gained weight throughout the remaining experimental days (days 11-15). The HPG-HCP and the HPP-HCG-FL groups gained weight from days 2 and 3, respectively. Among the HPG-HCP, HPP-HCG-SL and HPP-HCG-FL groups body weight was significantly affected by group, $F(2,315)=491.95$, $p<0.0001$. The HPP-HCG-SL group had significantly lower body weight compared to HPP-HCG-FL from days 5-15 and to HPG-HCP dietary group from days 2-15. From day-4 body weight was not significantly different between the HPG-HCP dietary group and the HPP-HCG-FL.

DIETARY INTAKES

HPP-HCG and HPG-HCP Dietary Intakes

12 h dark and light phases, and 24 h intakes

No significant main effect of diet texture (powder vs. granular) was found for energy intakes from carbohydrate during the light and dark phases and 24 h period. During the 24 h period, daily energy intakes from carbohydrate ranged from 44.1 to 55.6 kcal and from 42.4 to 75.9 kcal for the HPG-HCP and HPP-HCG dietary groups, respectively, over the 15-day experimental period (Table A6.1). During the 12 h dark phase energy intakes from carbohydrate ranged from 31.5 kcal to 43.4 kcal for rats fed

HPG-HCP diets and from 30.6 to 51.0 kcal for rats fed HPP-HCG diets, over the 15-days (Table A6.2). Energy intake from carbohydrate during the 12 h light phase for the HPG-HCP and HPP-HCG dietary groups ranged from 5.0 to 14.1 kcal and from 7.1 to 25.0 kcal, respectively, over the 15 days (Table A6.2).

In contrast, a significant main effect of diet texture was found for energy intakes from protein, $F(1,22)=13.91$, $p<0.01$. Specifically, the HPG-HCP dietary group consumed significantly more protein than the HPP-HCG dietary group during the dark phase of days 1-10 (Fig. 2). However, during the light phase protein intake was not significantly different between the two dietary groups. Over 24 h protein intake was significantly affected by diet texture, $F(1,11)=9.13$, $p<0.05$, with the HPG-HCP dietary group consuming significantly more protein than the HPP-HCG dietary group from days 1-10 (Fig. 2). A significant main effect of diet texture on total energy was also found, $F(1,10)=15.94$, $p<0.01$, with the HPG-HCP dietary group consuming significantly more total energy than the HPP-HCG dietary from days 5-7, 9, 10 and 15 of the dark phase (Fig. 3). On the other hand, during the light phase total energy was not significantly different between the two dietary groups. Over 24 h total energy was significantly affected by diet texture, $F(1,5)=9.34$, $p<0.05$. Specifically, the HPG-HCP dietary group consumed significantly more total energy compared to the HPP-HCG dietary group from days 3, 5-7, 9-11 (Fig. 3).

A significant main effect of diurnal phase (12 h light vs. 12 h dark) was found for energy intakes from carbohydrate, $F(1,24)=107.16$, $p<0.0001$, with rats in both dietary groups consuming more carbohydrate during the dark phase than the light phase, except on day 2 for the HPP-HCG dietary group (Table A6.2). A significant main effect of diurnal phase was also found for energy intakes from protein, $F(1,22)=13.82$, $p<0.01$, with the HPG-HCP dietary group consuming significantly more protein during the dark phase than the light phase on days 1, 2 and 5-10 (Table A5.2). However, it was only on day 14 that protein intake in the HPP-HCG dietary group was significantly higher during the dark vs. the light phase. A significant main effect of diurnal phase was also found for total energy intake, $F(1,10)=166.70$, $p<0.0001$. Animals consumed significantly more total energy during the dark phase compared to

the light phase from days 1-15 in the HPG-HCP dietary group and from days 1-7 and 9-14 in the HPP-HCG dietary group (Table A10.2).

4 h early, middle and late dark phase intakes

No significant main effect of diet texture (powder vs. granular) was found for energy intakes from carbohydrate during the early, middle and late dark phases (Table A6.3). However, in the early and late part of the dark phase, energy intakes from protein were significantly affected by diet texture, $F(1,33)=19.53$, $p<0.0001$. Specifically, the HPG-HCP dietary group consumed significantly more protein than the HPP-HCG dietary group during the early dark phase of days 1, 2 and 5-7 and the late dark phase of days 1 and 2 (Fig. 4). A significant main effect of diet texture on total energy was also found, $F(1,15)=22.51$, $p<0.01$, with the HPG-HCP dietary group consuming significantly more total energy compared to the HPP-HCG dietary group during the early dark phase of day-5 and during the middle dark phase of days 5,6 and 9 (Table A10.3).

Although nocturnal phase did not significantly affect protein intake (Table A5.3), a significant main effect of phase was found for carbohydrate intake, $F(2,36)=8.41$, $p<0.001$. Within the HPG-HCP dietary group, carbohydrate intake was significantly higher in the early vs. the late dark phase (day-6) and middle dark phase (day-7) (Table A6.3). A significant main effect of phase on total energy was also found, $F(2,15)=5.92$, $p<0.05$. Within the HPP-HCG dietary group, total energy intake was significantly higher during the early dark phase vs. the middle dark phase and late dark phase on days 3 and 6, respectively (Table A10.3). On day-5 energy intake was higher during the early dark compared to middle dark and late dark phase (Table A10.3).

HPP-HCG-SL and HPP-HCG-FL Dietary Intakes

12 h dark and light phases and 24 h intakes

Within the HPP-HCG dietary group two subgroups were identified [slow learners (HPP-HCG-SL) and fast learners (HPP-HCG-FL)] according to their protein intake. A significant main effect of group, $F(1,12)=16.07$, $p<0.01$ (HPP-HCG-SL vs. HPP-HCG-FL) was found for energy intakes from protein. At the start of the

experiment (days 1 and 2) both groups consumed a similar low level of protein during the dark phase. However, from days 3-9 the HPP-HCG-FL consumed significantly more protein than the HPP-HCG-SL (Fig. 5). At day-10 the HPP-HCG-SL increased their protein intake and subsequently consumed similar levels to that of the HPP-HCG-FL. During the light phase protein intake was significantly higher in the HPP-HCG-FL compared to the HPP-HCG-SL from days 4-7 (Fig. 5). Over 24 h, protein intake was significantly affected by group, $F(1,6)=9.87$, $p<0.05$. The HPP-HCG-FL group consumed significantly more protein than the HPP-HCG-SL group from days 3-7 (Fig. 5). No significant main effect of group (HPP-HCG-SL vs. HPP-HCG-FL) was found for energy intakes from carbohydrate during the light and dark phases and 24 h period. Energy intakes from protein during the light and dark phases and 24 h period did not differ between the HPG-HCP dietary group and the HPP-HCG-FL group.

A significant main effect of diurnal phase was found for energy intakes from protein, $F(1,12)=21.18$, $p<0.01$, with the HPP-HCG-FL consuming significantly more protein during the dark phase than the light phase on days 3-7 (Table A13.2). However, the HPP-HCG-SL consumed similar levels of protein during the dark and light phases (Table A13.2).

4 h early, middle and late dark phase intakes

In the early, middle and late portions of the dark phase protein intake was significantly affected by group (HPP-HCG-SL vs. HPP-HCG-FL), $F(1,33)=19.53$, $p<0.0001$. Specifically, the HPP-HCG-FL consumed significantly more protein than the HPP-HCG-SL during the early (days 3-7), middle (days 3-9 and 11) and late (days 3-8) dark phases (Fig. 6). No significant main effect of group was found for energy intakes from carbohydrate during the early, middle and late dark phases. Energy intakes from protein during the early, middle and late dark phases did not differ between the HPG-HCP dietary group and the HPP-HCG-FL group. No significant main effect of phase (4 h early, middle and late dark) was found for protein intake (Table A13.3).

MEAL PATTERNS

HPP-HCG and HPG-HCP Meal Patterns

Meal Number

No significant overall main effect of dietary group (HPP-HCG vs. HPG-HCP) was found for the number of meals consumed during the light and dark phases. However, the HPG-HCP dietary group consumed significantly more meals than did the HPP-HCG dietary group on day-9 of the dark phase, $F(1,10)=16.95$, $p<0.01$ (Table A15.2). During the light phase meal number was not significantly different between the two dietary groups (Table 15.2). Over 24 h, meal number was not significantly affected by dietary group. However, the HPG-HCP dietary group consumed significantly more meals compared to the HPP-HCG dietary group on day-9, $F(1,5)=17.86$, $p<0.01$ and day-10, $F(1,5)=10.99$, $p<0.05$ (Table A15.1).

A significant overall main effect of diurnal phase (12 h light vs. 12 h dark) was found for the number of meals consumed, $F(1,10)=46.13$, $p<0.0001$. Specifically, the HPG-HCP dietary group consumed significantly more meals during the dark phase than the light phase on days 1, 2, 6-13 and 15 (Table A15.2). For the HPP-HCG dietary group more meals were consumed during the dark vs. the light phase on days 1, 10, 12, 13 and 15 (Table A15.2).

Meal Duration

No significant overall main effect of dietary group was found for the time taken to eat a meal during the light and dark cycles (Table A16.2). Over 24 h, meal duration was not significantly affected by dietary group. However, the HPP-HCG dietary group spent significantly more time eating a meal than did the HPG-HCP dietary group on day-3, $F(1,5)=22.36$, $p<0.01$ and day-4, $F(1,5)=10.9$, $p<0.05$ (Table A16.1). Furthermore, no significant overall main effect of diurnal phase was found for the duration of a meal (Table A16.2).

Meal Size

No significant overall main effect of dietary group was found for the size of a meal during the light and dark cycles (Table A17.2). However, a significant overall main effect of dietary group was found for the size of a meal during the 24-h period,

$F(1,5)=8.81$, $p<0.05$. Specifically, the HPP-HCG dietary group consumed significantly larger meals compared to the HPG-HCP dietary group on days 2, 3 and 4 (Table A17.1). No significant overall main effect of diurnal phase was found for the size of a meal (Table A17.2).

Meal Composition

No significant overall main effect of dietary group was found for both the protein (Table A18.2) or carbohydrate (Table A19.2) composition of a meal consumed during the light and dark cycles. Over 24 h, the protein composition of a meal was not significantly affected by dietary group. However, on day-1 the HPG-HCP dietary group consumed significantly more protein per meal than did the HPP-HCG dietary group, $F(1,5)=7.61$, $p<0.05$ (Table A18.1). In contrast, a significant overall main effect of dietary group was found for the carbohydrate composition of a meal during the 24-h period, $F(1,5)=11.94$, $p<0.05$. Specifically, the HPP-HCG dietary group consumed significantly more carbohydrate per meal than did the HPG-HCP dietary group on days 1-4 and 9 (Table A19.1). No significant overall main effect of diurnal phase was found for both the protein (Table A18.2) and carbohydrate (Table A19.2) composition of a meal.

Intermeal Interval

A significant overall main effect of dietary group was found for the interval between meals, $F(1,4)=12.34$, $p<0.05$. Although multiple comparisons could not be performed due to missing data, the intermeal interval was consistently greater (1 to 126%) for the HPP-HCG dietary group than the HPG-HCP dietary group from days 1-12 of the dark cycle (Table A20.2). Over 24 h, the intermeal interval was not significantly affected by dietary group. However, on day-9, the HPP-HCG dietary group demonstrated a significantly larger intermeal interval compared to the HPG-HCP dietary group, $F(1,5)=12.86$, $p<0.05$ (Table A20.1). The main effect of diurnal phase could not be tested due to missing data.

HPP-HCG-SL and HPP-HCG-FL Meal Patterns

Meal Number

No significant overall main effect of group (HPP-HCG-SL vs. HPP-HCG-FL)

was found for the number of meals consumed during the light and dark phases and 24-h period (Table A21.2; Table A21.1). A significant overall main effect of diurnal phase (12 h light vs. 12 h dark) was found for the number of meals consumed, $F(1,2)=438.49$, $p<0.05$. Specifically, the HPP-HCG-FL consumed significantly more meals during the dark phase than the light phase on days 4, 5, 12 and 13 (Table A21.2). For the HPP-HCG-SL, more meals were consumed during the dark vs. the light phase on days 11-13 (Table A21.2).

Meal Duration

No significant overall main effect of group was found for the time taken to eat a meal during the light and dark phases and 24-h period (Table A22.2; Table A22.1). Meal duration was not significantly affected by diurnal phase (Table A22.2).

Meal Size

No significant overall main effect of group was found for the size of a meal for the light and dark phases and over 24 h (Table A23.2; Table A23.1). No significant overall main effect of diurnal phase was found for the size of a meal (Table A23.2).

Meal Composition

No significant overall main effect of group was found for both the protein (Table A24.2) and carbohydrate (Table A25.2) composition of a meal consumed during the light and dark cycles. Similarly over 24 h, the protein and carbohydrate composition of a meal was not significantly affected by group (Table A24.1; Table A25.1). No significant overall main effect of diurnal phase was found for both the protein and carbohydrate composition of a meal (Table A24.2; Table A25.2).

Intermeal Interval

No significant overall main effect of group was found for the interval between meals during the light and dark cycles (Table A26.2). Over 24 h, the interval between meals was not significantly affected by group (Table A26.1). The main effect of diurnal phase could not be tested due to missing data (Table A26.2).

PLASMA CONCENTRATIONS OF GLUCOSE AND INSULIN

On day-16, plasma glucose and insulin concentrations before the dark phase (at 18 00 h) were not significantly different between dietary groups (HPP-HCG vs. HPG-HCG) (Table 2). Although, plasma glucose was 13.1% lower in the HPP-HCG group vs. the HPG-HCP group and plasma insulin was 15.4% higher in the HPP-HCG group vs. the HPG-HCP group. Similarly, when the HPP-HCG group was subsequently separated into two subgroups, no significant main effect of group (HPG-HCP, HPP-HCG-SL vs. HPP-HCG-FL) was found.

TABLE 1
COMPOSITION OF DIETS (DRY WEIGHT, g/100 g DIET)

Ingredients	High Protein	High Carbohydrate
Vitamin-free casein*	77.3	0.0
Corn oil ****	5.0	5.0
Lard*****	5.0	5.0
Dextrin**	0.0	58.5
Sucrose*	0.0	18.8
AIN76 mineral mix*	5.0	5.0
AIN76A vitamin mix*	2.0	2.0
Alphacel*	4.44	5.0
DL-Methionine*	0.56	0.0
Choline Chloride*	0.2	0.2
Artificial peanut butter flavour***	0.5	0.5
Energy density (kcal/g)	4.1	4.0

*ICN Biochem (Montreal, Can.)
**BDH (Toronto, Can.)
***Bush Boake Allen Americas (Chicago, Illinois)
****Mazola
*****Tenderflake

TABLE 2
Plasma concentrations of glucose and insulin

Dietary group	**Glucose** (mmol/L)	**Insulin** (pmol/L)
HPP-HCG (n=11)	7.39 ± 0.25*	475.18 ± 71.90*
HPP-HCG-SL (n=7)	7.30 ± 0.28#	435.78 ± 101.19#
HPP-HCG-FL (n=4)	7.53 ± 0.54#	544.14 ± 95.22#
HPG-HCP (n=12)	8.36 ± 0.57*#	411.82 ± 27.32*#

Mean (±SEM) plasma concentrations of glucose and insulin prior to the dark phase (18 00 h) on day-16 in rats fed a choice between high protein powder high carbohydrate granular (HPP-HCG) diets or high protein granular high carbohydrate powder (HPG-HCP) diets for 15 days.
Within the HPP-HCG group two sub-groups were identified [high protein powder high carbohydrate granular-slow learners (HPP-HCG-SL) and high protein powder high carbohydrate granular-fast learners (HPP-HCG-FL)].
* Plasma glucose and insulin concentrations were not significantly different between HPP-HCG and HPG-HCP by Student T-Test.
# No significant main effect of group (HPP-HCG-SL, HPP-HCG-FL, HPG-HCP) was found for plasma glucose and insulin concentrations by one-way ANOVA.

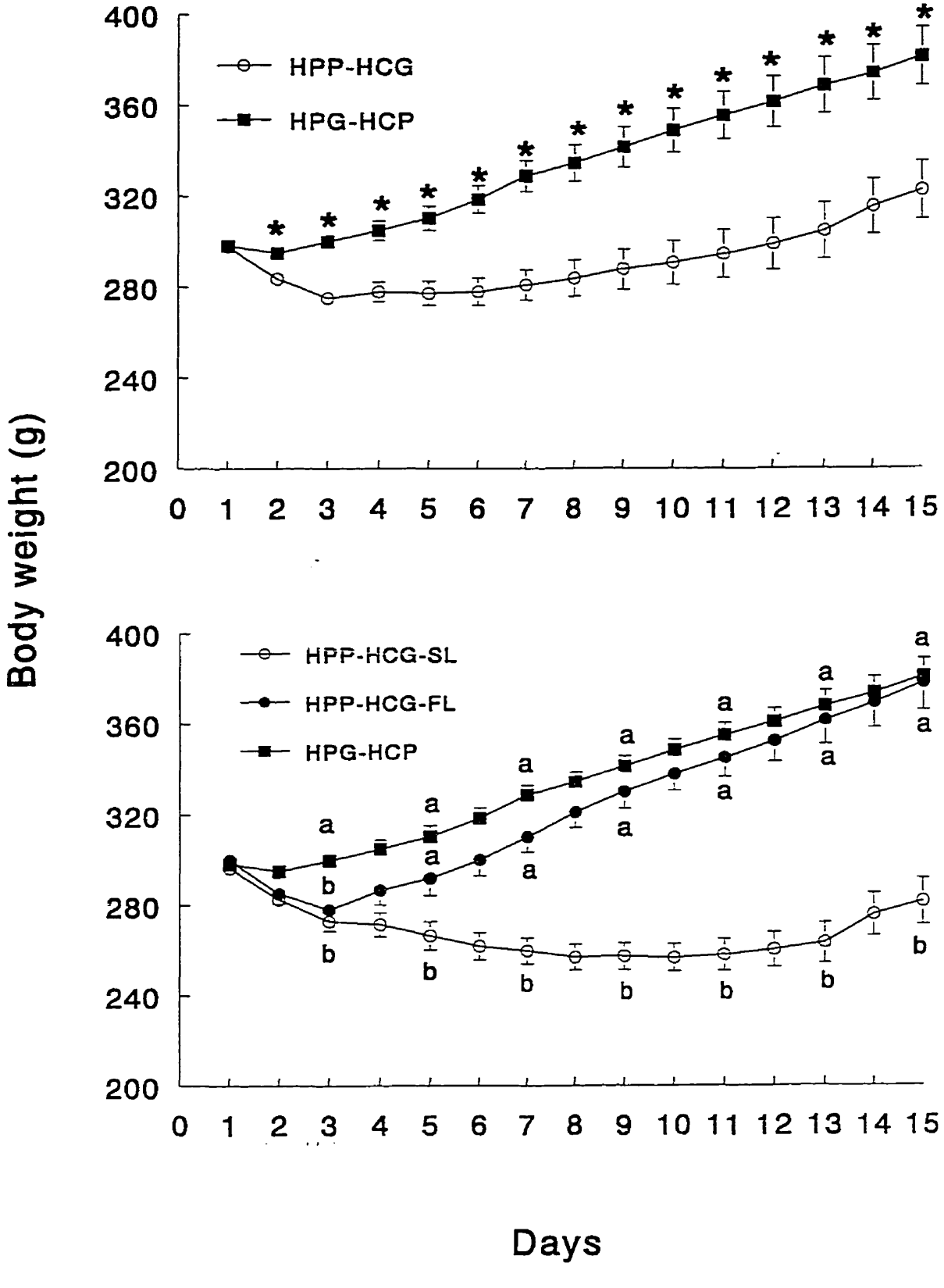

FIG. 1. Least Square (LS) Mean (±SEM) daily body weight variations in groups of rats fed a choice between high-protein powder high-carbohydrate granular (HPP-HCG) diets or high-protein granular high-carbohydrate powder (HPG-HCP) diets. Within the HPP-HCG group two subgroups were identified [high-protein powder high-carbohydrate granular-slow learners (HPP-HCG-SL) and high-protein powder high-carbohydrate granular-fast learners (HPP-HCG-FL). Within day comparisons of individual LS means with * or different letters are significantly different at $p<0.05$ with Tukey's Test.

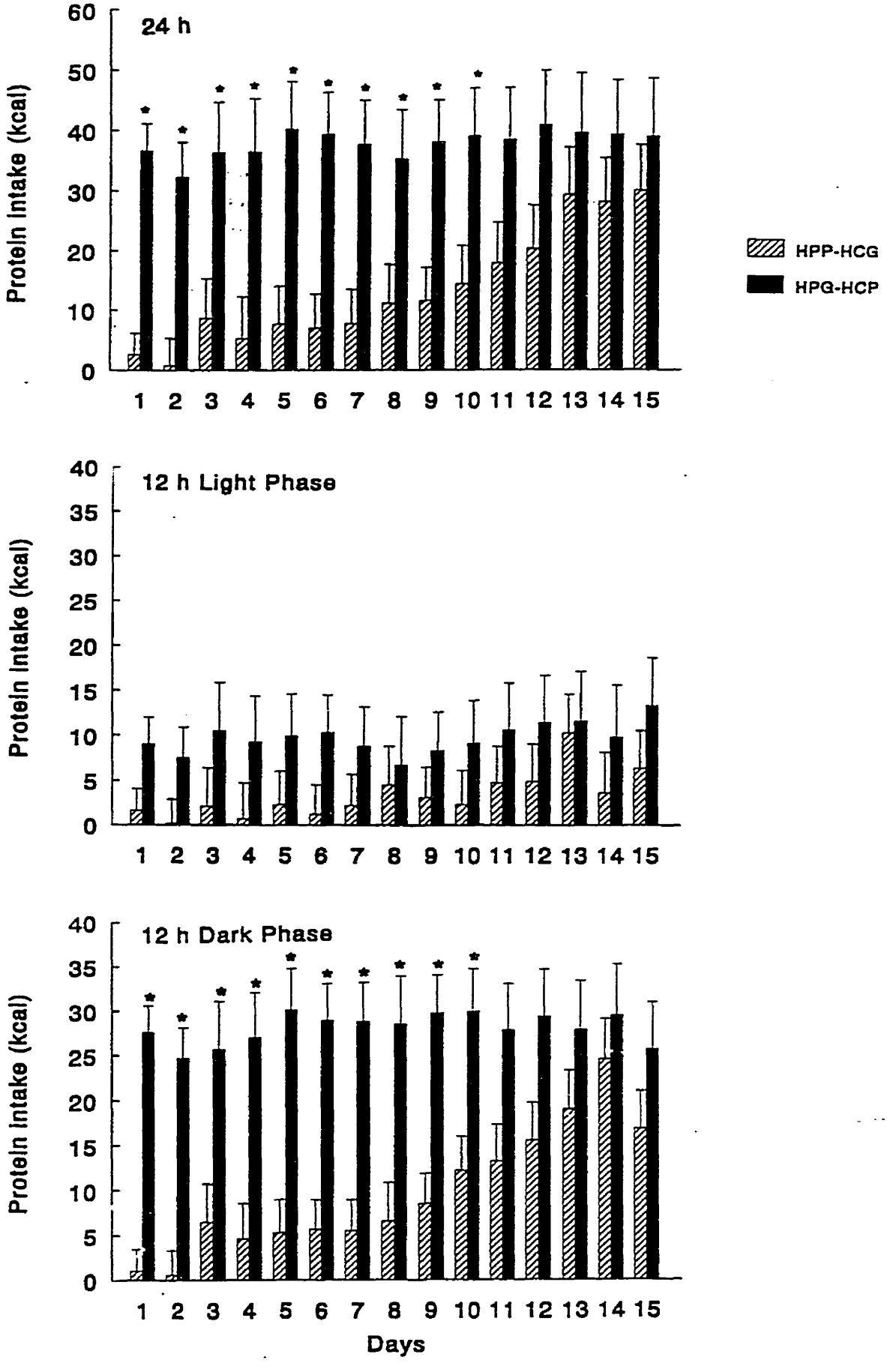

FIG. 2. Least Square (LS) Mean (±SEM) daily energy intakes from protein in groups of rats fed a choice between high-protein powder high-carbohydrate granular (HPP-HCG) diets or high-protein granular high-carbohydrate powder (HPG-HCP) diets over 24 h and during the 12 h light and dark phases. * Within day comparisons of individual LS means are significantly different at $p<0.05$ with Tukey's Test.

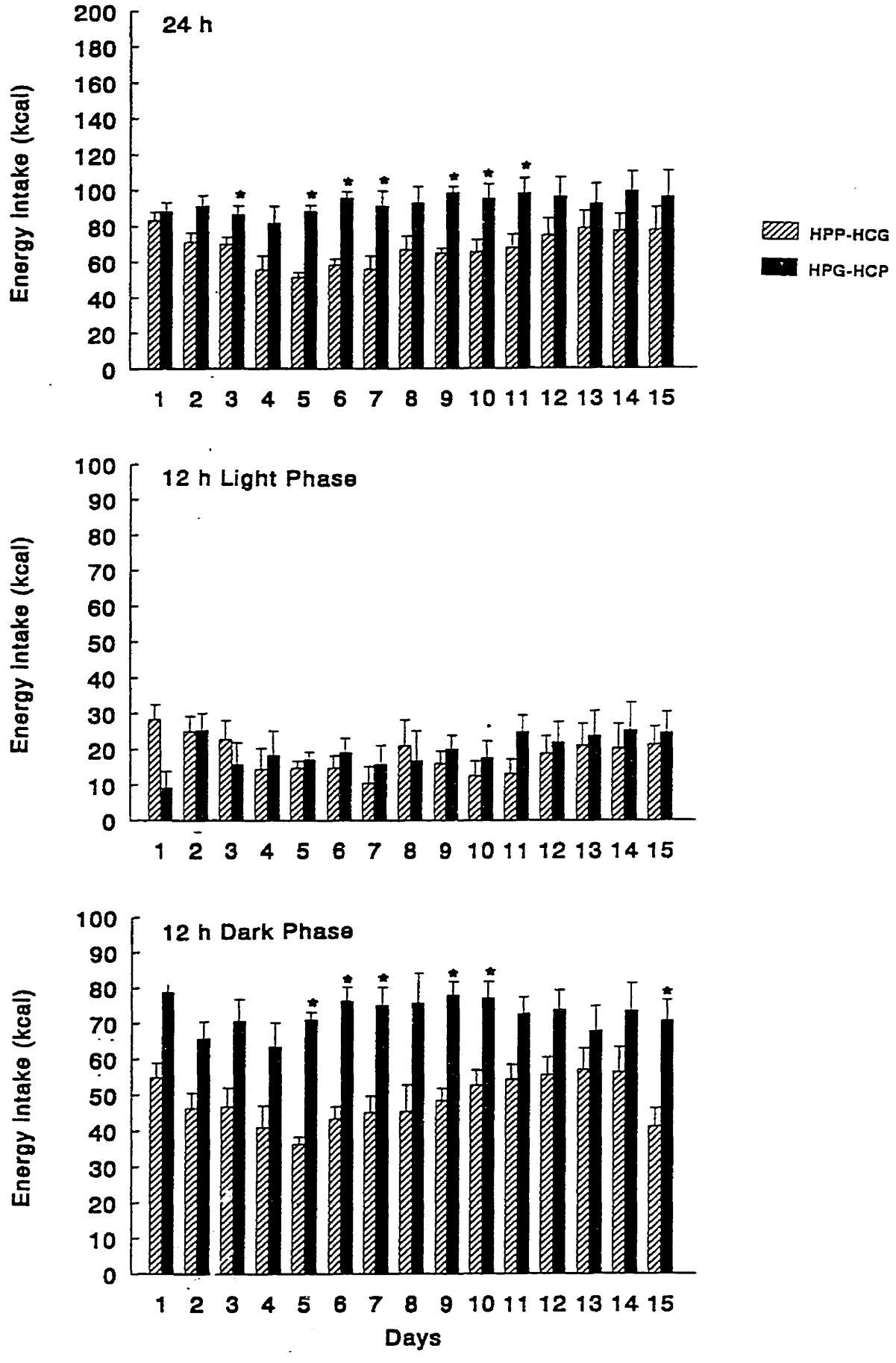

FIG. 3. Least Square (LS) Mean (±SEM) daily energy intakes in groups of rats fed a choice between high-protein powder high-carbohydrate granular (HPP-HCG) diets or high-protein granular high-carbohydrate powder (HPG-HCP) diets over 24 h and during the 12 h light and dark phases. * Within day comparisons of individual LS means are significantly different at $p<0.05$ with Tukey's Test.

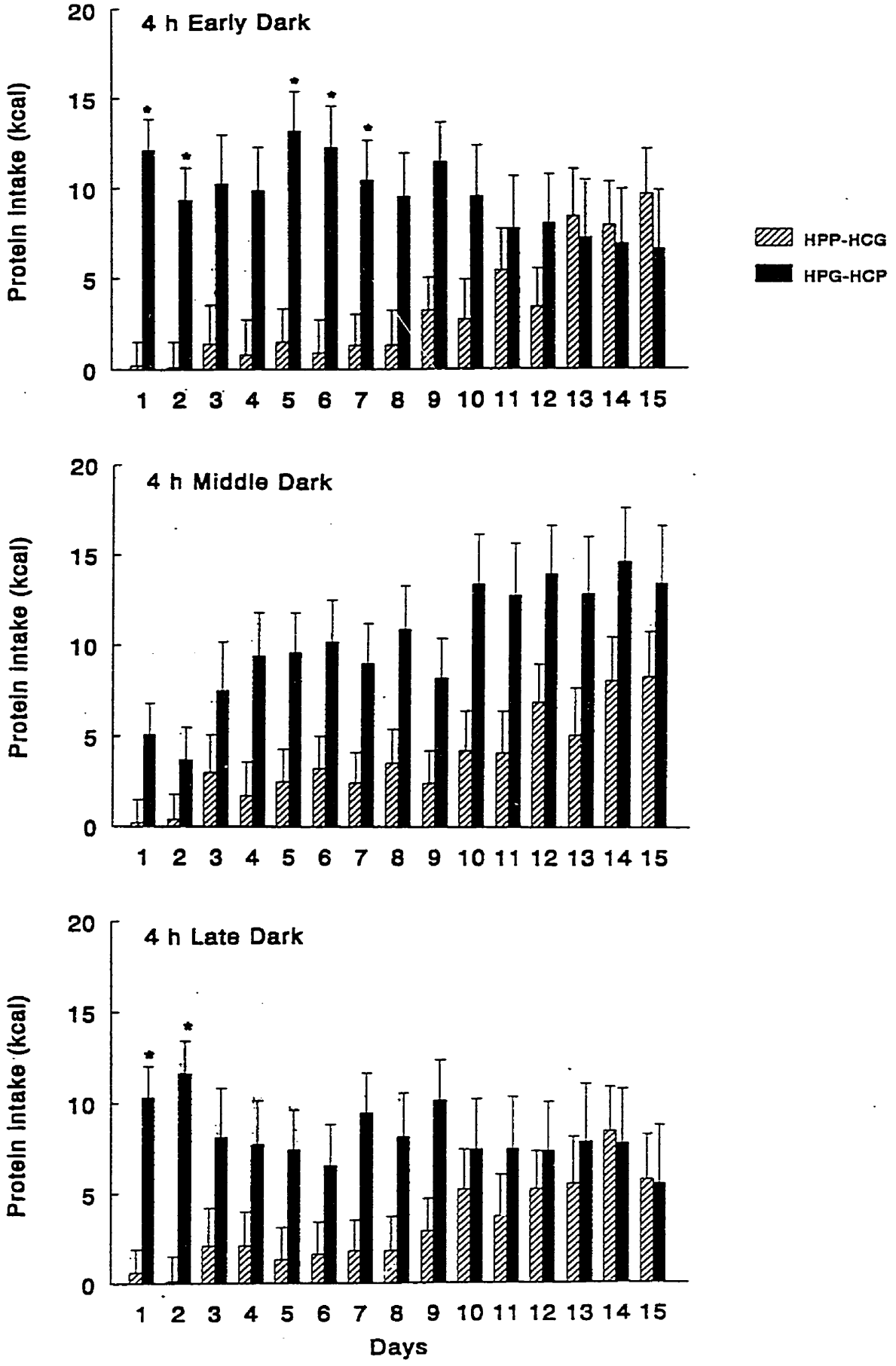

FIG. 4. Least Square (LS) Mean (±SEM) daily energy intakes from protein in groups of rats fed a choice between high-protein powder high-carbohydrate granular (HPP-HCG) diets or high-protein granular high-carbohydrate powder (HPG-HCP) diets during the 4 h early, middle and late dark phases. * Within day comparisons of individual LS means are significantly different at $p<0.05$ with Tukey's Test.

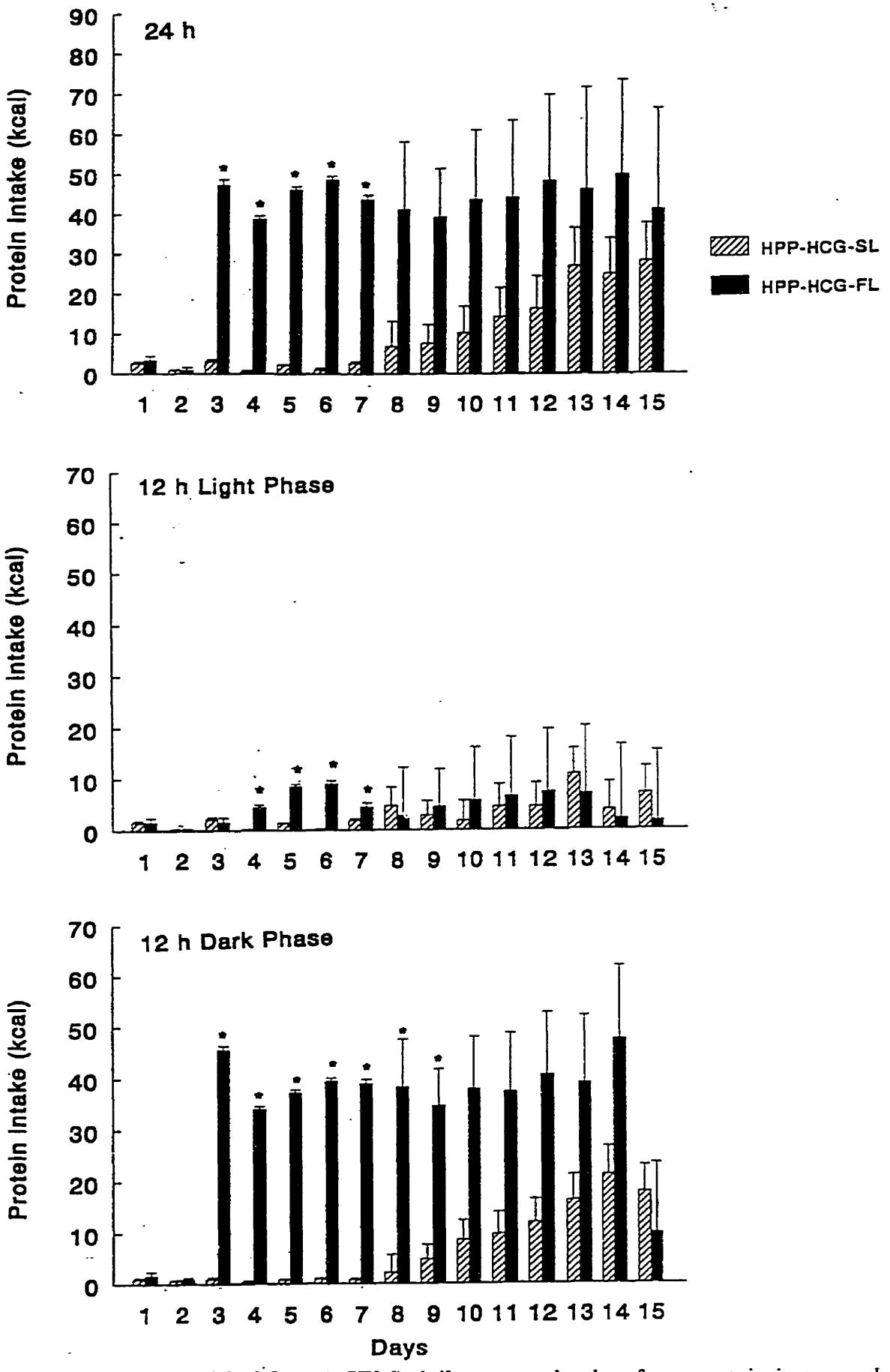

FIG. 5. Least Square (LS) Mean (±SEM) daily energy intakes from protein in two subgroups [high-protein powder high-carbohydrate granular-slow learners (HPP-HCG-SL) and high-protein powder high-carbohydrate granular-fast learners (HPP-HCG-FL)] of rats fed a choice between high-protein powder high-carbohydrate granular (HPP-HCG) diets over 24 h and during the 12 h light and dark phases. * Within day comparisons of individual LS means are significantly different at $p<0.05$ with Tukey's Test

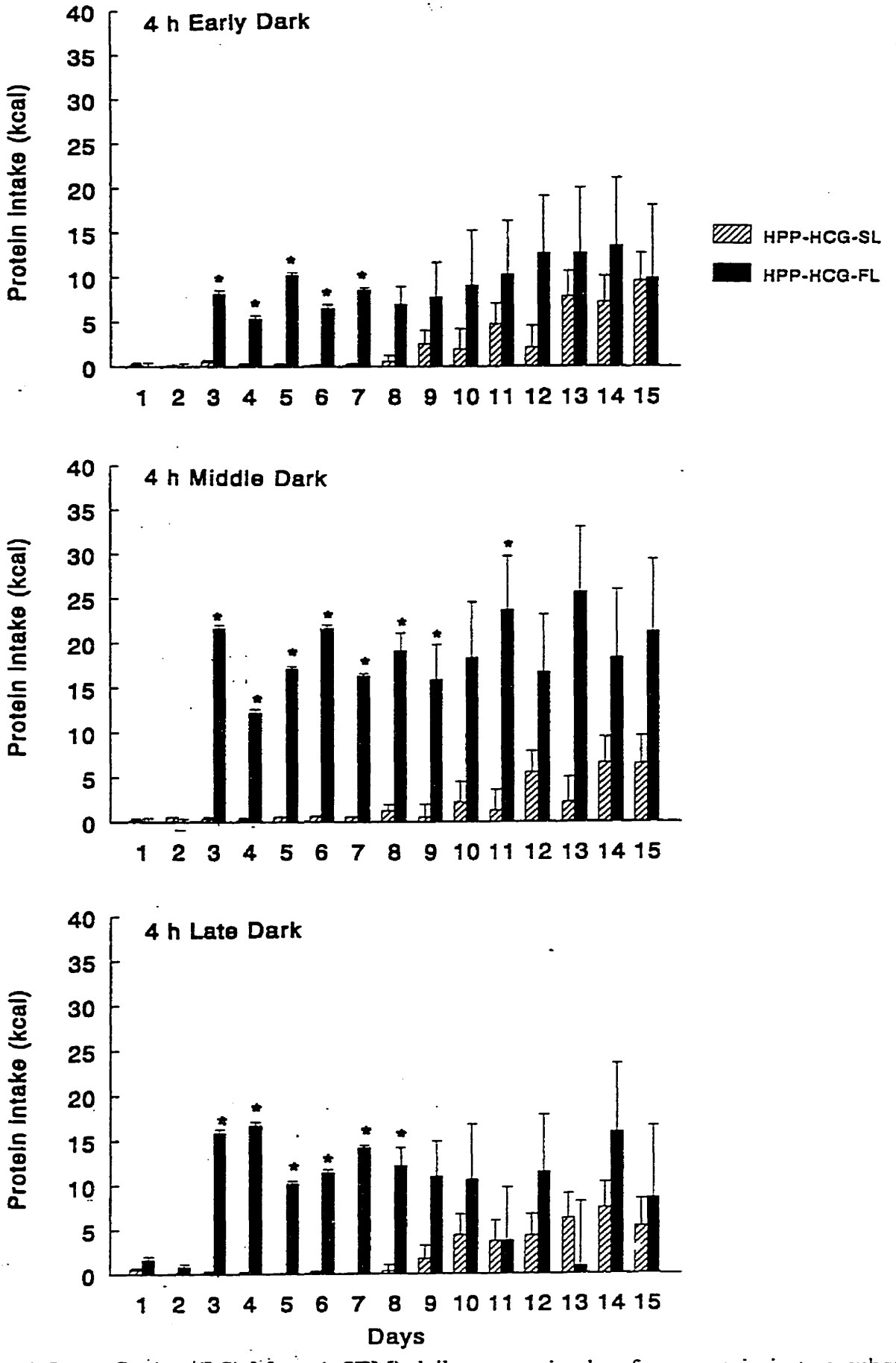

FIG. 6. Least Square (LS) Mean (±SEM) daily energy intakes from protein in two subgroups [high-protein powder high-carbohydrate granular-slow learners (HPP-HCG-SL) and high-protein powder high-carbohydrate granular-fast learners (HPP-HCG-FL)] of rats fed a choice between high-protein powder high-carbohydrate granular (HPP-HCG) diets during the 4 h early, middle and late dark phases. * Within day comparisons of individual LS means are significantly different at $p<0.05$ with Tukey's Test

DISCUSSION

Protein- and carbohydrate-rich diets presented in different textural forms (powder and granular) altered the circadian rhythmicity of protein-rich diet ingestion and total energy intake. However, carbohydrate-rich diet ingestion was not altered. The protein and energy intakes for the high-protein granular and high-carbohydrate powder dietary group were significantly higher than those of the high-protein powder and high-carbohydrate granular dietary group during the 4 h early and late dark phases, 12 h dark phase and over 24 h. These results therefore demonstrate the potential for diet texture to influence macronutrient selection patterns in rats.

The higher protein intake of rats fed a protein-rich diet in granular form versus powder form has been demonstrated in previous studies in which three groups of rats were given a choice between protein-rich and carbohydrate-rich diets in different textural forms (powder, gel or granular) (Bise et al. 1983; McArthur and Blundell, 1986). However, the two-way choice that was offered within a particular dietary group consisted of a protein-rich and a carbohydrate-rich diet of the same texture.

The low level of protein intake of rats fed a protein-rich diet in powder form observed in the present study also concurs with the findings that consumption of powders tends to be lower than other forms of food, such as granules, pellets and liquids (Blundell, 1983; Naim et al.1986; Sclafani, 1987b; Sclafani and Xenakis, 1984). This may be due to the difficulty of making appropriate motor movements and the problems of ingesting a very dry material, or the difficulty that rats have in eating finely powdered casein (Bise et al. 1983). In rats, powders appear to be least preferred and may be regarded as slightly aversive. On the other hand, granules are more readily accepted due to the rat's natural tendency to grasp food materials with its forepaws and to nibble.

In contrast to the present study, these previous studies (Bise et al. 1983; McArthur and Blundell, 1986) reported no effect of diet texture on mean daily energy intake. The discrepancy in results may have been due to the dietary choice offered to the experimental groups. In the present study each group received a two-way choice between a protein-rich and a carbohydrate-rich diet of different textures (powder vs.

granular). Diet texture only differed among the dietary groups; that is the diet texture of the protein- and carbohydrate-rich diets was the same within a particular dietary group. Another difference is that the carbohydrate-rich diet employed in previous experiments consisted predominantly of cornstarch. In the present experiment however, the combination of dextrin and sucrose were used as the carbohydrate source.

Casein was used as the protein source in the present experiment and those experiments previously mentioned (Bise et al. 1983; McArthur and Blundell, 1986), thus the reduced protein intake may have been due to the aversion that some rats demonstrate for powdered casein (Kon, 1931; Scott, 1946; Pilgrim and Patton, 1947). Also rats on a dietary self-selection regimen are more likely to develop conditioned aversions to the protein source than the carbohydrate source (Bernstein et al. 1984). It has been demonstrated that when casein is the protein source, self-selecting growing rats do not regulate protein intake at a constant proportion of total calories (Peters and Harper, 1984). According to Scott (1946), "rats either do or do not like casein; if they like it they eat an average of 3 g per day and grow well; if they do not, they eat less than 0.1 g per day, lose weight and die within a short period (3 weeks)." Similar findings were observed in the present study, among the slow learners who consumed less than 1 g per day of the protein-rich diet from days 1-7 of the experimental period and became protein-depleted. It was only after 10 days of exposure to diets that symptoms of deficiency, such as body weight loss of up to 15.4% reinforced the choice of the protein-rich diet in powder form.

The present results show that adaptation to a protein-rich but not a carbohydrate-rich diet is influenced by its texture, in the absence of different odour and taste cues since the smell and taste of the diets were masked with an artificial flavouring agent. It has been demonstrated that textural differences provide the learned cues that are required to control protein intake (Booth, 1987). According to Larue and LeMagnen (1971) sensory stimuli provided by various proteins can be olfactory, but in the absence of olfactory cues (as in the present experiment) texture is the most plausible sensory characteristic in which protein might be distinctive. In the present experiment, energy intakes from protein in the high-protein powder and high-

carbohydrate granular dietary group were significantly lower than the high-protein granular and high-carbohydrate powder dietary group from days 1-10 of the experimental period. Furthermore, rats that ate inadequate amounts of protein lost weight and reduced total energy intake. This finding is similar to that of Leathwood and Ashley (1983), who followed the development of protein selection in adult male Sprague-Dawley rats. In this experiment rats were offered a choice between 0% and 40% granulated casein diets. Rats initially selected the 0% casein diet and lost weight and reduced total food intake, which may have been due to the initial selection being based on palatability (taste, smell and texture) rather than long term protein needs. Within approximately 10 days, the percentage of total energy ingested as protein rose to a steady mean of 30%.

An important difference between the study by Leathwood and Ashley (1983) and the present experiment was a reduced protein intake only observed in rats receiving a choice between a protein-rich powder and a carbohydrate-rich granular diet. This was not observed in rats receiving protein-rich granular and carbohydrate-rich powder diets. There are several possible explanations for the reduced protein intake: First, the carbohydrate-rich granular diet was preferred for its texture or ease of consumption over the protein-rich diet presented in powder form, thereby compromising protein intake to maintain intake of a food preferred for its sensory characteristics (Blundell, 1983); that is intake of the preferred carbohydrate-rich granular diet. Second, adaptability represents the capacity to use informational cues to make appropriate behavioral actions. If rats are unprepared or contraprepared to consume a particular form of food such as powder, this may interfere with the development of associations between nutrient content and sensory characteristics. Thus it may be presumed that rats are not naturally prepared to form associations between all possible combinations of nutrient density and the taste or texture (in the present experiment) of a diet (Blundell, 1983); that is they are unable to learn about the metabolic properties of the foods from which they are choosing (Ashley, 1985).

Another possible explanation for the reduced powder protein intake may have been that rats were selecting from the macronutrient of which they had been pre-

exposed (Reed et al, 1992). In the present study, rats had been pre-exposed to a chow diet which is rich in carbohydrate. Therefore, rats previously adapted to a pelleted chow diet and subsequently given a choice between protein-rich powder and carbohydrate-rich granular diets selected more from the carbohydrate-rich granular diet. Also, the granular diet resembles more the familiar pellets than powder does. The pre-exposure to a chow diet which is rich in carbohydrate could explain the finding that carbohydrate intake did not differ between powder and granular textures. This might suggest that rats can use either a powder or a granular texture as a cue for the presence of carbohydrate or that carbohydrate appetite may be learned. In contrast, this finding might also suggest that in the regulation of carbohydrate intake the stimuli provided by carbohydrate are not textural. It is possible that the artificial flavour added to the diets did not completely mask the taste of sugars, thus providing rats a gustatory cue for carbohydrate. The speed with which the intake of the carbohydrate-rich diet was stabilized rules out learning through beneficial after effects of digestion and absorption of nutrients during the experimental period. The immediate response for carbohydrate might suggest that carbohydrate appetite may be unlearned. For protein appetite however, choice is made on the basis of exteroceptive sensory cues; that is textural in this case.

It is generally believed that organisms can learn to make beneficial selection among macronutrient-rich diets. There is evidence that appetite for the sensory properties of a protein-containing food can be learned (Baker et al. 1987). It has been demonstrated that protein-deprived rats develop a preference for a flavour associated with administration of a balanced amino acid mixture (Booth and Simson, 1971). Similarly, protein-deprived rats can use odour cues in making their selection of certain proteins (Heinrichs et al. 1990). However, taste and olfaction arise from sensory characteristics of the diet whereas somatosensory input is generated by the process of feeding itself (grasping, chewing, swallowing) and could therefore mediate the association of a given feeding pattern (meal size, meal frequency) with its metabolic consequences (Miller and Teates, 1984; 1986). It was reported by Miller and Teates (1984; 1985) that quantitative protein and carbohydrate selection requires an

associative learning process in which somatosensory inputs from feeding activities and/or from the food's sensory properties link dietary choice behavior to later metabolic consequences. Previous findings and the present results demonstrate that protein intake can be learned. In the present study, the exposure to the unfamiliar protein-rich powdered diet induced protein deficiency (depletion) in 7 out of 12 rats (the slow learners) and the preference of that protein-rich diet was learned. The slow learners required 10 days of adaptation to the protein-rich powder diet. All rats demonstrated an immediate response for protein in granular form. Thus adaptation to a protein-rich diet was necessary for the powdered but not for the granulated texture.

There was an immediate response for carbohydrate, either powder or granular, and thus no adaptation was necessary for carbohydrate intake. Theall et al. (1984) reported an intrinsic requirement for dietary carbohydrate. Furthermore, carbohydrate consumption may depend primarily on its relative palatability, for example, innate preference for sweet taste (Steiner, 1974). In the present study, consumption of adequate levels of a carbohydrate-rich diet (either powder or granular) manifested itself from the first day which was similar to a protein-rich granular diet.

In the present study, as in the study of Leathwood and Ashley (1983), protein intake resumed within 10 days, thus the need for energy caused the slow learners to eat a non-preferred food (Schutz and Pilgrim, 1954), such as powder casein. Furthermore, rats acquire an appetite for protein when they are protein-depleted (Baker et al. 1987). In addition, animals will depress their intake of diets containing highly inadequate or excessive amounts of protein (Semon et al. 1987). Despite the initially low consumption of a protein-rich powder diet, rats gradually become adapted to such a diet and ultimately consume adequate levels of a protein-rich diet in powder form. Thus sensory preferences must be learned in such a way that they increase while the relevant deficit is being signalled (Booth et al. 1993). Peters and Harper (1984) explained this shift in preference from the protein-free diet to the high protein diet as the result of two factors: "the development of an aversion to the protein-free diet and an adaptive increase in the animal's capacity to degrade surplus amino acids, which would enable it to consume more of the high protein diet."

An interesting finding of the present experiment was that Wistar rats can be differentiated into two subpopulations according to their different adaptation abilities to a powdered high-protein diet: slow learners and fast learners. The importance of individual differences of natural feeding patterns was also demonstrated in Sprague-Dawley rats (Shor-Posner et al. 1991) which were categorized into three subpopulations according to their 24 h and 12 h nocturnal pattern of nutrient intake as carbohydrate-, protein- and fat-preferrers. In the present experiment, a greater circadian discrepancy was observed between the slow learners and the fast learners in comparison to the two dietary groups (high-protein powder and high-carbohydrate granular and high-protein granular and high-carbohydrate powder); that is the fast learners consumed significantly more protein than did the slow learners during both the light and dark phases, however it was only during the active dark phase that the two dietary groups differed in their protein intake. Protein intake was not significantly different between the two dietary groups during the 12 h light phase. Similarly, during the early, middle and late dark phases fast learners consumed significantly more protein than did the slow learners, whereas it was only during the early and late portions of the dark phase that the two dietary groups differed in their protein intake. Thus, the different adaptation abilities and food intake patterns in these rats, that is slow and fast learners who were of the same age and strain, may have been determined genetically. A role for hereditary factors in nutrient choice was supported by Scott (1946) who found that littermates displayed remarkably similar patterns of diet selection.

The present findings concur with the findings of Pilgrim and Patton (1947) who demonstrated the wide variability in dietary choice among animals of similar genetic and physiological background and tested under the same conditions. In the study by Pilgrim and Patton (1947) male weanling Sprague-Dawley rats were offered a four-way choice consisting of casein, salts, sucrose and hydrogenated vegetable oil. Approximately 1/3 of the animals grew at subnormal rates; that is they gained less than 2.8 g per day due to inadequate casein consumption; that is they consumed less than 1.45 g per day of casein. In the present experiment 7 out of 12 rats in the high-

protein powder and high-carbohydrate granular dietary group lost weight up to day-10 and subsequently gained weight from days 11-15. These rats were identified as the slow learners. The remaining 5 rats in this dietary group were categorized as the fast learners. Within 2-3 days, the fast learners consumed similar amounts of protein and energy intakes as did the high-protein granular high-carbohydrate-powder dietary group and were also similar in terms of their daily body weights by day-4. Thus, intakes for dietary components are not always determined by nutritional or physiological requirements.

The appetite for protein was not related to physiological need; since not all rats ate powdered casein. Similarly, Scott (1946) reported that both male and female albino rats of mixed strain (21-25 days old) adapted for 3 weeks to a four-way choice (sucrose, casein, hydrogenated vegetable fat and mineral salts) could be separated into two subgroups according to their intake of casein. Thirty-four of the 87 rats consumed an average of 1.3 g casein, failed to grow and lost an average of 21 g in body weight over the three weeks. The second group consisted of the 53 remaining rats. This group ate adequate amounts of protein, that is an average of 60.1 g over the 3-week experimental period and grew well. More recently, Leathwood and Ashley (1983) also demonstrated the necessity for determining the patterns of protein selection by the individuals of a given group of rats. In the experiment there was a considerable inter-individual variation; some animals chose stable protein almost immediately, while others persisted in eating only the 0% casein diet for up to 9-10 days, followed by an abrupt change to an adequate choice of energy selected as protein. Animals who persisted in eating the 0% casein diet lost weight and ate less food. When they began to eat protein, there was an immediate transfer to a stable choice pattern of energy selected as protein, an increase in food intake and a resumption of growth. A similar trend was observed among the slow learners in the present experiment. By day-11, daily intake of the protein-rich powder diet reached a mean of 3.5 g and subsequently increased throughout the remaining experimental days. An increase in body weight was also observed among the slow learners thereafter. The present and previous findings have implications for dietary self-selection studies and demonstrate the

importance of determining the patterns of choice of dietary components by the individuals of any given group of rats before the effect of a variable can be properly evaluated.

In the present study rats from both dietary groups consumed more meals during the dark versus the light phase. Similarly, it has been demonstrated that female Sprague-Dawley rats adapted to a choice among carbohydrate-rich, protein-rich and fat-rich diets consumed 70% of meals during the dark cycle versus only 30% during the light cycle (Miller et al. 1994). The rat's more frequent meals by night than by day were explained by Booth (1993) as the resulting ultradian and circadian rhythms in upper intestinal stimulation and absorption.

Although carbohydrate intake was not altered by presenting the macronutrient-rich diets in different textural forms, the average meal size and its carbohydrate composition taken over 24 h was affected by texture. It seems that the group receiving the high-protein powder and high-carbohydrate granular diets compensated for the reduced protein intake and energy intake by increasing the average meal size and this increase was due to an increase in the average carbohydrate composition of a meal. Perhaps the carbohydrate-rich diet in granular form was preferred for its sensory characteristics. It is fairly certain that palatability, a hedonic response which partly depends on diet sensory characteristics, will affect feeding mainly during direct contact with food (Rogers and Blundell, 1984), thus meal size should increase when a highly palatable food, such as a carbohydrate-rich granular diet is given.

Previous adaptation to a carbohydrate-rich or a protein-rich diet presented in different textural forms did not significantly influence plasma glucose and insulin concentrations immediately before the active dark phase. The lack of a statistically significant difference may have been due to the large inter-individual variability within a dietary group. Also blood sampling was performed on day-16; the day after the last experimental day. However, during the last 5 days of the experimental period, all rats had adapted to the protein-rich diet, thus both dietary groups demonstrated similar patterns of macronutrient and energy intake.

The findings suggest that macronutrient intake is controlled by sensory

differences of the diet and not by nutrient content. The relative intake of the carbohydrate-rich and protein-rich diets depends on the physical form of the diet. This shows that when powdered macronutrient-rich diets are used (as in most food selection studies) macronutrient-specific regulation may not exist. Protein appetite was induced from the first exposure with granular texture but after 10 days with powder texture. On the other hand, carbohydrate appetite manifested itself from the first day with either granular or powder texture. Furthermore, behavior from first exposure predicted the outcome; that is stable protein intake with granular protein-rich diet. Thus, the design of the individual variables, that is diet composition and sensory characteristics is crucial for macronutrient selection and indeed caloric control of intake.

It has been demonstrated that the monoamine neurotransmitters are involved in the brainstem sensorimotor reflexes of eating, for example serotonin plays a role in both reflex and automatic swallowing (Hashim and Beiger, 1987) and has been shown to inhibit mastication at the moment of swallowing (Chandler et al. 1985). Appetite suppressant drugs will affect the oral processing of food and textural preferences independently of nutritional effects (Baker and Booth, 1990), and therefore should be tested with diets having different sensory characteristics. Furthermore, these results have a direct impact on nutritional studies using diets of different textures. For example studies in which various groups of animals are offered diets of different composition. These diets will also differ in terms of their texture. In studies using fat-rich diets, texture is affected by the fat content of a diet. Therefore, diets containing different levels of dietary fat will alter the diet's texture and thus subsequent feeding patterns.

Chapter 4

GENERAL CONCLUSIONS

In summary, protein- and carbohydrate-rich diets simultaneously presented in different textural forms (powder and granular) altered the circadian rhythmicity of protein-rich diet ingestion and total energy intake. However, carbohydrate-rich diet ingestion was not altered. The protein and energy intakes for the high-protein granular and high-carbohydrate powder dietary group were significantly higher than those of the high-protein powder and high-carbohydrate granular dietary group during the 4 h early and late dark phases, 12 h dark phase and over 24 h. These results therefore demonstrate the potential for diet texture to influence macronutrient selection patterns in rats.

The present study demonstrated that adaptation to a protein-rich but not a carbohydrate-rich diet is influenced by its texture, in the absence of different odour and taste cues. Energy intakes from protein in the high-protein powder and high-carbohydrate granular dietary group were significantly lower than the high-protein granular and high-carbohydrate powder dietary group from days 1-10 of the experimental period. The exposure to the unfamiliar protein-rich powdered diet induced protein deficiency in 7 out of 12 rats (the slow learners) and the preference of that protein-rich diet was learned. The slow learners required 10 days of adaptation to the protein-rich powder diet. However, all rats demonstrated an immediate response for protein in granular form. Thus adaptation to a protein-rich diet was necessary for the powdered but not for the granulated texture. This demonstrates that protein appetite can be learned and choice is made on the basis of exteroceptive sensory cues; that is textural in this case. Consumption of adequate levels of a carbohydrate-rich diet, either powder or granular, manifested itself from the first day and thus no adaptation was necessary for carbohydrate intake. Therefore, carbohydrate appetite may be unlearned.

A novel finding of the present study was that Wistar rats can be differentiated into two subpopulations according to their different adaptation abilities to ingest powdered protein-rich diet: slow learners and fast learners. In addition, a greater circadian discrepancy was observed between the slow learners and the fast learners in

comparison to the two dietary groups. Specifically, the fast learners consumed significantly more protein than did the slow learners during both the light and dark phases, however it was only during the active dark phase that the two dietary groups differed in their protein intake. Similarly, during the early, middle and late dark phases fast learners consumed significantly more protein than did the slow learners, whereas it was only during the early and late portions of the dark phase that the two dietary groups differed in their protein intake. The findings demonstrate the importance of determining the patterns of choice of dietary components by the individuals of any given group of rats before the effect of a variable can be properly evaluated.

In conclusion, the results suggest that macronutrient intake is controlled by sensory differences of the diet and not by nutrient content. The relative intake of the carbohydrate-rich and protein-rich diets depends on the physical form of the diet. Thus animals may select foods according to the texture of the diet, regardless of the nutrient content. This shows that when powdered macronutrient-rich diets are used (as in most food selection studies) macronutrient-specific regulation may not exist. Protein appetite was induced from the first exposure with granular texture but after 10 days with powder texture. On the other hand, carbohydrate appetite manifested itself from the first day with either granular or powder texture. Furthermore, behavior from first exposure predicted the outcome; that is stable protein intake with granular protein-rich diet. Thus, the design of the individual variables, that is diet composition and sensory characteristics is crucial for macronutrient selection and indeed caloric control of intake.

Table A 1.1 : Average intake of powder and granular protein-rich diets (least square means g±SEM) in rats fed a choice between a protein-rich and a carbohydrate-rich diet over 24 h.

	24h		texture df (1,11)	
day	powder (n=12)	granular (n=12)	F value	p
1	0.65 ± 0.87	8.98 ± 1.1 *	35.6	0.0001
2	0.2 ± 1.11	7.9 ± 1.41 *	18.45	0.0013
3	2.13 ± 1.62	8.9 ± 2.04 *	6.76	0.0247
4	1.29 ± 1.7	8.92 ± 2.15 *	7.75	0.0178
5	1.86 ± 1.55	9.84 ± 1.96 *	10.22	0.0085
6	1.71 ± 1.37	9.64 ± 1.73 *	12.93	0.0042
7	1.89 ± 1.41	9.24 ± 1.78 *	10.47	0.0079
8	2.74 ± 1.59	8.64 ± 2.01 *	5.31	0.0417
9	2.85 ± 1.36	9.34 ± 1.72 *	8.81	0.0128
10	3.55 ± 1.56	9.58 ± 1.97 *	5.74	0.0355
11	4.4 ± 1.67	9.44 ± 2.11	3.51	0.0877
12	4.99 ± 1.76	10 ± 2.23	3.11	0.1056
13	7.2 ± 1.92	9.68 ± 2.43	0.64	0.44
14	6.9 ± 1.76	9.64 ± 2.23	0.93	0.3552
15	7.35 ± 1.86	9.56 ± 2.35	0.54	0.4762

* Within day comparisons of individual means are significantly different at $p<0.05$.

Table A1.2 : Average intake of powder and granular protein-rich diets (least square means g±SEM) in rats fed a choice between a protein-rich and a carbohydrate-rich diet during the 12h dark and light phases of the diurnal cycle.

	12h dark		12h light		texture		phase		interaction	
					df (1,22)		df (1,22)		df (1,22)	
day	powder (n=12)	granular (n=12)	powder (n=12)	granular (n=12)	F value	p	F value	p	F value	p
1	0.25 ± 0.59 b	6.78 ± 0.75 a	0.4 ± 0.59 b	2.2 ± 0.75 b	38.37	0.0001	10.85	0.0033	12.37	0.0019
2	0.15 ± 0.67 b	6.06 ± 0.85 a	0.05 ± 0.67 b	1.84 ± 0.85 b	25.41	0.0001	8	0.0098	7.28	0.0132
3	1.6 ± 1.05 b	6.3 ± 1.33 a	0.53 ± 1.05 b	2.6 ± 1.33 ab	7.99	0.0098	4.04	0.057	1.24	0.2782
4	1.13 ± 0.99 b	6.64 ± 1.25 a	0.16 ± 0.99 b	2.28 ± 1.25 ab	11.48	0.0026	5.58	0.0274	2.28	0.146
5	1.3 ± 0.91 b	7.4 ± 1.16 a	0.56 ± 0.91 b	2.44 ± 1.16 b	14.65	0.0009	7.47	0.0121	4.1	0.0551
6	1.41 ± 0.82 b	7.1 ± 1.03 a	0.3 ± 0.82 b	2.54 ± 1.03 b	18.16	0.0003	9.3	0.0059	3.43	0.0773
7	1.35 ± 0.86 b	7.08 ± 1.09 a	0.54 ± 0.86 b	2.16 ± 1.09 b	14.05	0.0011	8.54	0.0079	4.39	0.048
8	1.63 ± 1.05 b	7 ± 1.33 a	1.11 ± 1.05 b	1.64 ± 1.33 b	6.1	0.0218	6.04	0.0224	4.11	0.0548
9	2.09 ± 0.83 b	7.3 ± 1.06 a	0.76 ± 0.83 b	2.04 ± 1.06 b	11.62	0.0025	11.97	0.0022	4.27	0.0507
10	2.99 ± 0.94 b	7.34 ± 1.18 a	0.56 ± 0.94 b	2.24 ± 1.18 b	8	0.0098	12.45	0.0019	1.57	0.2229
11	3.24 ± 1 ab	6.84 ± 1.27 a	1.16 ± 1 b	2.6 ± 1.27 ab	4.85	0.0384	7.62	0.0114	0.9	0.3544
12	3.8 ± 1.03 ab	7.2 ± 1.3 a	1.19 ± 1.03 b	2.8 ± 1.3 ab	4.55	0.0443	8.9	0.0068	0.58	0.455
13	4.68 ± 1.1	6.84 ± 1.3	2.53 ± 1.1	2.84 ± 1.3	1.05	0.3158	6.48	0.0184	0.59	0.4519
14	6.01 ± 1.12 *	7.22 ± 1.41	0.89 ± 1.12	2.42 ± 1.41	1.16	0.294	15.18	0.0008	0.02	0.8996
15	4.14 ± 1	6.28 ± 1.3	1.55 ± 1	3.28 ± 1.3	2.77	0.1104	5.76	0.0253	0.03	0.861

ab Within day comparisons of individual means.
Means with different letters are significantly different at $p<0.05$ with Tukey's Test.

* Within texture and day comparisons of individual means are significantly different at $p<0.05$ with Tukey's Test.

Table A1.3 : Average intake of powder and granular protein-rich diets (least square means g±SEM) in rats fed a choice between a protein-rich and a carbohydrate-rich diet during the 4 h early, middle and late dark phases of the diurnal cycle.

	early dark		middle dark		late dark		texture		phase		interaction	
							df (1,33)		df (2,33)		df (2,33)	
day	powder (n=12)	granular (n=12)	powder (n=12)	granular (n=12)	powder (n=12)	granular (n=12)	F value	p	F value	p	F value	p
1	0.05 ± 0.33	2.98 ± 0.41 *	0.05 ± 0.33	1.26 ± 0.41	0.15 ± 0.33	2.54 ± 0.41 *	51.63	0.0001	3.01	0.0628	2.81	0.0746
2	0.03 ± 0.34	2.28 ± 0.44 *	0.1 ± 0.34	0.92 ± 0.44	0.03 ± 0.34	2.86 ± 0.44 *	37.82	0.0001	2.96	0.0658	3.5	0.042
3	0.35 ± 0.53	2.5 ± 0.67	0.74 ± 0.53	1.84 ± 0.67	2.5 ± 0.53	1.98 ± 0.67	10.3	0.003	0.05	0.9528	0.39	0.6787
4	0.19 ± 0.48	2.42 ± 0.6	0.43 ± 0.48	2.32 ± 0.6	0.51 ± 0.48	1.9 ± 0.6	17.26	0.0002	0.05	0.9537	0.81	0.737
5	0.36 ± 0.44	3.22 ± 0.55 *	0.63 ± 0.44	2.36 ± 0.55	0.31 ± 0.44	1.82 ± 0.55	24.98	0.0001	1.07	0.3547	1.05	0.3606
6	0.23 ± 0.44	3 ± 0.56 *	0.79 ± 0.44	2.5 ± 0.56	0.4 ± 0.44	1.6 ± 0.56	21.11	0.0001	1.03	0.3676	1.26	0.296
7	0.31 ± 0.43	2.56 ± 0.54 *	0.6 ± 0.43	2.2 ± 0.54	0.44 ± 0.43	2.32 ± 0.54	23.1	0.0001	0.01	0.9929	0.22	0.8018
8	0.33 ± 0.47	2.34 ± 0.59	0.85 ± 0.47	2.68 ± 0.59	0.45 ± 0.47	1.98 ± 0.59	17.12	0.0002	0.6	0.5566	0.11	0.8993
9	0.78 ± 0.43	2.8 ± 0.55	0.6 ± 0.43	2.02 ± 0.55	0.71 ± 0.43	2.48 ± 0.55	18.63	0.0001	0.48	0.6259	0.19	0.8282
10	0.68 ± 0.55	2.34 ± 0.69	1.04 ± 0.55	3.3 ± 0.69	1.28 ± 0.55	1.82 ± 0.69	8.53	0.0062	0.7	0.502	0.97	0.3885
11	1.33 ± 0.56	1.88 ± 0.71	1 ± 0.56	3.14 ± 0.71	0.91 ± 0.56	1.82 ± 0.71	5.27	0.0282	0.63	0.5415	0.84	0.4392
12	0.84 ± 0.52	1.96 ± 0.66	1.69 ± 0.52	3.44 ± 0.66	1.28 ± 0.52	1.8 ± 0.66	5.49	0.0253	2.31	0.1155	0.54	0.5898
13	2.08 ± 0.63	1.76 ± 0.8	1.25 ± 0.63	3.16 ± 0.8	1.35 ± 0.63	1.92 ± 0.8	1.51	0.228	0.31	0.7329	1.21	0.3106
14	1.95 ± 0.58	1.7 ± 0.74	1.99 ± 0.58	3.62 ± 0.74	2.08 ± 0.58	1.9 ± 0.74	0.55	0.4623	1.25	0.2991	1.29	0.288
15	2.35 ± 0.62	1.62 ± 0.78	2.04 ± 0.62	3.32 ± 0.78	1.41 ± 0.62	1.34 ± 0.78	0.08	0.7829	1.71	0.1971	1.06	0.3587

* Within phase and day comparisons of individual means are significantly different at $p<0.05$ with Tukey's Test.

Table A2.1 : Average intake of powder and granular carbohydrate-rich diets (least square means g±SEM) in rats fed a choice between a protein-rich and a carbohydrate-rich diet over 24 h.

	24h		texture df (1,12)	
day	powder (n=12)	granular (n=12)	F value	p
1	12.21 ± 1.93	19.17 ± 2.23 *	5.57	0.0361
2	12.53 ± 1.98	16.48 ± 2.29	1.71	0.2156
3	12.15 ± 1.46	15.17 ± 1.69	1.83	0.2012
4	11.14 ± 1.13	12.35 ± 1.3	0.49	0.4958
5	11.93 ± 1.27	10.7 ± 1.46	0.4	0.5391
6	12.85 ± 1.31	12.03 ± 1.51	0.17	0.6894
7	11.83 ± 1.3	11.62 ± 1.5	0.01	0.9181
8	12.19 ± 1.26	11.88 ± 1.45	0.03	0.8769
9	12.28 ± 1.42	11.93 ± 1.64	0.02	0.8778
10	12.88 ± 1.18	11 ± 1.36	1.09	0.3172
11	14.04 ± 1.34	11.4 ± 1.55	1.66	0.2217
12	12.89 ± 1.28	11.97 ± 1.47	0.22	0.645
13	12.09 ± 1.14	12.98 ± 1.31	0.27	0.6154
14	12.94 ± 1.21	12.7 ± 1.39	0.02	0.8996
15	12.44 ± 1.11	12.73 ± 1.29	0.03	0.8649

* Within day comparisons of individual means are significantly different at $p<0.05$.

Table A2.2 : Average intake of powder and granular carbohydrate-rich diet (least square means g±SEM) in rats fed a choice between a protein-rich and a carbohydrate-rich diet during the 12h dark and light phases of the diurnal cycle.

	12h dark		12h light		texture df (1,24)		phase df (1,24)		interaction df (1,24)	
day	powder (n=12)	granular (n=12)	powder (n=12)	granular (n=12)	F value	p	F value	p	F value	p
1	10.84 ± 1.19 ac	12.87 ± 1.37 a	1.38 ± 1.19 b	6.3 ± 1.37 bc	7.32	0.0124	38.88	0.0001	1.27	0.2711
2	8.96 ± 1.08 *	10.43 ± 1.25	3.56 ± 1.08	6.05 ± 1.25	2.86	0.1039	17.46	0.0003	0.19	0.668
3	9.49 ± 0.88 *	10.47 ± 1.02 *	2.66 ± 0.88	4.7 ± 1.02	2.49	0.1274	43.45	0.0001	0.31	0.5847
4	8.78 ± 0.79 *	9.5 ± 0.91 *	2.36 ± 0.79	2.85 ± 0.91	0.51	0.4385	58.8	0.0001	0.02	0.8903
5	8.83 ± 0.76 *	8.08 ± 0.88 *	3.1 ± 0.76	2.62 ± 0.88	0.56	0.4635	46.34	0.0001	0.02	0.8765
6	10.96 ± 0.82 *	9.47 ± 0.95 *	1.89 ± 0.82	2.57 ± 0.95	0.21	0.6495	81.04	0.0001	1.5	0.2322
7	10.58 ± 0.88 *	9.82 ± 1.02 *	1.25 ± 0.88	1.8 ± 1.02	0.01	0.9137	83.21	0.0001	0.47	0.4979
8	9.81 ± 0.94 *	9.45 ± 1.08 *	2.38 ± 0.94	2.43 ± 1.08	0.02	0.8819	50.94	0.0001	0.04	0.8371
9	10.29 ± 0.86 *	8.98 ± 0.99 *	1.99 ± 0.86	2.95 ± 0.99	0.03	0.8556	59.56	0.0001	1.49	0.2342
10	10.9 ± 0.85 *	8.67 ± 0.98 *	1.98 ± 0.85	2.33 ± 0.98	1.05	0.3154	69.63	0.0001	2.01	0.1692
11	10.23 ± 0.85 *	8.85 ± 0.98 *	3.81 ± 0.85	2.55 ± 0.98	2.07	0.1632	48.06	0.0001	0	0.9516
12	10.2 ± 0.78 *	8.97 ± 0.9 *	2.69 ± 0.78	3 ± 0.9	0.3	0.5909	63.61	0.0001	0.84	0.3695
13	9.4 ± 0.83 *	9.63 ± 0.96 *	2.69 ± 0.83	3.35 ± 0.96	0.25	0.6225	52.36	0.0001	0.06	0.8132
14	10.05 ± 0.85 *	8.88 ± 0.98 *	2.89 ± 0.85	3.82 ± 0.98	0.02	0.8984	44.14	0.0001	1.3	0.2661
15	7.96 ± 0.87 *	7.73 ± 1.01 *	2.39 ± 0.87	3.55 ± 1.01	0.25	0.625	26.79	0.0001	0.54	0.4675

abc Within day comparisons of individual means.
Means with different letters are significantly different at $p<0.05$ with Tukey's Test.

* Within texture and day comparisons of individual means are significantly different at $p<0.05$ with Tukey's Test.

Table A2.3: Average intake of powder and granular carbohydrate-rich diets (least square means g±SEM) in rats fed a choice between a protein-rich and a carbohydrate-rich diet during the 4 h early, middle and late dark phases of the diurnal cycle.

	early dark		middle dark		late dark		texture		phase		interaction	
							df (1,36)		df (2,36)		df (2,36)	
day	powder (n=12)	granular (n=12)	powder (n=12)	granular (n=12)	powder (n=12)	granular (n=12)	F value	p	F value	p	F value	p
1	3.71 ± 0.81	4.58 ± 0.93	3.19 ± 0.81	3.93 ± 0.93	3.94 ± 0.81	4.35 ± 0.93	0.9	0.3482	0.3	0.742	0.04	0.9638
2	4.19 ± 0.6	4.48 ± 0.7	3.04 ± 0.6	3.23 ± 0.7	1.74 ± 0.6	2.72 ± 0.7	0.85	0.3629	5.27	0.0098	0.21	0.8083
3	4.25 ± 0.48	4.17 ± 0.56	2.63 ± 0.48	3.05 ± 0.56	2.61 ± 0.48	3.25 ± 0.56	0.58	0.4503	4.28	0.0216	0.25	0.7801
4	3.8 ± 0.4	3.28 ± 0.46	2.24 ± 0.4	2.48 ± 0.46	2.74 ± 0.4	3.73 ± 0.46	0.48	0.4949	4.08	0.0253	1.55	0.2257
5	3.96 ± 0.53	4.03 ± 0.62	1.86 ± 0.53	2.3 ± 0.62	3 ± 0.53	1.75 ± 0.62	0.28	0.6028	6.41	0.0042	1.18	0.3176
6	4.89 ± 0.47 a	4.25 ± 0.54	3.28 ± 0.47 ab	2.27 ± 0.54	2.8 ± 0.47 b	2.95 ± 0.54	1.44	0.2383	7.86	0.0015	0.67	0.5156
7	5.04 ± 0.53 a	4.3 ± 0.62	2.59 ± 0.53 b	2.88 ± 0.62	2.95 ± 0.53 ab	2.63 ± 0.62	0.29	0.5951	7.27	0.0022	0.41	0.6699
8	4.06 ± 0.59	4.27 ± 0.68	3.44 ± 0.59	2.65 ± 0.68	2.31 ± 0.59	2.53 ± 0.68	0.05	0.8174	3.85	0.0306	0.41	0.6656
9	4.34 ± 0.47	3.65 ± 0.54	3.59 ± 0.47	2.42 ± 0.54	2.36 ± 0.47	2.92 ± 0.54	1.11	0.2983	3.86	0.0302	1.56	0.2249
10	4.75 ± 0.54	3.95 ± 0.62	3.38 ± 0.54	2.98 ± 0.62	2.78 ± 0.54	1.73 ± 0.62	2.44	0.1273	6.47	0.004	0.16	0.8543
11	3.9 ± 0.4	3.23 ± 0.47	3.98 ± 0.4	3.02 ± 0.47	2.35 ± 0.4	2.6 ± 0.47	1.66	0.2053	3.94	0.0284	1.05	0.3606
12	3.76 ± 0.51	3.53 ± 0.58	4 ± 0.51	3.03 ± 0.58	2.44 ± 0.51	2.4 ± 0.58	0.85	0.3635	3.04	0.06	0.4	0.6719
13	3.74 ± 0.54	4.35 ± 0.63	3.68 ± 0.54	2.25 ± 0.63	1.99 ± 0.54	3.03 ± 0.63	0.03	0.8717	3.62	0.037	2.54	0.0932
14	3.9 ± 0.59	3.55 ± 0.68	3.79 ± 0.59	2.98 ± 0.68	2.36 ± 0.59	2.35 ± 0.68	0.55	0.4612	2.48	0.0976	0.19	0.8254
15	3.89 ± 0.47	3.58 ± 0.54	3.9 ± 0.47	3 ± 0.54	2.26 ± 0.47	2.6 ± 0.54	0.48	0.491	3.64	0.0364	0.74	0.4838

ab Within texture and day comparisons of individual means.
Means with different letters are significantly different at $p<0.05$ with Tukey's Test.

Table A3.1 : Average absolute intake of powder and granular protein (least square means g±SEM) in rats fed a choice between a protein-rich and a carbohydrate-rich diet over 24 h.

	24h		texture df (1,11)	
day	powder (n=12)	granular (n=12)	F value	p
1	0.47 ± 0.63	6.56 ± 0.8 *	35.6	0.0001
2	0.15 ± 0.81	5.77 ± 1.03 *	18.45	0.0013
3	1.55 ± 1.18	6.5 ± 1.49 *	6.76	0.0247
4	0.94 ± 1.24	6.51 ± 1.57 *	7.75	0.0178
5	1.36 ± 1.13	7.18 ± 1.43 *	10.22	0.0085
6	1.25 ± 1	7.04 ± 1.26 *	12.93	0.0042
7	1.38 ± 1.03	6.75 ± 1.3 *	10.47	0.0079
8	2 ± 1.16	6.31 ± 1.47 *	5.31	0.0417
9	2.08 ± 0.99	6.82 ± 1.25 *	8.81	0.0128
10	2.59 ± 1.14	6.99 ± 1.44 *	5.74	0.0355
11	3.21 ± 1.22	6.89 ± 1.54	3.51	0.0877
12	3.64 ± 1.29	7.3 ± 1.63	3.11	0.1056
13	5.26 ± 1.4	7.07 ± 1.77	0.64	0.44
14	5.04 ± 1.29	7.04 ± 1.63	0.93	0.3552
15	5.37 ± 1.36	6.98 ± 1.72	0.54	0.4762

* Within day comparisons of individual means are significantly different at $p<0.05$.

Table A3.2 : Average absolute intake of powder and granular protein (least square means g±SEM) in rats fed a choice between a protein-rich and a carbohydrate-rich diet during the 12h dark and light phases of the diurnal cycle.

	12h dark		12h light		texture df (1,22)		phase df (1,22)		interaction df (1,22)	
day	powder (n=12)	granular (n=12)	powder (n=12)	granular (n=12)	F value	p	F value	p	F value	p
1	0.18 ± 0.43 b	4.95 ± 0.54 a	0.29 ± 0.43 b	1.61 ± 0.54 b	38.37	0.0001	10.85	0.0033	12.37	0.0019
2	0.11 ± 0.49 b	4.42 ± 0.62 a	0.04 ± 0.49 b	1.34 ± 0.62 b	25.41	0.0001	8	0.0098	7.28	0.0132
3	1.17 ± 0.77 b	4.61 ± 0.97 a	0.38 ± 0.77 b	1.88 ± 0.97 ab	7.99	0.0098	4.04	0.057	1.24	0.2782
4	0.82 ± 0.72 b	4.85 ± 0.91 a	0.12 ± 0.72 b	1.66 ± 0.91 ab	11.48	0.0026	5.58	0.0274	2.28	0.1457
5	0.95 ± 0.67 b	5.4 ± 0.84 a	0.41 ± 0.67 b	1.78 ± 0.84 b	14.65	0.0009	7.47	0.0121	4.1	0.0551
6	1.03 ± 0.6 b	5.18 ± 0.75 a	0.22 ± 0.6 b	1.85 ± 0.75 b	18.16	0.0003	9.3	0.0059	3.43	0.0773
7	0.99 ± 0.63 b	5.17 ± 0.79 a	0.39 ± 0.63 b	1.58 ± 0.79 b	14.05	0.0011	8.54	0.0079	4.39	0.048
8	1.19 ± 0.77 b	5.11 ± 0.97 a	0.81 ± 0.77 b	1.2 ± 0.97 b	6.1	0.0218	6.04	0.0224	4.11	0.0548
9	1.52 ± 0.61 b	5.33 ± 0.77 a	0.56 ± 0.61 b	1.49 ± 0.77 b	11.62	0.0025	11.97	0.0022	4.27	0.0507
10	2.18 ± 0.68 b	5.36 ± 0.86 a	0.41 ± 0.68 b	1.64 ± 0.86 b	8	0.0098	12.45	0.0019	1.57	0.2229
11	2.36 ± 0.73 ab	4.99 ± 0.93 a	0.85 ± 0.73 b	1.9 ± 0.93 ab	4.85	0.0384	7.62	0.0114	0.9	0.3544
12	2.77 ± 0.75 ab	5.26 ± 0.95 a	0.87 ± 0.75 b	2.04 ± 0.95 ab	4.55	0.0443	8.9	0.0068	0.58	0.455
13	3.41 ± 0.77	4.99 ± 0.98	1.84 ± 0.77	2.07 ± 0.98	1.05	0.3158	6.48	0.0184	0.59	0.4519
14	4.39 ± 0.82 *	5.27 ± 1.03	0.65 ± 0.82	1.77 ± 1.03	1.16	0.2937	15.18	0.0008	0.02	0.8996
15	3.02 ± 0.75	4.58 ± 0.94	1.13 ± 0.75	2.39 ± 0.94	2.77	0.1104	5.76	0.0253	0.03	0.861

ab Within day comparisons of individual means.
Means with different letters are significantly different at $p<0.05$ with Tukey's Test.

* Within texture and day comparisons of individual means are significantly different at $p<0.05$ with Tukey's Test.

Table A3.3 : Average absolute intake of powder and granular protein (least square means g±SEM) in rats fed a choice between a protein-rich and a carbohydrate-rich diet during the 4 h early, middle and late dark phases of the diurnal cycle.

	early dark		middle dark		late dark		texture		phase		interaction	
							df (1,33)		df (2,33)		df (2,33)	
day	powder (n=12)	granular (n=12)	powder (n=12)	granular (n=12)	powder (n=12)	granular (n=12)	F value	p	F value	p	F value	p
1	0.04 ± 0.24	2.18 ± 0.3 *	0.04 ± 0.24	0.92 ± 0.3	0.11 ± 0.24	1.85 ± 0.3 *	51.63	0.0001	3.01	0.0628	2.81	0.0746
2	0.02 ± 0.25	1.66 ± 0.32 *	0.07 ± 0.25	0.67 ± 0.32	0.02 ± 0.25	2.09 ± 0.32 *	37.82	0.0001	2.96	0.0658	3.5	0.042
3	0.26 ± 0.38	1.83 ± 0.49	0.54 ± 0.38	1.34 ± 0.49	0.37 ± 0.38	1.45 ± 0.49	10.3	0.003	0.05	0.9528	0.39	0.6787
4	0.14 ± 0.35	1.77 ± 0.44	0.31 ± 0.35	1.69 ± 0.44	0.37 ± 0.35	1.39 ± 0.44	17.26	0.0002	0.05	0.9537	0.81	0.737
5	0.26 ± 0.32	2.35 ± 0.4 *	0.46 ± 0.32	1.72 ± 0.4	0.23 ± 0.32	1.33 ± 0.4	24.98	0.0001	1.07	0.3547	1.05	0.3606
6	0.16 ± 0.32	2.19 ± 0.41 *	0.57 ± 0.32	1.83 ± 0.41	0.29 ± 0.32	1.17 ± 0.41	21.11	0.0001	1.03	0.3676	1.26	0.296
7	0.23 ± 0.31	1.87 ± 0.39 *	0.44 ± 0.31	1.61 ± 0.39	0.32 ± 0.31	1.69 ± 0.39	23.1	0.0001	0.01	0.9929	0.22	0.8018
8	0.24 ± 0.34	1.71 ± 0.43	0.62 ± 0.34	1.96 ± 0.43	0.33 ± 0.34	1.45 ± 0.43	17.12	0.0002	0.6	0.5566	0.11	0.8993
9	0.57 ± 0.32	2.04 ± 0.4	0.44 ± 0.32	1.47 ± 0.4	0.52 ± 0.32	1.81 ± 0.4	18.63	0.0001	0.48	0.6259	0.19	0.8282
10	0.49 ± 0.4	1.71 ± 0.51	0.76 ± 0.4	2.41 ± 0.51	0.93 ± 0.4	1.33 ± 0.51	8.53	0.0062	0.7	0.502	0.97	0.3885
11	0.97 ± 0.41	1.37 ± 0.52	0.73 ± 0.41	2.29 ± 0.52	0.67 ± 0.41	1.33 ± 0.52	5.27	0.0282	0.63	0.5415	0.84	0.4392
12	0.61 ± 0.38	1.43 ± 0.48	1.23 ± 0.38	2.51 ± 0.48	0.93 ± 0.38	1.31 ± 0.48	5.49	0.0253	2.31	0.1155	0.54	0.5898
13	1.51 ± 0.46	1.28 ± 0.58	0.91 ± 0.46	2.31 ± 0.58	0.99 ± 0.46	1.4 ± 0.58	1.51	0.228	0.31	0.7329	1.21	0.3106
14	1.42 ± 0.42	1.24 ± 0.54	1.45 ± 0.42	2.64 ± 0.54	1.51 ± 0.42	1.39 ± 0.54	0.55	0.4623	1.25	0.2991	1.29	0.288
15	1.72 ± 0.45	1.18 ± 0.57	1.49 ± 0.45	2.42 ± 0.57	1.03 ± 0.45	0.98 ± 0.57	0.08	0.7829	1.71	0.1971	1.06	0.3587

* Within phase and day comparisons of individual means are significantly different at $p<0.05$ with Tukey's Test.

Table A4.1 : Average absolute intake of powder and granular carbohydrate (least square means g±SEM) in rats fed a choice between a protein-rich and a carbohydrate-rich diet over 24 h.

	24h		texture df (1,12)	
day	powder (n=12)	granular (n=12)	F value	p
1	10.04 ± 1.51	15.39 ± 1.75 *	5.37	0.0389
2	10.29 ± 1.55	13.31 ± 1.79	1.63	0.2254
3	9.98 ± 1.13	12.28 ± 1.3	1.78	0.2071
4	9.19 ± 0.87	9.95 ± 1	0.33	0.5752
5	9.84 ± 0.97	8.69 ± 1.12	0.6	0.4523
6	10.6 ± 1	9.76 ± 1.16	0.3	0.5926
7	9.75 ± 1	9.44 ± 1.15	0.04	0.8408
8	10.06 ± 0.96	9.7 ± 1.1	0.06	0.81
9	10.16 ± 1.09	9.73 ± 1.26	0.07	0.8006
10	10.6 ± 0.9	9.01 ± 1.04	1.33	0.2704
11	11.54 ± 1.05	9.34 ± 1.21	1.88	0.195
12	10.62 ± 0.97	9.82 ± 1.13	0.29	0.6012
13	9.98 ± 0.88	10.61 ± 1.01	0.22	0.6475
14	10.66 ± 0.94	10.38 ± 1.08	0.04	0.8465
15	10.26 ± 0.87	10.43 ± 1.01	0.02	0.9002

* Within day comparisons of individual means are significantly different at $p<0.05$.

Table A4.2 : Average absolute intake of powder and granular carbohydrate (least square means g±SEM) in rats fed a choice between a protein-rich and a carbohydrate-rich diet during the 12h dark and light phases of the diurnal cycle.

	12h dark		12h light		texture df (1,24)		phase df (1,24)		interaction df (1,24)	
day	powder (n=12)	granular (n=12)	powder (n=12)	granular (n=12)	F value	p	F value	p	F value	p
1	8.88 ± 0.94 ac	10.31 ± 1.08 a	1.16 ± 0.94 b	5.08 ± 1.08 bc	7	0.0141	40.94	0.0001	1.51	0.2304
2	7.37 ± 0.85 *	8.37 ± 0.98	2.92 ± 0.85	4.93 ± 0.98	2.71	0.1128	18.54	0.0002	0.31	0.5848
3	7.79 ± 0.7 *	8.38 ± 0.81 *	2.2 ± 0.7	3.9 ± 0.81	2.31	0.1414	44.58	0.0001	0.53	0.4724
4	7.22 ± 0.62 *	7.65 ± 0.72 *	1.97 ± 0.62	2.3 ± 0.72	0.32	0.5749	62.66	0.0001	0.01	0.935
5	7.3 ± 0.59 *	6.55 ± 0.68 *	2.54 ± 0.59	2.14 ± 0.68	0.83	0.3722	52.23	0.0001	0.08	0.7837
6	9.01 ± 0.64 *	7.68 ± 0.74 *	1.58 ± 0.64	2.08 ± 0.74	0.37	0.5473	89.42	0.0001	1.77	0.1956
7	8.69 ± 0.69 *	7.97 ± 0.79 *	1.07 ± 0.69	1.47 ± 0.79	0.04	0.8342	90.85	0.0001	0.58	0.4547
8	8.08 ± 0.73 *	7.68 ± 0.85 *	1.98 ± 0.73	2.02 ± 0.85	0.05	0.8229	55.03	0.0001	0.08	0.7829
9	8.47 ± 0.66 *	7.33 ± 0.76 *	1.69 ± 0.66	2.39 ± 0.76	0.09	0.7661	67.19	0.0001	1.66	0.2103
10	8.93 ± 0.65 *	7.11 ± 0.75 *	1.67 ± 0.65	1.9 ± 0.75	1.26	0.2729	78.04	0.0001	2.11	0.1589
11	8.39 ± 0.66 *	7.25 ± 0.76 *	3.15 ± 0.66	2.09 ± 0.76	2.36	0.1379	52.88	0.0001	0	0.9548
12	8.37 ± 0.6 *	7.36 ± 0.7 *	2.25 ± 0.6	2.47 ± 0.7	0.38	0.5449	71.56	0.0001	0.88	0.3569
13	7.73 ± 0.65 *	7.88 ± 0.75 *	2.26 ± 0.65	2.73 ± 0.75	0.2	0.659	57.15	0.0001	0.05	0.8173
14	8.25 ± 0.67 *	7.29 ± 0.78 *	2.42 ± 0.67	3.09 ± 0.78	0.04	0.8469	47.71	0.0001	1.27	0.2711
15	6.54 ± 0.7 *	6.34 ± 0.81 *	2.02 ± 0.7	2.9 ± 0.81	0.2	0.6562	27.72	0.0001	0.5	0.4842

abc Within day comparisons of individual means.
Means with different letters are significantly different at $p<0.05$ with Tukey's Test.

* Within texture and day comparisons of individual means are significantly different at $p<0.05$ with Tukey's Test.

Table A4.3: Average absolute intake of powder and granular carbohydrate (least square means g±SEM) in rats fed a choice between a protein-rich and a carbohydrate-rich diet during the 4 h early, middle and late dark phases of the diurnal cycle.

	early dark		middle dark		late dark		texture df (1,36)		phase df (2,36)		interaction df (2,36)	
day	powder (n=12)	granular (n=12)	powder (n=12)	granular (n=12)	powder (n=12)	granular (n=12)	F value	p	F value	p	F value	p
1	3.05 ± 0.64	3.67 ± 0.74	2.6 ± 0.64	3.15 ± 0.74	3.23 ± 0.64	3.49 ± 0.74	0.71	0.4035	0.33	0.7199	0.04	0.9615
2	3.43 ± 0.48	3.59 ± 0.55	2.46 ± 0.48	2.61 ± 0.55	1.48 ± 0.48	2.17 ± 0.55	0.63	0.4329	5.37	0.0091	0.18	0.8329
3	3.48 ± 0.39	3.34 ± 0.45	2.15 ± 0.39	2.44 ± 0.45	2.16 ± 0.39	2.6 ± 0.45	0.34	0.563	4.4	0.0195	0.26	0.7728
4	3.12 ± 0.32	2.63 ± 0.37	1.85 ± 0.32	2 ± 0.37	2.25 ± 0.32	3.03 ± 0.37	0.27	0.6067	4.2	0.023	1.72	0.1936
5	3.26 ± 0.42	3.27 ± 0.49	1.57 ± 0.42	1.86 ± 0.49	2.47 ± 0.42	1.42 ± 0.49	0.45	0.5055	6.71	0.0033	1.18	0.3189
6	4 ± 0.38 a	3.45 ± 0.43	2.69 ± 0.38 ab	1.83 ± 0.43	2.33 ± 0.38 b	2.39 ± 0.43	1.81	0.1868	8.18	0.0012	0.67	0.5203
7	4.11 ± 0.42 a	3.5 ± 0.49	2.13 ± 0.42 b	2.33 ± 0.49	2.45 ± 0.42 ab	2.14 ± 0.49	0.41	0.5252	7.55	0.0018	0.4	0.6725
8	3.34 ± 0.47	3.46 ± 0.54	2.81 ± 0.47	2.16 ± 0.54	1.93 ± 0.47	2.06 ± 0.54	0.11	0.7469	4.04	0.0262	0.4	0.6708
9	3.55 ± 0.37 a	2.98 ± 0.42	2.95 ± 0.37 ab	1.98 ± 0.42	1.96 ± 0.37 b	2.38 ± 0.42	1.37	0.2492	4.12	0.0244	1.63	0.2099
10	3.87 ± 0.43	3.21 ± 0.49	2.77 ± 0.43	2.43 ± 0.49	2.29 ± 0.43	1.46 ± 0.49	2.59	0.1163	6.55	0.0037	0.15	0.8633
11	3.2 ± 0.32	2.66 ± 0.37	3.25 ± 0.32	2.45 ± 0.37	1.94 ± 0.32	2.14 ± 0.37	1.79	0.1888	4.01	0.0267	1.09	0.348
12	3.07 ± 0.4	2.87 ± 0.46	3.29 ± 0.4	2.5 ± 0.46	2.01 ± 0.4	1.99 ± 0.46	0.91	0.3469	3.11	0.0565	0.43	0.6545
13	3.06 ± 0.44	3.53 ± 0.5	3.01 ± 0.44	1.86 ± 0.5	1.66 ± 0.44	2.48 ± 0.5	0.02	0.8973	3.56	0.0388	2.51	0.0958
14	3.18 ± 0.48	2.88 ± 0.55	3.12 ± 0.48	2.47 ± 0.55	1.95 ± 0.48	1.94 ± 0.55	0.58	0.4516	2.46	0.0996	0.2	0.8183
15	3.17 ± 0.38	2.92 ± 0.44	3.21 ± 0.38	2.46 ± 0.44	1.86 ± 0.38	2.15 ± 0.44	0.5	0.4835	3.63	0.0366	0.8	0.4559

ab Within texture and day comparisons of individual means.
Means with different letters are significantly different at $p<0.05$ with Tukey's Test.

Table A5.1 : Average absolute intake of powder and granular protein-rich diets (least square means kcal±SEM) in rats fed a choice between a protein-rich and a carbohydrate-rich diet over 24 h.

	24h		texture df (1,11)	
day	powder (n=12)	granular (n=12)	F value	p
1	2.65 ± 3.52	36.55 ± 4.46 *	35.6	0.0001
2	0.81 ± 4.53	32.15 ± 5.72 *	18.45	0.0013
3	8.65 ± 6.58	36.22 ± 8.32 *	6.76	0.0247
4	5.24 ± 6.92	36.3 ± 8.76 *	7.75	0.0178
5	7.58 ± 6.3	40.05 ± 7.97 *	10.22	0.0085
6	6.97 ± 5.56	39.23 ± 7.04 *	12.93	0.0042
7	7.68 ± 5.74	37.61 ± 7.25 *	10.47	0.0079
8	11.14 ± 6.47	35.16 ± 8.18 *	5.31	0.0417
9	11.6 ± 5.52	38.01 ± 6.98 *	8.81	0.0128
10	14.45 ± 6.35	38.99 ± 8.03 *	5.74	0.0355
11	17.91 ± 6.79	38.42 ± 8.59	3.51	0.0877
12	20.3 ± 7.18	40.7 ± 9.08	3.11	0.1056
13	29.3 ± 7.81	39.4 ± 9.88	0.64	0.44
14	28.08 ± 7.17	39.23 ± 9.06	0.93	0.3552
15	29.91 ± 7.56	38.91 ± 9.57	0.54	0.4762

* Within day comparisons of individual means are significantly different at $p<0.05$.

Table A5.2 : Average absolute intake of powder and granular protein-rich diets (least square means kcal±SEM) in rats fed a choice between a protein-rich and a carbohydrate-rich diet during the 12h dark and light phases of the diurnal cycle.

	12h dark		12h light		texture		phase		interaction	
					df (1,22)		df (1,22)		df (1,22)	
day	powder (n=12)	granular (n=12)	powder (n=12)	granular (n=12)	F value	p	F value	p	F value	p
1	1.02 ± 2.4 b	27.59 ± 3.04 a	1.63 ± 2.4 b	8.95 ± 3.04 b	38.37	0.0001	10.85	0.0033	12.37	0.0019
2	0.61 ± 2.73 b	24.66 ± 3.45 a	0.2 ± 2.73 b	7.49 ± 3.45 b	25.41	0.0001	8	0.0098	7.28	0.0132
3	6.51 ± 4.28 b	25.72 ± 5.41 a	2.14 ± 4.28 b	10.5 ± 5.41 ab	7.99	0.0098	4.04	0.057	1.24	0.2782
4	4.58 ± 4.02 b	27.02 ± 5.08 a	0.66 ± 4.02 b	9.28 ± 5.08 ab	11.48	0.0026	5.58	0.0274	2.28	0.1457
5	5.29 ± 3.72 b	30.12 ± 4.71 a	2.29 ± 3.72 b	9.93 ± 4.71 b	14.65	0.0009	7.47	0.0121	4.1	0.0551
6	5.75 ± 3.32 b	28.9 ± 4.2 a	1.22 ± 3.32 b	10.34 ± 4.2 b	18.16	0.0003	9.3	0.0059	3.43	0.0773
7	5.49 ± 3.5 b	28.82 ± 4.43 a	2.19 ± 3.5 b	8.79 ± 4.43 b	14.05	0.0011	8.54	0.0079	4.39	0.048
8	6.61 ± 4.27 b	28.49 ± 5.4 a	4.53 ± 4.27 b	6.67 ± 5.4 b	6.1	0.0218	6.04	0.0224	4.11	0.0548
9	8.5 ± 3.4 b	29.71 ± 4.3 a	3.1 ± 3.4 b	8.3 ± 4.3 b	11.62	0.0025	11.97	0.0022	4.27	0.0507
10	12.16 ± 3.81 b	29.87 ± 4.81 a	2.29 ± 3.81 b	9.12 ± 4.81 b	8	0.0098	12.45	0.0019	1.57	0.2229
11	13.18 ± 4.08 ab	27.84 ± 5.17 a	4.73 ± 4.08 b	10.58 ± 5.17 ab	4.85	0.0384	7.62	0.0114	0.9	0.3544
12	15.47 ± 4.19 ab	29.3 ± 5.31 a	4.83 ± 4.19 b	11.4 ± 5.31 ab	4.55	0.0443	8.9	0.0068	0.58	0.455
13	19.03 ± 4.31	27.84 ± 5.45	10.28 ± 4.31	11.56 ± 5.45	1.05	0.3158	6.48	0.0184	0.59	0.4519
14	24.47 ± 4.55 *	29.39 ± 5.75	3.61 ± 4.55	9.85 ± 5.75	1.16	0.294	15.18	0.0008	0.02	0.8996
15	16.84 ± 4.16	25.56 ± 5.26	6.31 ± 4.16	13.35 ± 5.26	2.77	0.1104	5.76	0.0253	0.03	0.861

ab Within day comparisons of individual means.
Means with different letters are significantly different at $p<0.05$ with Tukey's Test.

* Within texture and day comparisons of individual means are significantly different at $p<0.05$ with Tukey's Test.

Table A5.3 : Average absolute intake of powder and granular protein-rich diets (least square means kcal±SEM) in rats fed a choice between a protein-rich and a carbohydrate-rich diet during the 4 h early, middle and late dark phases of the diurnal cycle.

	early dark		middle dark		late dark		texture df (1,33)		phase df (2,33)		interaction df (2,33)	
day	powder (n=12)	granular (n=12)	powder (n=12)	granular (n=12)	powder (n=12)	granular (n=12)	F value	p	F value	p	F value	p
1	0.2 ± 1.32	12.13 ± 1.68 *	0.2 ± 1.32	5.13 ± 1.68	0.61 ± 1.32	10.34 ± 1.68 *	51.63	0.0001	3.01	0.0628	2.81	0.0746
2	0.1 ± 1.4	9.28 ± 1.77 *	0.41 ± 1.4	3.74 ± 1.77	0.1 ± 1.4	11.64 ± 1.77 *	37.82	0.0001	2.96	0.0658	3.5	0.042
3	1.42 ± 2.14	10.18 ± 2.71	3 ± 2.14	7.49 ± 2.71	2.09 ± 2.14	8.06 ± 2.71	10.3	0.003	0.05	0.9528	0.39	0.6787
4	0.76 ± 1.93	9.85 ± 2.45	1.73 ± 1.93	9.44 ± 2.45	2.09 ± 1.93	7.73 ± 2.45	17.26	0.0002	0.05	0.9537	0.31	0.737
5	1.48 ± 1.78	13.11 ± 2.25 *	2.54 ± 1.78	9.61 ± 2.25	1.27 ± 1.78	7.41 ± 2.25	24.98	0.0001	1.07	0.3547	1.05	0.3606
6	0.92 ± 1.8	12.21 ± 2.28 *	3.21 ± 1.8	10.18 ± 2.28	1.63 ± 1.8	6.51 ± 2.28	21.11	0.0001	1.03	0.3676	1.26	0.296
7	1.27 ± 1.74	10.42 ± 2.2 *	2.44 ± 1.74	8.95 ± 2.2	1.78 ± 1.74	9.44 ± 2.2	23.1	0.0001	0.01	0.9929	0.22	0.8018
8	1.32 ± 1.89	9.52 ± 2.39	3.46 ± 1.89	10.91 ± 2.39	1.83 ± 1.89	8.06 ± 2.39	17.12	0.0002	0.6	0.5566	0.11	0.8993
9	3.15 ± 1.76	11.4 ± 2.23	2.44 ± 1.76	8.22 ± 2.23	2.9 ± 1.76	10.09 ± 2.23	18.63	0.0001	0.48	0.6259	0.19	0.8282
10	2.75 ± 2.23	9.52 ± 2.82	4.22 ± 2.23	13.43 ± 2.82	5.19 ± 2.23	7.41 ± 2.82	8.53	0.0062	0.7	0.5	0.97	0.3885
11	5.39 ± 2.29	7.65 ± 2.89	4.07 ± 2.29	12.78 ± 2.89	3.71 ± 2.29	7.41 ± 2.89	5.27	0.0282	0.63	0.5415	0.84	0.4392
12	3.41 ± 2.12	7.98 ± 2.68	6.87 ± 2.12	14 ± 2.68	5.19 ± 2.12	7.33 ± 2.68	5.49	0.0253	2.31	0.1155	0.54	0.5898
13	8.45 ± 2.57	7.16 ± 3.25	5.09 ± 2.57	12.86 ± 3.25	5.49 ± 2.57	7.81 ± 3.25	1.51	0.228	0.31	0.7329	1.21	0.3106
14	7.94 ± 2.37	6.92 ± 2.99	8.09 ± 2.37	14.73 ± 2.99	8.45 ± 2.37	7.73 ± 2.99	0.55	0.4623	1.25	0.2991	1.29	0.288
15	9.56 ± 2.52	6.59 ± 3.19	8.29 ± 2.52	13.51 ± 3.19	5.75 ± 2.52	5.45 ± 3.19	0.08	0.7829	1.71	0.1971	1.06	0.3587

* Within phase and day comparisons of individual means are significantly different at $p<0.05$ with Tukey's Test.

Table A6.1 : Average intake of powder and granular carbohydrate-rich diets (least square means kcal±SEM) in rats fed a choice between a protein-rich and a carbohydrate-rich diet over 24 h.

	24h		texture df (1,12)	
day	powder (n=12)	granular (n=12)	F value	p
1	48.36 ± 7.64	75.9 ± 8.82 *	5.57	0.0361
2	49.6 ± 7.85	65.27 ± 9.06	1.71	0.2156
3	48.11 ± 5.78	60.06 ± 6.68	1.83	0.2012
4	44.1 ± 4.47	48.91 ± 5.17	0.49	0.4958
5	47.22 ± 5.02	42.37 ± 5.8	0.4	0.5391
6	50.89 ± 5.17	47.65 ± 5.97	0.17	0.6894
7	46.83 ± 5.15	46 ± 5.94	0.01	0.9181
8	48.26 ± 4.98	47.06 ± 5.75	0.03	0.8769
9	48.61 ± 5.64	47.26 ± 6.51	0.02	0.8778
10	50.99 ± 4.66	43.56 ± 5.38	1.09	0.3172
11	55.59 ± 5.31	45.14 ± 6.13	1.66	0.2217
12	51.03 ± 5.05	47.39 ± 5.83	0.22	0.645
13	47.87 ± 4.5	51.41 ± 5.2	0.27	0.6154
14	51.23 ± 4.78	50.29 ± 5.52	0.02	0.8996
15	49.25 ± 4.41	50.42 ± 5.09	0.03	0.8649

* Within day comparisons of individual means are significantly different at $p<0.05$.

Table A6.2 : Average intake of powder and granular carbohydrate-rich diets (least square means kcal±SEM) in rats fed a choice between a protein-rich and a carbohydrate-rich diet during the 12h dark and light phases of the diurnal cycle.

	12h dark		12h light		texture df (1,24)		phase df (1,24)		interaction df (1,24)	
day	powder (n=12)	granular (n=12)	powder (n=12)	granular (n=12)	F value	p	F value	p	F value	p
1	42.92 ± 4.71 ac	50.95 ± 5.44 a	5.45 ± 4.71 b	24.95 ± 5.44 bc	7.32	0.0124	38.88	0.0001	1.27	0.2711
2	35.49 ± 4.29 *	41.32 ± 4.96	14.11 ± 4.29	23.96 ± 4.96	2.86	0.1039	17.46	0.0003	0.19	0.668
3	37.57 ± 3.5 *	41.45 ± 4.04 *	10.54 ± 3.5	18.61 ± 4.04	2.49	0.1274	43.45	0.0001	0.31	0.5847
4	34.75 ± 3.12 *	37.62 ± 3.61 *	9.36 ± 3.12	11.29 ± 3.61	0.51	0.4385	58.8	0.0001	0.02	0.8903
5	34.95 ± 3.01 *	32.01 ± 3.48 *	12.28 ± 3.01	10.36 ± 3.48	0.56	0.4635	46.34	0.0001	0.02	0.8765
6	43.41 ± 3.25 *	37.49 ± 3.76 *	7.47 ± 3.25	10.16 ± 3.76	0.21	0.6495	81.04	0.0001	1.5	0.2322
7	41.88 ± 3.49 *	38.87 ± 4.02 *	4.95 ± 3.49	7.13 ± 4.02	0.01	0.9137	83.21	0.0001	0.47	0.4979
8	38.86 ± 3.71 *	37.42 ± 4.29 *	9.41 ± 3.71	9.64 ± 4.29	0.02	0.8819	50.94	0.0001	0.04	0.8371
9	40.74 ± 3.4 *	35.57 ± 3.93 *	7.87 ± 3.4	11.68 ± 3.93	0.03	0.8556	59.56	0.0001	1.49	0.2342
10	43.16 ± 3.35 *	34.32 ± 3.87 *	7.82 ± 3.35	9.24 ± 3.87	1.05	0.3154	69.63	0.0001	2.01	0.1692
11	40.49 ± 3.36 *	35.05 ± 3.88 *	15.1 ± 3.36	10.1 ± 3.88	2.07	0.1632	48.06	0.0001	0	0.9516
12	40.39 ± 3.1 *	35.51 ± 3.58 *	10.64 ± 3.1	11.88 ± 3.58	0.3	0.5909	63.61	0.0001	0.84	0.3695
13	37.22 ± 3.29 *	38.15 ± 3.8 *	10.64 ± 3.29	13.27 ± 3.8	0.25	0.6225	52.36	0.0001	0.06	0.8132
14	39.8 ± 3.37 *	35.18 ± 3.9 *	11.43 ± 3.37	15.11 ± 3.9	0.02	0.8984	44.14	0.0001	1.3	0.2661
15	31.53 ± 3.46 *	30.62 ± 3.99 *	9.45 ± 3.46	14.06 ± 3.99	0.25	0.625	26.79	0.0001	0.54	0.4675

abc Within day comparisons of individual means.
Means with different letters are significantly different at $p<0.05$ with Tukey's Test.

* Within texture and day comparisons of individual means are significantly different at $p<0.05$ with Tukey's Test.

Table A6.3 : Average intake of powder and granular carbohydrate-rich diets (least square means kcal±SEM) in rats fed a choice between a protein-rich and a carbohydrate-rich diet during the 4 h early, middle and late dark phases of the diurnal cycle.

	early dark		middle dark		late dark		texture		phase		interaction	
							df (1,36)		df (2,36)		df (2,36)	
day	powder (n=12)	granular (n=12)	powder (n=12)	granular (n=12)	powder (n=12)	granular (n=12)	F value	p	F value	p	F value	p
1	14.7 ± 3.2	18.15 ± 3.69	12.62 ± 3.2	15.58 ± 3.69	15.59 ± 3.2	17.23 ± 3.69	0.9	0.3482	0.3	0.742	0.04	0.9638
2	15.58 ± 2.39	17.75 ± 2.76	12.03 ± 2.39	12.8 ± 2.76	6.88 ± 2.39	10.75 ± 2.76	0.85	0.3629	5.27	0.0098	0.21	0.8083
3	16.83 ± 1.92	16.5 ± 2.22	10.4 ± 1.92	12.08 ± 2.22	10.35 ± 1.92	12.87 ± 2.22	0.58	0.4503	4.28	0.0216	0.25	0.7801
4	15.05 ± 1.57	13 ± 1.82	8.86 ± 1.57	9.83 ± 1.82	10.84 ± 1.57	14.78 ± 1.82	0.48	0.4949	4.08	0.0253	1.55	0.2257
5	15.69 ± 2.11	15.97 ± 2.44	7.38 ± 2.11	9.11 ± 2.44	11.88 ± 2.11	6.93 ± 2.44	0.28	0.6028	6.41	0.0042	1.18	0.3176
6	19.35 ± 1.87 a	16.83 ± 2.16	12.97 ± 1.87 ab	8.98 ± 2.16	11.09 ± 1.87 b	11.68 ± 2.16	1.44	0.2383	7.86	0.0015	0.67	0.5156
7	19.95 ± 2.12 a	17.03 ± 2.44	10.25 ± 2.12 b	11.42 ± 2.44	11.68 ± 2.12 ab	10.43 ± 2.44	0.29	0.5951	7.27	0.0022	0.41	0.6699
8	16.09 ± 2.33	16.9 ± 2.69	13.61 ± 2.33	10.49 ± 2.69	9.16 ± 2.33	10.03 ± 2.69	0.05	0.8174	3.85	0.0306	0.41	0.6656
9	17.18 ± 1.85	14.45 ± 2.14	14.21 ± 1.85	9.57 ± 2.14	9.36 ± 1.85	11.55 ± 2.14	1.11	0.2983	3.86	0.0302	1.56	0.2249
10	18.81 ± 2.14	15.64 ± 2.47	13.37 ± 2.14	11.81 ± 2.47	10.99 ± 2.14	6.86 ± 2.47	2.44	0.1273	6.47	0.004	0.16	0.8543
11	15.44 ± 1.6	12.8 ± 1.84	15.74 ± 1.6	11.95 ± 1.84	9.31 ± 1.6	10.3 ± 1.84	1.66	0.2053	3.94	0.0284	1.05	0.3606
12	14.9 ± 2.01	13.99 ± 2.32	15.84 ± 2.01	12.01 ± 2.32	9.65 ± 2.01	9.5 ± 2.32	0.85	0.3635	3.04	0.06	0.4	0.6719
13	14.8 ± 2.15	17.23 ± 2.48	14.55 ± 2.15	8.91 ± 2.48	7.87 ± 2.15	12.01 ± 2.48	0.03	0.8717	3.62	0.037	2.54	0.0932
14	15.44 ± 2.34	14.06 ± 2.71	15 ± 2.34	11.81 ± 2.71	9.36 ± 2.34	9.31 ± 2.71	0.55	0.4612	2.48	0.0976	0.19	0.8254
15	15.39 ± 1.86	14.19 ± 2.15	15.44 ± 1.86	11.88 ± 2.15	8.96 ± 1.86	10.3 ± 2.15	0.48	0.491	3.64	0.0364	0.74	0.4838

ab Within texture and day comparisons of individual means.
Means with different letters are significantly different at $p<0.05$ with Tukey's Test.

Table A7.1 : Average absolute intake of powder and granular protein (least square means kcal±SEM) in rats fed a choice between a protein-rich and a carbohydrate-rich diet over 24 h.

	24h		texture df (1,11)	
day	powder (n=12)	granular (n=12)	F value	p
1	1.9 ± 2.53	26.22 ± 3.2 *	35.6	0.0001
2	0.58 ± 3.25	23.07 ± 4.11 *	18.45	0.0013
3	6.21 ± 4.72	25.99 ± 5.97 *	6.76	0.0247
4	3.76 ± 4.97	26.05 ± 6.28 *	7.75	0.0178
5	5.44 ± 4.52	28.73 ± 5.72 *	10.22	0.0085
6	5 ± 3.99	28.15 ± 5.05 *	12.93	0.0042
7	5.51 ± 4.11	26.98 ± 5.21 *	10.47	0.0079
8	7.99 ± 4.64	25.23 ± 5.87 *	5.31	0.0417
9	8.32 ± 3.96	27.27 ± 5 *	8.81	0.0128
10	10.37 ± 4.56	27.97 ± 5.76 *	5.74	0.0355
11	12.85 ± 4.87	27.56 ± 6.16	3.51	0.0877
12	14.62 ± 5.74	34.47 ± 7.26	4.6	0.055
13	21.02 ± 5.61	28.27 ± 7.09	0.64	0.44
14	20.15 ± 5.14	28.15 ± 6.5	0.93	0.3552
15	21.46 ± 5.43	27.92 ± 6.86	0.54	0.4762

* Within day comparisons of individual means are significantly different at $p<0.05$.

Table A7.2 : Average absolute intake of powder and granular protein (least square means kcal±SEM) in rats fed a choice between a protein-rich and a carbohydrate-rich diet during the 12h dark and light phases of the diurnal cycle.

	12h dark		12h light		texture		phase		interaction	
					df (1,22)		df (1,22)		df (1,22)	
day	powder (n=12)	granular (n=12)	powder (n=12)	granular (n=12)	F value	p	F value	p	F value	p
1	0.73 ± 1.72 b	19.8 ± 2.18 a	1.17 ± 1.72 b	6.42 ± 2.18 b	38.37	0.0001	10.85	0.0033	12.37	0.0019
2	0.44 ± 1.96 b	17.7 ± 2.47 a	0.15 ± 1.96 b	5.37 ± 2.47 b	25.41	0.0001	8	0.0098	7.28	0.0132
3	4.67 ± 3.07 b	18.45 ± 3.88 a	1.53 ± 3.07 b	7.53 ± 3.88 ab	7.99	0.0098	4.04	0.057	1.24	0.2782
4	3.29 ± 2.88 b	19.39 ± 3.65 a	0.47 ± 2.88 b	6.66 ± 3.65 ab	11.48	0.0026	5.58	0.0274	2.28	0.1457
5	3.8 ± 2.67 b	21.61 ± 3.38 a	1.64 ± 2.67 b	7.12 ± 3.38 b	14.65	0.0009	7.47	0.0121	4.1	0.0551
6	4.12 ± 2.38 b	20.73 ± 3.01 a	0.88 ± 2.38 b	7.42 ± 3.01 b	18.16	0.0003	9.3	0.0059	3.43	0.0773
7	3.94 ± 2.51 b	20.67 ± 3.18 a	1.57 ± 2.51 b	6.31 ± 3.18 b	14.05	0.0011	8.54	0.0079	4.39	0.048
8	4.75 ± 3.06 b	20.44 ± 3.87 a	3.25 ± 3.06 b	4.79 ± 3.87 b	6.1	0.0218	6.04	0.0224	4.11	0.0548
9	6.1 ± 2.44 b	21.32 ± 3.08 a	2.23 ± 2.44 b	5.96 ± 3.08 b	11.62	0.0025	11.97	0.0022	4.27	0.0507
10	8.72 ± 2.73 b	21.43 ± 3.45 a	1.64 ± 2.73 b	6.54 ± 3.45 b	8	0.0098	12.45	0.0019	1.57	0.2229
11	9.45 ± 2.93 ab	19.97 ± 3.71 a	3.39 ± 2.93 b	7.59 ± 3.71 ab	4.85	0.0384	7.62	0.0114	0.9	0.3544
12	11.15 ± 3.33 ab	24.93 ± 4.22 a	3.47 ± 3.33 b	9.54 ± 4.22 ab	6.83	0.0159	9.22	0.0061	1.03	0.3211
13	13.65 ± 3.09	19.97 ± 3.91	7.37 ± 3.09	8.29 ± 3.91	1.05	0.3158	6.48	0.0184	0.59	0.4519
14	17.56 ± 3.26 *	21.08 ± 4.13	2.59 ± 3.26	7.07 ± 4.13	1.16	0.2937	15.18	0.0008	0.02	0.8996
15	12.08 ± 2.98	18.34 ± 3.77	4.53 ± 2.98	9.58 ± 3.77	2.77	0.1104	5.76	0.0253	0.03	0.861

ab Within day comparisons of individual means.
Means with different letters are significantly different at $p<0.05$ with Tukey's Test.

* Within texture and day comparisons of individual means are significantly different at $p<0.05$ with Tukey's Test.

Table A7.3 : Average absolute intake of powder and granular protein (least square means kcal±SEM) in rats fed a choice between a protein-rich and a carbohydrate-rich diet during the 4 h early, middle and late dark phases of the diurnal cycle.

	early dark		middle dark		late dark		texture df (1,33)		phase df (2,33)		interaction df (2,33)	
day	powder (n=12)	granular (n=12)	powder (n=12)	granular (n=12)	powder (n=12)	granular (n=12)	F value	p	F value	p	F value	p
1	0.15 ± 0.95	8.7 ± 1.2 *	0.15 ± 0.95	3.68 ± 1.2	0.44 ± 0.95	7.42 ± 1.2 *	51.63	0.0001	3.01	0.0628	2.81	0.0746
2	0.07 ± 1	6.66 ± 1.27 *	0.29 ± 1	2.69 ± 1.27	0.07 ± 1	8.35 ± 1.27 *	37.82	0.0001	2.96	0.0658	3.5	0.042
3	1.02 ± 1.54	7.3 ± 1.94	2.15 ± 1.54	5.37 ± 1.94	1.5 ± 1.54	5.78 ± 1.94	10.3	0.003	0.05	0.9528	0.39	0.6787
4	0.55 ± 1.39	7.07 ± 1.76	1.24 ± 1.39	6.77 ± 1.76	1.5 ± 1.39	5.55 ± 1.76	17.26	0.0002	0.05	0.9537	0.31	0.737
5	1.06 ± 1.28	9.4 ± 1.61 *	1.83 ± 1.28	6.89 ± 1.61	0.91 ± 1.28	5.31 ± 1.61	24.98	0.0001	1.07	0.3547	1.05	0.3606
6	0.66 ± 1.29	8.76 ± 1.64 *	2.3 ± 1.29	7.3 ± 1.64	1.17 ± 1.29	4.67 ± 1.64	21.11	0.0001	1.03	0.3676	1.26	0.296
7	0.91 ± 1.25	7.48 ± 1.58 *	1.75 ± 1.25	6.42 ± 1.58	1.28 ± 1.25	6.77 ± 1.58	23.1	0.0001	0.01	0.9929	0.22	0.8018
8	0.95 ± 1.36	6.83 ± 1.72	2.48 ± 1.36	7.83 ± 1.72	1.31 ± 1.36	5.78 ± 1.72	17.12	0.0002	0.6	0.5566	0.11	0.8993
9	2.26 ± 1.26	8.18 ± 1.6	1.75 ± 1.26	5.9 ± 1.6	2.08 ± 1.26	7.24 ± 1.6	18.63	0.0001	0.48	0.6259	0.19	0.8282
10	1.97 ± 1.6	6.83 ± 2.02	3.03 ± 1.6	9.64 ± 2.02	3.72 ± 1.6	5.31 ± 2.02	8.53	0.0062	0.7	0.5	0.97	0.3885
11	3.87 ± 1.64	5.49 ± 2.08	2.92 ± 1.64	9.17 ± 2.08	2.66 ± 1.64	5.31 ± 2.08	5.27	0.0282	0.63	0.5415	0.84	0.4392
12	2.47 ± 1.68	6.67 ± 2.12	4.95 ± 1.68	11.95 ± 2.12	3.72 ± 1.68	6.31 ± 2.12	8.67	0.0059	2.46	0.1006	0.68	0.5145
13	6.06 ± 1.84	5.14 ± 2.33	3.65 ± 1.84	9.23 ± 2.33	3.94 ± 1.84	5.61 ± 2.33	1.51	0.228	0.31	0.7329	1.21	0.3106
14	5.69 ± 1.7	4.96 ± 2.15	5.8 ± 1.7	10.57 ± 2.15	6.06 ± 1.7	5.55 ± 2.15	0.55	0.4623	1.25	0.2991	1.29	0.288
15	6.86 ± 1.81	4.73 ± 2.29	5.95 ± 1.81	9.69 ± 2.29	4.12 ± 1.81	3.91 ± 2.29	0.08	0.7829	1.71	0.1971	1.06	0.3587

* Within phase and day comparisons of individual means are significantly different at $p<0.05$ with Tukey's Test .

Table A8.1 : Average absolute intake of powder and granular carbohydrate (least square means kcal±SEM) in rats fed a choice between a protein-rich and a carbohydrate-rich diet over 24 h.

	24h		texture df (1,12)	
day	powder (n=12)	granular (n=12)	F value	p
1	40.16 ± 6.05	61.58 ± 6.98 *	5.37	0.0389
2	41.15 ± 6.18	53.23 ± 7.14	1.63	0.2254
3	39.93 ± 4.51	49.11 ± 5.2	1.78	0.2071
4	36.75 ± 3.46	39.79 ± 4	0.33	0.5752
5	39.36 ± 3.89	34.74 ± 4.49	0.6	0.4523
6	42.4 ± 4.01	39.03 ± 4.63	0.3	0.5926
7	39.01 ± 4	37.76 ± 4.62	0.04	0.8408
8	40.25 ± 3.83	38.82 ± 4.42	0.06	0.81
9	40.63 ± 4.36	38.9 ± 5.04	0.07	0.8006
10	42.4 ± 3.59	36.06 ± 4.15	1.33	0.2704
11	46.15 ± 4.19	37.37 ± 4.83	1.88	0.195
12	46.2 ± 5.11	43.43 ± 5.9	0.13	0.7285
13	39.92 ± 3.5	42.43 ± 4.04	0.22	0.6475
14	42.66 ± 3.75	41.53 ± 4.33	0.04	0.8465
15	41.05 ± 3.49	41.73 ± 4.02	0.02	0.9002

* Within day comparisons of individual means are significantly different at $p<0.05$.

Table A8.2 : Average absolute intake of powder and granular carbohydrate (least square means kcal±SEM) in rats fed a choice between a protein-rich and a carbohydrate-rich diet during the 12h dark and light phases of the diurnal cycle.

	12h dark		12h light		texture df (1,24)		phase df (1,24)		interaction df (1,24)	
day	powder (n=12)	granular (n=12)	powder (n=12)	granular (n=12)	F value	p	F value	p	F value	p
1	35.51 ± 3.75 ac	41.24 ± 4.32 a	4.65 ± 3.75 b	20.34 ± 4.32 bc	7	0.0141	40.94	0.0001	1.51	0.2304
2	29.49 ± 3.4 *	33.49 ± 3.92	11.67 ± 3.4	19.73 ± 3.92	2.71	0.1128	18.54	0.0002	0.31	0.5848
3	31.14 ± 2.79 *	33.53 ± 3.23 *	8.79 ± 2.79	15.58 ± 3.23	2.31	0.1414	44.58	0.0001	0.53	0.4724
4	28.87 ± 2.48 *	30.61 ± 2.86 *	7.88 ± 2.48	9.18 ± 2.86	0.32	0.5749	62.66	0.0001	0.01	0.935
5	29.2 ± 2.35 *	26.19 ± 2.71 *	10.16 ± 2.35	8.55 ± 2.71	0.83	0.3722	52.23	0.0001	0.08	0.7837
6	36.06 ± 2.55 *	30.71 ± 2.95 *	6.34 ± 2.55	8.32 ± 2.95	0.37	0.5473	89.42	0.0001	1.77	0.1956
7	34.74 ± 2.74 *	31.87 ± 3.17 *	4.26 ± 2.74	5.89 ± 3.17	0.04	0.8342	90.85	0.0001	0.58	0.4547
8	32.34 ± 2.94 *	30.73 ± 3.39 *	7.92 ± 2.94	8.08 ± 3.39	0.05	0.8229	55.03	0.0001	0.08	0.7829
9	33.87 ± 2.65 *	29.33 ± 3.06 *	6.75 ± 2.65	9.57 ± 3.06	0.09	0.7661	67.19	0.0001	1.66	0.2103
10	35.72 ± 2.61 *	28.45 ± 3.02 *	6.67 ± 2.61	7.61 ± 3.02	1.26	0.2729	78.04	0.0001	2.11	0.1589
11	33.55 ± 2.65 *	29 ± 3.06 *	12.6 ± 2.65	8.37 ± 3.06	2.36	0.1379	52.88	0.0001	0	0.9548
12	36.41 ± 3.07 *	32.28 ± 3.54 *	9.79 ± 3.07	11.15 ± 3.54	0.17	0.6795	51.89	0.0001	0.69	0.4148
13	30.9 ± 2.6 *	31.5 ± 3 *	9.02 ± 2.6	10.93 ± 3	0.2	0.659	57.15	0.0001	0.05	0.8173
14	32.98 ± 2.69 *	29.15 ± 3.1 *	9.68 ± 2.69	12.38 ± 3.1	0.04	0.8469	47.71	0.0001	1.27	0.2711
15	26.15 ± 2.8 *	25.37 ± 3.23 *	8.09 ± 2.8	11.6 ± 3.23	0.2	0.6562	27.72	0.0001	0.5	0.4842

abc Within day comparisons of individual means.
Means with different letters are significantly different at $p<0.05$ with Tukey's Test.

* Within texture and day comparisons of individual means are significantly different at $p<0.05$ with Tukey's Test.

Table A8.3: Average absolute intake of powder and granular carbohydrate (least square means kcal±SEM) in rats fed a choice between a protein-rich and a carbohydrate-rich diet during the 4 h early, middle and late dark phases of the diurnal cycle.

	early dark		middle dark		late dark		texture		phase		interaction	
							df (1,36)		df (2,36)		df (2,36)	
day	powder (n=12)	granular (n=12)	powder (n=12)	granular (n=12)	powder (n=12)	granular (n=12)	F value	p	F value	p	F value	p
1	12.2 ± 2.56	14.68 ± 2.96	10.38 ± 2.56	12.6 ± 2.96	12.93 ± 2.56	13.96 ± 2.96	0.71	0.4035	0.33	0.7199	0.04	0.9615
2	13.72 ± 1.91	14.36 ± 2.2	9.85 ± 1.91	10.44 ± 2.2	5.92 ± 1.91	8.7 ± 2.2	0.63	0.4329	5.37	0.0091	0.18	0.8329
3	13.91 ± 1.55	13.35 ± 1.78	8.58 ± 1.55	9.77 ± 1.78	8.65 ± 1.55	10.4 ± 1.78	0.34	0.563	4.4	0.0195	0.26	0.7728
4	12.48 ± 1.27	10.51 ± 1.47	7.38 ± 1.27	7.98 ± 1.47	9.01 ± 1.27	12.12 ± 1.47	0.27	0.6067	4.2	0.023	1.72	0.1936
5	13.06 ± 1.69	13.06 ± 1.95	6.27 ± 1.69	7.43 ± 1.95	9.87 ± 1.69	5.7 ± 1.95	0.45	0.5055	6.71	0.0033	1.18	0.3189
6	16.02 ± 1.5 a	13.81 ± 1.73	10.74 ± 1.5 ab	7.34 ± 1.73	9.3 ± 1.5 b	9.57 ± 1.73	1.81	0.1868	8.18	0.0012	0.67	0.5203
7	16.43 ± 1.69 a	13.98 ± 1.96	8.53 ± 1.69 b	9.33 ± 1.96	9.78 ± 1.69 ab	8.56 ± 1.96	0.41	0.5252	7.55	0.0018	0.4	0.6725
8	13.36 ± 1.86	13.85 ± 2.15	11.25 ± 1.86	8.63 ± 2.15	7.73 ± 1.86	8.26 ± 2.15	0.11	0.7469	4.01	0.0269	0.4	0.6708
9	14.21 ± 1.47 a	11.92 ± 1.69	11.81 ± 1.47 ab	7.9 ± 1.69	7.85 ± 1.47 b	9.51 ± 1.69	1.37	0.2492	4.12	0.0244	1.63	0.2099
10	15.5 ± 1.71	12.86 ± 1.98	11.08 ± 1.71	9.74 ± 1.98	9.16 ± 1.71	5.85 ± 1.98	2.59	0.1163	6.55	0.0037	0.15	0.8633
11	12.79 ± 1.28	10.64 ± 1.48	12.98 ± 1.28	9.81 ± 1.48	7.78 ± 1.28	8.54 ± 1.48	1.79	0.1888	4.01	0.0267	1.09	0.348
12	13.19 ± 1.89	12.57 ± 2.18	14.33 ± 1.89	11.05 ± 2.18	8.9 ± 1.89	8.66 ± 2.18	0.69	0.4132	2.57	0.0904	0.33	0.7212
13	12.23 ± 1.74	14.11 ± 2.01	12.05 ± 1.74	7.45 ± 2.01	6.62 ± 1.74	9.94 ± 2.01	0.02	0.8973	3.56	0.0388	2.51	0.0958
14	12.7 ± 1.9	11.51 ± 2.2	12.49 ± 1.9	9.87 ± 2.2	7.79 ± 1.9	7.77 ± 2.2	0.58	0.4516	2.46	0.0996	0.2	0.8183
15	12.66 ± 1.51	11.7 ± 1.74	12.84 ± 1.51	9.84 ± 1.74	7.46 ± 1.51	8.59 ± 1.74	0.5	0.4835	3.63	0.0360	0.8	0.4559

ab Within texture and day comparisons of individual means.
Means with different letters are significantly different at $p<0.05$ with Tukey's Test.

Table A9.1 : Average total intake (least square means g±SEM) of rats fed a choice between high protein powder and high carbohydrate granular (HPP-HCG) diets or high protein granular and high carbohydrate powder (HPG-HCP) diets over 24 h.

	24h			dietary group df (1,5)	
day	HPP-HCG (n=12)	HPG-HCP (n=12)		F value	p
1	21.73 ± 1.26	21.97 ± 1.26		0.02	0.9021
2	18 ± 1.6	22.73 ± 1.6		4.38	0.1046
3	17.63 ± 1.31	21.57 ± 1.31		4.54	0.1002
4	15.17 ± 2.21	20.33 ± 2.21		2.73	0.1736
5	13.67 ± 0.49	21.93 ± 0.49	*	143.7	0.0003
6	15.33 ± 0.81	23.77 ± 0.81	*	54.34	0.0018
7	14 ± 2.31	22.63 ± 2.31		6.97	0.0576
8	17.9 ± 2.2	23.07 ± 2.2		2.75	0.1727
9	16.47 ± 0.9	24.53 ± 0.9	*	40.61	0.0031
10	17.23 ± 1.98	23.7 ± 1.98		5.33	0.0822
11	18.63 ± 1.61	24.37 ± 1.61		6.36	0.0652
12	20.77 ± 1.97	23.9 ± 1.97		1.26	0.3243
13	21.4 ± 2.54	22.87 ± 2.54		0.17	0.7035
14	21.53 ± 1.93	24.67 ± 1.93		1.32	0.3139
15	22.43 ± 2.55	23.8 ± 2.55		0.14	0.7236

* Within day comparisons of individual means are significantly different at $p<0.05$.

Table A9.2 : Average total intake (least square means g±SEM) of rats fed a choice between high protein powder and high carbohydrate granular (HPP-HCG) diets or high protein granular and high carbohydrate powder (HPG-HCP) diets during the 12h dark and light phases of the diurnal cycle.

	12h dark		12h light		dietary group df (1,10)		phase df (1,10)		interaction df (1,10)	
day	HPP-HCG (n=12)	HPG-HCP (n=12)	HPP-HCG (n=12)	HPG-HCP (n=12)	F value	p	F value	p	F value	p
1	13.9 ± 1.08 *	19.7 ± 1.24 *	6.58 ± 1.08	2.27 ± 1.24	0.41	0.5357	113.35	0.0001	18.89	0.0015
2	11.6 ± 1.03 *	16.4 ± 1.18 *	6.68 ± 1.03	6.33 ± 1.18	4.05	0.072	45.76	0.0001	5.38	0.0428
3	14.35 ± 2.1	17.67 ± 2.42 *	6.05 ± 2.1	3.9 ± 2.42	0.07	0.8019	23.75	0.0006	1.46	0.2551
4	13.43 ± 2.06 *	15.8 ± 2.37 *	3.68 ± 2.06	4.53 ± 2.37	0.53	0.4834	22.38	0.0008	0.12	0.7399
5	12.05 ± 1.53 *	17.7 ± 1.77 *	3.8 ± 1.53	4.23 ± 1.77	3.38	0.0959	43.07	0.0001	2.49	0.146
6	13.18 ± 1.53 *	19.03 ± 1.76 *	4.65 ± 1.53	4.73 ± 1.76	3.25	0.1016	47.97	0.0001	3.07	0.1103
7	13.33 ± 1.73 *	18.73 ± 1.99 *	2.8 ± 1.73	3.9 ± 1.99	3.04	0.1117	46.19	0.0001	1.33	0.2751
8	13.63 ± 2.16	18.9 ± 2.5 *	6.2 ± 2.16	4.17 ± 2.5	0.48	0.5032	22.53	0.0008	2.45	0.1485
9	14.23 ± 1.39 *	19.5 ± 1.6 *	4.1 ± 1.39	5.03 ± 1.6	4.3	0.0648	67.52	0.0001	2.1	0.1775
10	15.05 ± 1.31 *	19.3 ± 1.51 *	4.05 ± 1.31	4.4 ± 1.51	2.64	0.135	83.84	0.0001	1.9	0.198
11	15.35 ± 0.84 a	18.17 ± 0.97 a	4.25 ± 0.84 b	6.2 ± 0.97 b	6.96	0.0248	162.96	0.0001	0.23	0.6418
12	15.9 ± 1.04 *	18.43 ± 1.2 *	5.78 ± 1.04	5.47 ± 1.2	0.98	0.3452	105.7	0.0001	1.6	0.2345
13	16.1 ± 1.43 *	16.97 ± 1.65 *	5.85 ± 1.43	5.9 ± 1.65	0.09	0.7722	47.84	0.0001	0.07	0.7964
14	22.3 ± 3.74	18.37 ± 4.32	9.08 ± 3.74	6.3 ± 4.32	0.69	0.4262	9.78	0.0107	0.02	0.889
15	9.48 ± 1.38 b	17.67 ± 1.59 a	5.78 ± 1.38 b	6.13 ± 1.59 b	8.27	0.0165	26.27	0.0004	6.95	0.0249

ab Within day comparisons of individual means.
Means with different letters are significantly different at $p<0.05$ with Tukey's Test.

* Within group and day comparisons of individual means are significantly different at $p<0.05$ with Tukey' s Test.

Table A9.3 : Average total intake (least square means g±SEM) of rats fed a choice between high protein powder and high carbohydrate granular (HPP-HCG) diets or high protein granular and high carbohydrate powder (HPG-HCP) diets during the 4 h early, middle and late dark phases of the diurnal cycle.

	early dark		middle dark		late dark		dietary group		phase		interaction	
							df (1,15)		df (2,15)		df (2,15)	
day	HPP-HCG (n=12)	HPG-HCP (n=12)	HPP-HCG (n=12)	HPG-HCP (n=12)	HPP-HCG (n=12)	HPG-HCP (n=12)	F value	p	F value	p	F value	p
1	4.73 ± 1.16	6.57 ± 1.16	5.47 ± 1.16	4.73 ± 1.16	4.27 ± 1.16	8.4 ± 1.16	3.39	0.0904	0.57	0.5816	2.2	0.1533
2	4.63 ± 1.19	7.13 ± 1.19	4.2 ± 1.19	3.33 ± 1.19	2.53 ± 1.19	5.93 ± 1.19	2.99	0.1095	1.75	0.2153	1.79	0.2088
3	3.83 ± 0.93	8.4 ± 0.93 *	4 ± 0.93	4.17 ± 0.93	3.43 ± 0.93	5.1 ± 0.93	7.91	0.0157	2.93	0.092	2.9	0.094
4	3.63 ± 1.09	6.23 ± 1.09	3.2 ± 1.09	4.8 ± 1.09	3.93 ± 1.09	4.77 ± 1.09	3.57	0.0831	0.38	0.6942	0.33	0.7237
5	4.67 ± 0.55 b	8.2 ± 0.55 a	3.23 ± 0.55 bc	5.27 ± 0.55 b	1.47 ± 0.55 c	4.23 ± 0.55 b	38.04	0.0001	21.44	0.0001	0.92	0.4232
6	4.5 ± 0.98 ab	8.5 ± 0.98 a	2.77 ± 0.98 b	6.83 ± 0.98 ab	3.4 ± 0.98 b	3.7 ± 0.98 b	12.21	0.0044	4.59	0.0331	2.43	0.1298
7	4.3 ± 0.96	7.77 ± 0.96	3.4 ± 0.96	5.67 ± 0.96	3.17 ± 0.96	5.3 ± 0.96	11.08	0.006	2	0.1781	0.29	0.7535
8	4.4 ± 1	8.03 ± 1	3.9 ± 1	6.97 ± 1	2.63 ± 1	3.9 ± 1	10.57	0.0069	4.67	0.0317	0.76	0.4878
9	4.67 ± 0.7	7.83 ± 0.7	3.13 ± 0.7	6.4 ± 0.7	4.4 ± 0.7	5.27 ± 0.7	18.2	0.0011	2.88	0.0953	1.89	0.1936
10	5.03 ± 0.98	7.47 ± 0.98	4.47 ± 0.98	7.77 ± 0.98	3.83 ± 0.98	4.27 ± 0.98	6.66	0.0241	3.2	0.0771	1.14	0.3534
11	5.73 ± 1.17	6.37 ± 1.17	3.87 ± 1.17	7.5 ± 1.17	5.07 ± 1.17	4.3 ± 1.17	1.5	0.2446	0.73	0.5004	1.85	0.1989
12	4.47 ± 1.2	6.4 ± 1.2	6.1 ± 1.2	7.9 ± 1.2	4.37 ± 1.2	4.13 ± 1.2	1.42	0.2567	2.64	0.1119	0.51	0.6117
13	6.37 ± 1.52	5.6 ± 1.52	2.9 ± 1.52	7.5 ± 1.52	5.93 ± 1.52	3.87 ± 1.52	0.23	0.6435	0.27	0.7671	2.71	0.1072
14	7.5 ± 1.91	5.67 ± 1.91	6.5 ± 1.91	8.8 ± 1.91	7.83 ± 1.91	3.9 ± 1.91	0.55	0.4718	0.44	0.6517	1.39	0.2874
15	5.53 ± 1.23	5 ± 1.23	5.57 ± 1.23	8.47 ± 1.23	4.77 ± 1.23	4.2 ± 1.23	0.36	0.5616	2.22	0.1512	1.31	0.3059

abc Within day comparisons of individual means.
Means with different letters are signlficantly different at $p<0.05$ with Tukey's Test.

* Within phase and day comparisons of individual means are significantly different at $p<0.05$ with Tukey's Test.

Table A10.1 : Average total intake (least square means kcal±SEM) of rats fed a choice between high protein powder and high carbohydrate granular (HPP-HCG) diets or high protein granular and high carbohydrate powder (HPG-HCP) diets over 24 h.

	24h			dietary group df (1,5)	
day	HPP-HCG (n=12)	HPG-HCP (n=12)		F value	p
1	83.13 ± 4.56	87.88 ± 5.27		0.46	0.5264
2	71.1 ± 5.15	90.92 ± 5.94		6.35	0.0531
3	69.56 ± 4.26	86.39 ± 4.92	*	6.68	0.0491
4	55.36 ± 7.95	81.59 ± 9.18		4.67	0.0831
5	51.13 ± 2.87	88.14 ± 3.31	*	71.35	0.0004
6	58.04 ± 3.32	95.33 ± 3.84	*	53.98	0.0007
7	55.69 ± 7.27	90.78 ± 8.39	*	9.99	0.0251
8	66.45 ± 7.96	92.44 ± 9.19		4.57	0.0856
9	64.55 ± 2.95	98.27 ± 3.4	*	56.16	0.0007
10	65.32 ± 6.86	94.98 ± 7.92	*	8.02	0.0366
11	67.62 ± 7.42	97.6 ± 8.57	*	6.98	0.0458
12	74.37 ± 9.19	95.79 ± 10.61		2.33	0.1876
13	78.25 ± 9.84	91.67 ± 11.36		0.8	0.4128
14	76.69 ± 9.46	98.82 ± 10.92		2.35	0.1861
15	77.3 ± 12.55	95.38 ± 14.49		0.89	0.389

* Within day comparisons of individual means are significantly different at $p<0.05$.

Table A10.2 : Average total intake (least square means kcal±SEM) of rats fed a choice between high protein powder and high carbohydrate granular (HPP-HCG) diets or high protein granular and high carbohydrate powder (HPG-HCP) diets during the 12h dark and light phases of the diurnal cycle.

	12h dark		12h light		dietary group		phase		interaction	
					df (1,10)		df (1,10)		df (1,10)	
day	HPP-HCG (n=12)	HPG-HCP (n=12)	HPP-HCG (n=12)	HPG-HCP (n=12)	F value	p	F value	p	F value	p
1	54.79 ± 4.11 *	78.75 ± 4.74 *	28.35 ± 4.11	9.12 ± 4.74	0.29	0.6048	117.14	0.0001	23.68	0.0007
2	46.24 ± 4.28 *	65.67 ± 4.94 *	24.85 ± 4.28	25.25 ± 4.94	4.59	0.0578	44.66	0.0001	4.24	0.0666
3	46.85 ± 5.31 *	70.73 ± 6.14 *	22.72 ± 5.31	15.66 ± 6.14	2.15	0.1735	47.61	0.0001	7.26	0.0225
4	41.1 ± 5.99 *	63.38 ± 6.92 *	14.26 ± 5.99	18.21 ± 6.92	4.1	0.0703	30.94	0.0002	2.01	0.1869
5	36.44 ± 1.92 c	71.12 ± 2.22 b	14.69 ± 1.92 a	17.02 ± 2.22 a	79.3	0.0001	333.12	0.0001	60.55	0.0001
6	43.38 ± 3.44 c	76.3 ± 3.97 b	14.66 ± 3.44 a	19.03 ± 3.97 a	25.23	0.0005	134.15	0.0001	14.79	0.0032
7	45.16 ± 4.58 c	75.08 ± 5.29 b	10.53 ± 4.58 a	15.7 ± 5.29 a	12.57	0.0053	90.26	0.0001	6.26	0.0314
8	45.53 ± 7.34	75.82 ± 8.48 *	20.92 ± 7.34	16.62 ± 8.48	2.69	0.1322	27.93	0.0004	4.76	0.0541
9	48.52 ± 3.38 c	78.13 ± 3.9 b	16.03 ± 3.38 a	20.14 ± 3.9 a	21.36	0.0009	153.75	0.0001	12.21	0.0058
10	52.86 ± 4.07 c	77.33 ± 4.7 b	12.45 ± 4.07 a	17.65 ± 4.7 a	11.4	0.0071	129.72	0.0001	4.81	0.053
11	54.5 ± 4.07 a	72.8 ± 4.7 a	13.13 ± 4.07 b	24.79 ± 4.7 b	11.63	0.0066	103.46	0.0001	0.57	0.4675
12	55.55 ± 4.98 *	73.89 ± 5.74 *	18.81 ± 4.98	21.9 ± 5.74	3.97	0.0742	68.15	0.0001	2.01	0.1862
13	57.13 ± 6.07 *	68.02 ± 7.01 *	21.13 ± 6.07	23.65 ± 7.01	1.05	0.3305	37.54	0.0001	0.41	0.5379
14	56.5 ± 6.86 *	73.63 ± 7.93 *	20.19 ± 6.86	25.19 ± 7.93	2.23	0.1665	32.67	0.0002	0.67	0.4321
15	41.31 ± 5.11 a	70.76 ± 5.9 b	21.28 ± 5.11 a	24.63 ± 5.9 a	8.84	0.014	35.96	0.0001	5.6	0.0395

abc Within day comparisons of individual means.
Means with different letters are significantly different at $p<0.05$ with Tukey's Test.

* Within group and day comparisons of individual means are significantly different at $p<0.05$ with Tukey' s Test.

Table A10.3 : Average total intake (least square means kcal±SEM) of rats fed a choice between high protein powder and high carbohydrate granular (HPP-HCG) diets or high protein granular and high carbohydrate powder (HPG-HCP) diets during the 4 h early, middle and late dark phases of the diurnal cycle.

	early dark		middle dark		late dark		dietary group		phase		interaction	
							df (1,15)		df (2,15)		df (2,15)	
day	HPP-HCG (n=12)	HPG-HCP (n=12)	HPP-HCG (n=12)	HPG-HCP (n=12)	HPP-HCG (n=12)	HPG-HCP (n=12)	F value	p	F value	p	F value	p
1	18.92 ± 3.7	26.28 ± 4.28	19.61 ± 3.7	18.87 ± 4.28	16.26 ± 3.7	33.61 ± 4.28	5.98	0.0273	1.02	0.3827	2.57	0.1101
2	19.11 ± 3.76	28.52 ± 4.35	15.95 ± 3.76	13.3 ± 4.35	11.19 ± 3.76	23.85 ± 4.35	3.8	0.0701	2.67	0.1018	1.97	0.1739
3	17.44 ± 3.1 a	33.58 ± 3.58 b	15.26 ± 3.1 a	16.67 ± 3.58 a	14.16 ± 3.1 a	20.48 ± 3.58 ab	8.49	0.0107	4.77	0.025	2.52	0.1143
4	15.15 ± 3.49	24.97 ± 4.03	11.3 ± 3.49	19.25 ± 4.03	14.65 ± 3.49	19.16 ± 4.03	5.82	0.0291	0.83	0.4543	0.26	0.7779
5	18.12 ± 2 ad	32.91 ± 2.31 b	10.99 ± 2 cd	21.23 ± 2.31 a	7.33 ± 2 c	16.98 ± 2.31 ac	43.01	0.0001	20.22	0.0001	0.85	0.4481
6	18.91 ± 3.09 ab	34.04 ± 3.56 b	11.4 ± 3.09 a	27.42 ± 3.56 bc	13.07 ± 3.09 ac	14.85 ± 3.56 ac	16.26	0.0011	7.09	0.0068	2.87	0.0883
7	18.42 ± 3.19 ab	31.09 ± 3.68 b	15.16 ± 3.19 a	22.7 ± 3.68 ab	11.58 ± 3.19 a	21.3 ± 3.68 ab	12.58	0.0029	3.07	0.0763	0.28	0.7605
8	18.14 ± 3.13 ab	32.17 ± 3.61 b	16.1 ± 3.13 ac	27.94 ± 3.61 bc	11.29 ± 3.13 a	15.72 ± 3.61 ab	13.38	0.0023	6.36	0.01	1.11	0.356
9	19.81 ± 2.34 ab	31.32 ± 2.7 b	12.59 ± 2.34 a	25.63 ± 2.7 bc	16.12 ± 2.34 ac	21.18 ± 2.7 ab	22.88	0.0002	4.69	0.0262	1.4	0.2765
10	20.47 ± 3.08 ab	29.87 ± 3.56 ab	17.13 ± 3.08 ab	31.14 ± 3.56 b	15.26 ± 3.08 a	17.14 ± 3.56 ab	9.64	0.0073	4.36	0.0323	1.69	0.2173
11	21.6 ± 3.82	25.45 ± 4.42	14.7 ± 3.82	30.07 ± 4.42	18.19 ± 3.82	17.28 ± 4.42	3.27	0.0905	1.1	0.3576	2.06	0.1626
12	19.2 ± 4.21	25.6 ± 4.86	20.75 ± 4.21	31.69 ± 4.86	15.6 ± 4.21	16.6 ± 4.86	2.71	0.1205	2.53	0.1134	0.6	0.5629
13	25.28 ± 4.98	22.42 ± 5.75	11.59 ± 4.98	30.04 ± 5.75	20.26 ± 4.98	15.56 ± 5.75	0.68	0.4214	0.61	0.5566	2.86	0.0885
14	20.6 ± 5	22.64 ± 5.77	17.67 ± 5	33.31 ± 5.77	18.23 ± 5	15.68 ± 5.77	1.68	0.2147	1.56	0.2426	1.92	0.1807
15	22.07 ± 4.54	19.97 ± 5.24	17.55 ± 4.54	33.97 ± 5.24	16.41 ± 4.54	16.82 ± 5.24	1.51	0.2385	1.74	0.2085	2.11	0.1564

abc Within day comparisons of individual means.
Means with different letters are significantly different at $p<0.05$ with Tukey's Test.

Table A11.1 : Average intake of the protein-rich diet (least square means g±SEM) in slow learning (SL) and fast learning (FL) rats fed a choice between high protein powder and high carbohydrate granular (HPP-HCG) diets over 24 h.

	24h		group df (1,6)	
day	SL (n=7)	FL (n=5)	F value	p
1	0.63 ± 0.1	0.8 ± 0.27	0.36	0.5729
2	0.2 ± 0.06	0.2 ± 0.16	0	1
3	0.77 ± 0.13	11.6 ± 0.35 *	816.14	0.0001
4	0.11 ± 0.09	9.5 ± 0.23 *	1498.78	0.0001
5	0.51 ± 0.09	11.3 ± 0.23 *	1979.25	0.0001
6	0.26 ± 0.09	11.9 ± 0.25 *	1887	0.0001
7	0.63 ± 0.11	10.7 ± 0.29 *	1035.47	0.0001
8	1.69 ± 1.55	10.1 ± 4.11	3.67	0.104
9	1.89 ± 1.12	9.6 ± 2.97	5.92	0.051
10	2.53 ± 1.62	10.7 ± 4.29	3.18	0.1249
11	3.49 ± 1.78	10.8 ± 4.72	2.1	0.1974
12	4.01 ± 2	11.8 ± 5.3	1.89	0.2183
13	6.61 ± 2.34	11.3 ± 6.18	0.5	0.505
14	6.14 ± 2.18	12.2 ± 5.78	0.96	0.3645
15	6.96 ± 2.32	10.1 ± 6.13	0.23	0.6484

* Within day comparisons of individual means are significantly different at $p<0.05$.

Table A11.2 : Average intake of the protein-rich diet (least square means g±SEM) in slow learning (SL) and fast learning (FL) rats fed a choice between high protein powder and high carbohydrate granular (HPP-HCG) diets during the 12 h dark and light phases of the diurnal cycle.

	12h dark		12h light		group		phase		interaction	
					df (1,12)		df (1,12)		df (1,12)	
day	SL (n=7)	FL (n=5)	SL (n=7)	FL (n=5)	F value	p	F value	p	F value	p
1	0.23 ± 0.08	0.4 ± 0.21	0.4 ± 0.08	0.4 ± 0.21	0.3	0.5939	0.3	0.5939	0.3	0.5939
2	0.14 ± 0.04	0.2 ± 0.1	0.06 ± 0.04	0 ± 0.1	0	1	3.75	0.0767	0.6	0.4536
3	0.23 ± 0.09 a	11.2 ± 0.23 b	0.54 ± 0.09 a	0.4 ± 0.23 a	945.01	0.0001	886.11	0.0001	995.53	0.0001
4	0.09 ± 0.05 a	8.4 ± 0.12 b	0.03 ± 0.05 a	1.1 ± 0.12 c	2529.19	0.0001	1554.05	0.0001	1506.15	0.0001
5	0.17 ± 0.05 a	9.2 ± 0.12 b	0.34 ± 0.05 a	2.1 ± 0.12 c	3562..66	0.0001	1470.16	0.0001	1619.26	0.0001
6	0.23 ± 0.06 a	9.7 ± 0.16 b	0.03 ± 0.06 a	2.2 ± 0.16 c	2306.34	0.0001	1008.75	0.0001	906.67	0.0001
7	0.17 ± 0.07 a	9.6 ± 0.19 b	0.46 ± 0.07 a	1.1 ± 0.19 c	1294.34	0.0001	861	0.0001	984.96	0.0001
8	0.51 ± 0.87 a	9.4 ± 2.31 bc	1.17 ± 0.87 a	0.7 ± 2.31 ac	5.82	0.0328	5.32	0.0398	7.2	0.0199
9	1.17 ± 0.68 a	8.5 ± 1.79 bc	0.71 ± 0.68 a	1.1 ± 1.79 ac	8.11	0.0147	8.42	0.0133	6.57	0.0248
10	2.09 ± 0.95 ab	9.3 ± 2.53 b	0.44 ± 0.95 a	1.4 ± 2.53 ab	4.58	0.0536	6.25	0.028	2.69	1.1272
11	2.39 ± 1.06	9.2 ± 2.8	1.1 ± 1.06	1.6 ± 2.8	2.99	0.1093	4.41	0.0574	2.23	0.1613
12	2.91 ± 1.14	10 ± 3.01	1.1 ± 1.14	1.8 ± 3.01	2.93	0.1127	4.85	0.048	1.97	1.1857
13	3.97 ± 1.22	9.6 ± 3.23	2.64 ± 1.22	1.7 ± 3.23	0.92	0.3569	3.56	0.0836	1.81	0.2039
14	5.2 ± 1.35	11.7 ± 3.57	0.94 ± 1.35	0.5 ± 3.57	1.26	0.2834	8.21	0.0142	1.66	0.2223
15	4.39 ± 1.28	2.4 ± 3.37	1.71 ± 1.28	0.4 ± 3.37	0.42	0.53	0.84	0.3779	0.02	0.8975

abc Within day comparisons of individual means.
Means with different letters are significantly different at $p<0.05$ with Tukey's Test.

Table A11.3 : Average intake of the protein-rich diet (least square means g±SEM) in slow learning (SL) and fast learning (FL) rats fed a choice between high protein powder and high carbohydrate granular (HPP-HCG) diets during the 4 h early, middle and late dark phases of the diurnal cycle.

	early dark		middle dark		late dark		group		phase		interaction	
							df (1,18)		df (2,18)		df (2,18)	
day	SL (n=7)	FL (n=5)	SL (n=7)	FL (n=5)	SL (n=7)	FL (n=5)	F value	p	F value	p	F value	p
1	0.06 ± 0.04	0 ± 0.1	0.06 ± 0.04	0 ± 0.1	0.11 ± 0.04	0.4 ± 0.1	0.84	0.3705	6	0.0101	3.37	0.0569
2	0.03 ± 0.03	0 ± 0.08	0.11 ± 0.03	0 ± 0.08	0 ± 0.03	0.2 ± 0.08	0.17	0.6879	1.13	0.3464	4.04	0.0355
3	0.11 ± 0.04 a	2 ± 0.1 b	0.09 ± 0.04 a	5.3 ± 0.1 c	0.03 ± 0.04 a	3.9 ± 0.1 d	3686.4	0.0001	246.79	0.0001	257.64	0.0001
4	0.03 ± 0.04 a	1.3 ± 0.1 b	0.06 ± 0.04 a	3 ± 0.1 c	0 ± 0.04 a	4.1 ± 0.1 d	2117	0.0001	180.02	0.0001	185.79	0.0001
5	0.06 ± 0.03 a	2.5 ± 0.08 b	0.11 ± 0.03 a	4.2 ± 0.08 c	0 ± 0.03 a	2.5 ± 0.08 b	3404.2	0.0001	133.27	0.0001	108.93	0.0001
6	0.03 ± 0.03 a	1.6 ± 0.09 b	0.14 ± 0.03 a	5.3 ± 0.09 c	0.06 ± 0.03 a	2.8 ± 0.09 d	3170	0.0001	401.85	0.0001	354.4	0.0001
7	0.06 ± 0.03 a	2.1 ± 0.08 b	0.11 ± 0.03 a	4 ± 0.08 c	0 ± 0.03 a	3.5 ± 0.08 d	3712.5	0.0001	125.51	0.0001	118.36	0.0001
8	0.13 ± 0.18 a	1.7 ± 0.49 ac	0.3 ± 0.18 a	4.7 ± 0.49 b	0.09 ± 0.18 a	3 ± 0.49 bc	97.24	0.0001	9.42	0.0016	7.4	0.0045
9	0.61 ± 0.36 a	1.9 ± 0.96 ac	0.13 ± 0.36 a	3.9 ± 0.96 bc	0.43 ± 0.36 a	2.7 ± 0.96 ac	17.01	0.0006	0.55	0.5857	1.49	0.2522
10	0.46 ± 0.57	2.2 ± 1.51	0.54 ± 0.57	4.5 ± 1.51	1.09 ± 0.57	2.6 ± 1.51	6.62	0.0192	0.55	0.5885	0.69	0.5124
11	1.16 ± 0.56	2.5 ± 1.48	0.31 ± 0.56	5.8 ± 1.48 *	0.91 ± 0.56	0.9 ± 1.48	6.22	0.0226	1.87	0.183	3.3	0.0602
12	0.51 ± 0.6	3.1 ± 1.58	1.34 ± 0.6	4.1 ± 1.58	1.06 ± 0.6	2.8 ± 1.58	5.88	0.026	0.35	0.7116	0.1	0.9021
13	1.93 ± 0.68	3.1 ± 1.8	0.53 ± 0.68	6.3 ± 1.8	1.51 ± 0.68	0.2 ± 1.8	2.86	0.1079	1.82	0.1899	3.5	0.0519
14	1.76 ± 0.71	3.3 ± 1.87	1.63 ± 0.71	4.5 ± 1.87	1.81 ± 0.71	3.9 ± 1.87	3.53	0.0764	0.07	0.9297	0.11	0.8947
15	2.34 ± 0.75	2.4 ± 2	1.59 ± 0.75	5.2 ± 2	1.31 ± 0.75	2.1 ± 2	1.45	0.2434	0.63	0.5421	0.78	0.4752

abcd Within day comparisons of individual means.
Means with different letters are significantly different at $p<0.05$ with Tukey's Test.

* Within phase and day comparisons of individual means are significantly different at $p<0.05$ with Tukey's Test.

Table A12.1 : Average absolute intake of protein (least square means g±SEM) in slow learning (SL) and fast learning (FL) rats fed a choice between high protein powder and high carbohydrate granular (HPP-HCG) diets over 24 h.

	24h		group df (1,6)	
day	SL (n=7)	FL (n=5)	F value	p
1	0.46 ± 0.07	0.58 ± 0.2	0.36	0.5729
2	0.15 ± 0.05	0.15 ± 0.12	0	1
3	0.56 ± 0.1	8.47 ± 0.26 *	816.14	0.0001
4	0.08 ± 0.06	6.94 ± 0.17 *	1498.78	0.0001
5	0.38 ± 0.06	8.25 ± 0.17 *	1979.25	0.0001
6	0.19 ± 0.07	8.69 ± 0.18 *	1887	0.0001
7	0.46 ± 0.08	7.81 ± 0.21 *	1035.47	0.0001
8	1.23 ± 1.13	7.37 ± 3	3.67	0.104
9	1.38 ± 0.82	7.01 ± 2.17	5.92	0.051
10	1.85 ± 1.18	7.81 ± 3.13	3.18	0.1249
11	2.54 ± 1.3	7.88 ± 3.45	2.1	0.1974
12	2.93 ± 1.46	8.61 ± 3.87	1.89	0.2183
13	4.83 ± 1.71	8.25 ± 4.51	0.5	0.505
14	4.48 ± 1.59	8.91 ± 4.22	0.96	0.3645
15	5.08 ± 1.69	7.37 ± 4.47	0.23	0.6484

* Within day comparisons of individual means are significantly different at $p<0.05$.

Table A12.2 : Average absolute intake of protein (least square means g±SEM) in slow learning (SL) and fast learning (FL) rats fed a choice between high protein powder and high carbohydrate granular (HPP-HCG) diets during the 12h dark and light phases of the diurnal cycle.

					group		phase		interaction	
	12h dark		12h light		df (1,12)		df (1,12)		df (1,12)	
day	SL (n=7)	FL (n=5)	SL (n=7)	FL (n=5)	F value	p	F value	p	F value	p
1	0.17 ± 0.06	0.29 ± 0.15	0.29 ± 0.06	0.29 ± 0.15	0.3	0.5939	0.3	0.5939	0.3	0.5939
2	0.1 ± 0.03	0.15 ± 0.07	0.04 ± 0.03	0 ± 0.07	0	1	3.75	0.0767	0.6	0.4536
3	0.17 ± 0.06 a	8.18 ± 0.17 b	0.4 ± 0.06 a	0.29 ± 0.17 a	945.01	0.0001	886.11	0.0001	995.53	0.0001
4	0.06 ± 0.03 a	6.13 ± 0.09 b	0.02 ± 0.03 a	0.8 ± 0.09 c	2529.19	0.0001	1554.05	0.0001	1506.15	0.0001
5	0.13 ± 0.03 a	6.72 ± 0.09 b	0.25 ± 0.03 a	1.53 ± 0.09 c	3562..66	0.0001	1470.16	0.0001	1619.26	0.0001
6	0.17 ± 0.04 a	7.08 ± 0.12 b	0.02 ± 0.04 a	1.61 ± 0.12 c	2306.34	0.0001	1008.75	0.0001	906.67	0.0001
7	0.13 ± 0.05 a	7.01 ± 0.14 b	0.33 ± 0.05 a	0.8 ± 0.14 c	1294.34	0.0001	861	0.0001	984.96	0.0001
8	0.38 ± 0.64 a	6.86 ± 1.68 bc	0.86 ± 0.64 a	0.51 ± 1.68 ac	5.82	0.0328	5.32	0.0398	7.2	0.0199
9	0.86 ± 0.49 a	6.21 ± 1.31 bc	0.52 ± 0.49 a	0.8 ± 1.31 ac	8.11	0.0147	8.42	0.0133	6.57	0.0248
10	1.52 ± 0.7 ab	6.79 ± 1.84 b	0.32 ± 0.7 a	1.02 ± 1.84 ab	4.58	0.0536	6.25	0.028	2.69	1.1272
11	1.74 ± 0.77	6.72 ± 2.04	0.8 ± 0.77	1.17 ± 2.04	2.99	0.1093	4.41	0.0574	2.23	0.1613
12	2.13 ± 0.83	7.3 ± 2.2	0.8 ± 0.83	1.31 ± 2.2	2.93	0.1127	4.85	0.048	1.97	1.1857
13	2.9 ± 0.89	7.01 ± 2.36	1.93 ± 0.89	1.24 ± 2.36	0.92	0.3569	3.56	0.0836	1.81	0.2039
14	3.8 ± 0.98	8.54 ± 2.6	0.69 ± 0.98	0.37 ± 2.6	1.26	0.2834	8.21	0.0142	1.66	0.2223
15	3.2 ± 0.93	1.75 ± 2.46	1.25 ± 0.93	0.29 ± 2.46	0.42	0.53	0.84	0.3779	0.02	0.8975

abc Within day comparisons of individual means.
Means with different letters are significantly different at $p<0.05$ with Tukey's Test.

Table A12.3 : Average absolute intake of protein (least square means g±SEM) in slow learning (SL) and fast learning (FL) rats fed a choice between high protein powder and high carbohydrate granular (HPP-HCG) diets during the 4 h early, middle and late dark phases of the diurnal cycle.

	early dark		middle dark		late dark		group		phase		interaction	
							df (1,18)		df (2,18)		df (2,18)	
day	SL (n=7)	FL (n=5)	SL (n=7)	FL (n=5)	SL (n=7)	FL (n=5)	F value	p	F value	p	F value	p
1	0.04 ± 0.03	0 ± 0.07	0.04 ± 0.03	0 ± 0.07	0.08 ± 0.03	0.29 ± 0.07	0.84	0.3705	6	0.0101	3.37	0.0569
2	0.02 ± 0.02	0 ± 0.06	0.08 ± 0.02	0 ± 0.06	0 ± 0.02	0.15 ± 0.06	0.17	0.6879	1.13	0.3464	4.04	0.0355
3	0.08 ± 0.03 a	1.46 ± 0.07 b	0.06 ± 0.03 a	3.87 ± 0.07 c	0.02 ± 0.03 a	2.85 ± 0.07 d	3686.4	0.0001	246.79	0.0001	257.64	0.0001
4	0.02 ± 0.03 a	0.95 ± 0.07 b	0.04 ± 0.03 a	2.19 ± 0.07 c	0 ± 0.03 a	2.99 ± 0.07 d	2117	0.0001	180.02	0.0001	185.79	0.0001
5	0.04 ± 0.02 a	1.83 ± 0.06 b	0.08 ± 0.02 a	3.07 ± 0.06 c	0 ± 0.02 a	1.83 ± 0.06 b	3404.2	0.0001	133.27	0.0001	108.93	0.0001
6	0.02 ± 0.03 a	1.17 ± 0.07 b	0.1 ± 0.03 a	3.87 ± 0.07 c	0.04 ± 0.03 a	2.04 ± 0.07 d	3170	0.0001	401.85	0.0001	354.4	0.0001
7	0.04 ± 0.02 a	1.53 ± 0.06 b	0.08 ± 0.02 a	2.92 ± 0.06 c	0 ± 0.02 a	2.56 ± 0.06 d	3712.5	0.0001	125.51	0.0001	118.36	0.0001
8	0.09 ± 0.13 a	1.24 ± 0.36 ac	0.22 ± 0.13 a	3.43 ± 0.36 b	0.06 ± 0.13 a	2.19 ± 0.36 bc	97.24	0.0001	9.42	0.0016	7.4	0.0045
9	0.45 ± 0.26 a	1.39 ± 0.7 ac	0.09 ± 0.26 a	2.85 ± 0.7 bc	0.31 ± 0.26 a	1.97 ± 0.7 ac	17.01	0.0006	0.55	0.5857	1.49	0.2522
10	0.33 ± 0.42	1.61 ± 1.11	0.4 ± 0.42	3.29 ± 1.11	0.79 ± 0.42	1.9 ± 1.11	6.62	0.0192	0.55	0.5885	0.69	0.5124
11	0.84 ± 0.41	1.83 ± 1.08	0.23 ± 0.41	4.23 ± 1.08 *	0.67 ± 0.41	0.66 ± 1.08	6.22	0.0226	1.87	0.183	3.3	0.0602
12	0.38 ± 0.44	2.26 ± 1.15	0.98 ± 0.44	2.99 ± 1.15	0.77 ± 0.44	2.04 ± 1.15	5.88	0.026	0.35	0.7116	0.1	0.9021
13	1.41 ± 0.5	2.26 ± 1.31	0.39 ± 0.5	4.6 ± 1.31	1.11 ± 0.5	0.15 ± 1.31	2.86	0.1079	1.82	0.1899	3.5	0.0519
14	1.28 ± 0.52	2.41 ± 1.36	1.19 ± 0.52	3.29 ± 1.36	1.32 ± 0.52	2.85 ± 1.36	3.53	0.0764	0.07	0.9297	0.11	0.8947
15	1.71 ± 0.55	1.75 ± 1.46	1.16 ± 0.55	3.8 ± 1.46	0.96 ± 0.55	1.53 ± 1.46	1.45	0.2434	0.63	0.5421	0.78	0.4752

abcd Within day comparisons of individual means.
Means with different letters are significantly different at $p<0.05$ with Tukey's Test.

* Within phase and day comparisons of individual means are significantly different at $p<0.05$ with Tukey's Test.

Table A13.1 : Average intake of the protein-rich diet (least square means kcal±SEM) in slow learning (SL) and fast learning (FL) rats fed a choice between high protein powder and high carbohydrate granular (HPP-HCG) diets over 24 h.

	24h		group df (1,6)	
day	SL (n=7)	FL (n=5)	F value	p
1	2.56 ± 0.41	3.26 ± 1.09	0.36	0.5729
2	0.81 ± 0.25	0.81 ± 0.66	0	1
3	3.14 ± 0.55	47.21 ± 1.44 *	816.14	0.0001
4	0.47 ± 0.35	38.67 ± 0.92 *	1498.78	0.0001
5	2.09 ± 0.35	45.99 ± 0.92 *	1979.25	0.0001
6	1.05 ± 0.39	48.43 ± 1.02 *	1887	0.0001
7	2.56 ± 0.45	43.55 ± 1.19 *	1035.47	0.0001
8	6.86 ± 6.32	41.11 ± 16.7	3.67	0.104
9	7.67 ± 4.56	39.07 ± 12.1	5.92	0.051
10	10.29 ± 6.6	43.55 ± 17.5	3.18	0.1249
11	14.19 ± 7.26	43.96 ± 19.2	2.1	0.1974
12	16.34 ± 8.15	48.03 ± 21.6	1.89	0.2183
13	26.92 ± 9.51	45.99 ± 25.2	0.5	0.505
14	25 ± 8.88	49.65 ± 23.5	0.96	0.3645
15	28.32 ± 9.43	41.11 ± 24.9	0.23	0.6484

* Within day comparisons of individual means are significantly different at $p<0.05$.

Table A13.2 : Average intake of the protein-rich diet (least square means kcal±SEM) in slow learning (SL) and fast learning (FL) rats fed a choice between high protein powder and high carbohydrate granular (HPP-HCG) diets during the 12h dark and light phases of the diurnal cycle.

	12h dark		12h light		group		phase		interaction	
					df (1,12)		df (1,12)		df (1,12)	
day	SL (n=7)	FL (n=5)	SL (n=7)	FL (n=5)	F value	p	F value	p	F value	p
1	0.93 ± 0.32	1.63 ± 0.84	1.63 ± 0.32	1.63 ± 0.84	0.3	0.5939	0.3	0.5939	0.3	0.5939
2	0.58 ± 0.15	0.81 ± 0.4	0.23 ± 0.15	0 ± 0.4	0	1	3.75	0.0767	0.6	0.4536
3	0.93 ± 0.36 a	45.58 ± 0.95 b	2.21 ± 0.36 a	1.63 ± 0.95 a	945.01	0.0001	886.11	0.0001	995.53	0.0001
4	0.35 ± 0.19 a	34.19 ± 0.5 b	0.12 ± 0.19 a	4.48 ± 0.5 c	2529.19	0.0001	1554.05	0.0001	1506.15	0.0001
5	0.7 ± 0.18 a	37.44 ± 0.49 b	1.4 ± 0.18 a	8.55 ± 0.49 c	3562..66	0.0001	1470.16	0.0001	1619.26	0.0001
6	0.93 ± 0.25 a	39.48 ± 0.65 b	0.12 ± 0.25 a	8.95 ± 0.65 c	2306.34	0.0001	1008.75	0.0001	906.67	0.0001
7	0.7 ± 0.28 a	39.07 ± 0.75 b	1.86 ± 0.28 a	4.48 ± 0.75 c	1294.34	0.0001	861	0.0001	984.96	0.0001
8	2.09 ± 3.55 a	38.26 ± 9.39 bc	4.77 ± 3.55 a	2.85 ± 9.39 ac	5.82	0.0328	5.32	0.0398	7.2	0.0199
9	4.77 ± 2.76 a	34.6 ± 7.29 bc	2.91 ± 2.76 a	4.48 ± 7.29 ac	8.11	0.0147	8.42	0.0133	6.57	0.0248
10	8.49 ± 3.89 ab	37.85 ± 10.3 b	1.8 ± 3.89 a	5.7 ± 10.3 ab	4.58	0.0536	6.25	0.028	2.69	1.1272
11	9.71 ± 4.3	37.44 ± 11.4	4.48 ± 4.3	6.51 ± 11.4	2.99	0.1093	4.41	0.0574	2.23	0.1613
12	11.86 ± 4.63	40.7 ± 12.3	4.48 ± 4.63	7.33 ± 12.3	2.93	0.1127	4.85	0.048	1.97	1.1857
13	16.16 ± 4.98	39.07 ± 13.2	10.76 ± 4.98	6.92 ± 13.2	0.92	0.3569	3.56	0.0836	1.81	0.2039
14	21.16 ± 5.49	47.62 ± 14.5	3.84 ± 5.49	2.04 ± 14.5	1.26	0.2834	8.21	0.0142	1.66	0.2223
15	17.85 ± 5.19	9.77 ± 13.7	6.98 ± 5.19	1.63 ± 13.7	0.42	0.53	0.84	0.3779	0.02	0.8975

abc Within day comparisons of individual means.
Means with different letters are significantly different at $p<0.05$ with Tukey's Test.

Table A13.3 : Average intake of the protein-rich diet (least square means kcal±SEM) in slow learning (SL) and fast learning (FL) rats fed a choice between high protein powder and high carbohydrate granular (HPP-HCG) diets during the 4 h early, middle and late dark phases of the diurnal cycle.

	early dark		middle dark		late dark		group		phase		interaction	
							df (1,18)		df (2,18)		df (2,18)	
day	SL (n=7)	FL (n=5)	SL (n=7)	FL (n=5)	SL (n=7)	FL (n=5)	F value	p	F value	p	F value	p
1	0.23 ± 0.16	0 ± 0.41	0.23 ± 0.16	0 ± 0.41	0.47 ± 0.16	1.63 ± 0.41	0.84	0.3705	6	0.0101	3.37	0.0569
2	0.12 ± 0.12	0 ± 0.31	0.47 ± 0.12	0 ± 0.31	0 ± 0.12	0.81 ± 0.31	0.17	0.6879	1.13	0.3464	4.04	0.0355
3	0.47 ± 0.15 a	8.14 ± 0.4 b	0.35 ± 0.15 a	21.57 ± 0.4 c	0.12 ± 0.15 a	15.87 ± 0.4 d	3686.4	0.0001	246.79	0.0001	257.64	0.0001
4	0.12 ± 0.15 a	5.29 ± 0.4 b	0.23 ± 0.15 a	12.21 ± 0.4 c	0 ± 0.15 a	16.69 ± 0.4 d	2117	0.0001	180.02	0.0001	185.79	0.0001
5	0.23 ± 0.13 a	10.18 ± 0.34 b	0.47 ± 0.13 a	17.09 ± 0.34 c	0 ± 0.13 a	10.18 ± 0.34 b	3404.2	0.0001	133.27	0.0001	108.93	0.0001
6	0.12 ± 0.14 a	6.51 ± 0.37 b	0.58 ± 0.14 a	21.57 ± 0.37 c	0.23 ± 0.14 a	11.4 ± 0.37 d	3170	0.0001	401.85	0.0001	354.4	0.0001
7	0.23 ± 0.13 a	8.55 ± 0.34 b	0.47 ± 0.13 a	16.28 ± 0.34 c	0 ± 0.13 a	14.25 ± 0.34 d	3712.5	0.0001	125.51	0.0001	118.36	0.0001
8	0.52 ± 0.75 a	6.92 ± 1.98 ac	1.22 ± 0.75 a	19.13 ± 1.98 b	0.35 ± 0.75 a	12.21 ± 1.98 bc	97.24	0.0001	9.42	0.0016	7.4	0.0045
9	2.5 ± 1.48 a	7.73 ± 3.91 ac	0.52 ± 1.48 a	15.87 ± 3.91 bc	1.74 ± 1.48 a	10.99 ± 3.91 ac	17.01	0.0006	0.55	0.5857	1.49	0.2522
10	1.86 ± 2.33	8.95 ± 6.17	2.21 ± 2.33	18.32 ± 6.17	4.42 ± 2.33	10.58 ± 6.17	6.62	0.0192	0.55	0.5885	0.69	0.5124
11	4.71 ± 2.27	10.18 ± 6.01	1.28 ± 2.27	23.61 ± 6.01 *	3.72 ± 2.27	3.66 ± 6.01	6.22	0.0226	1.87	0.183	3.3	0.0602
12	2.09 ± 2.43	12.62 ± 6.42	5.47 ± 2.43	16.69 ± 6.42	4.3 ± 2.43	11.4 ± 6.42	5.88	0.026	0.35	0.7116	0.1	0.9021
13	7.85 ± 2.76	12.62 ± 7.31	2.15 ± 2.76	25.64 ± 7.31	6.16 ± 2.76	0.81 ± 7.31	2.86	0.1079	1.82	0.1899	3.5	0.0519
14	7.15 ± 2.87	13.43 ± 7.6	6.63 ± 2.87	18.32 ± 7.6	7.38 ± 2.87	15.87 ± 7.6	3.53	0.0764	0.07	0.9297	0.11	0.8947
15	9.54 ± 3.07	9.77 ± 8.12	6.45 ± 3.07	21.16 ± 8.12	5.35 ± 3.07	8.55 ± 8.12	1.45	0.2434	0.63	0.5421	0.78	0.4752

abcd Within day comparisons of individual means.
Means with different letters are significantly different at $p<0.05$ with Tukey's Test.

* Within phase and day comparisons of individual means are significantly different at $p<0.05$ with Tukey's Test.

Table A14.1 : Average absolute intake of protein (least square means kcal±SEM) in slow learning (SL) and fast learning (FL) rats fed a choice between high protein powder and high carbohydrate granular (HPP-HCG) diets over 24 h.

	24h		group df (1,6)	
day	SL (n=7)	FL (n=5)	F value	p
1	1.84 ± 0.3	2.34 ± 0.79	0.36	0.5729
2	0.58 ± 0.18	0.58 ± 0.48	0	1
3	2.25 ± 0.39	33.87 ± 1.04 *	816.14	0.0001
4	0.33 ± 0.25	27.74 ± 0.66 *	1498.78	0.0001
5	1.5 ± 0.25	33 ± 0.66 *	1979.25	0.0001
6	0.75 ± 0.28	34.75 ± 0.73 *	1887	0.0001
7	1.84 ± 0.32	31.24 ± 0.85 *	1035.47	0.0001
8	4.92 ± 4.54	29.49 ± 12	3.67	0.104
9	5.51 ± 3.27	28.03 ± 8.66	5.92	0.051
10	7.38 ± 4.73	31.24 ± 12.5	3.18	0.1249
11	10.18 ± 5.21	31.54 ± 13.8	2.1	0.1974
12	11.78 ± 5.83	34.46 ± 15.4	1.89	0.2183
13	19.31 ± 6.82	33 ± 18.1	0.5	0.505
14	17.94 ± 6.37	35.62 ± 16.9	0.96	0.3645
15	20.31 ± 6.76	29.49 ± 17.9	0.23	0.6484

* Within day comparisons of individual means are significantly different at $p<0.05$.

Table A14.2 : Average absolute intake of protein (least square means kcal±SEM) in slow learning (SL) and fast learning (FL) rats fed a choice between high protein powder and high carbohydrate granular (HPP-HCG) diets during the 12h dark and light phases of the diurnal cycle.

	12h dark		12h light		group		phase		interaction	
					df (1,12)		df (1,12)		df (1,12)	
day	SL (n=7)	FL (n=5)	SL (n=7)	FL (n=5)	F value	p	F value	p	F value	p
1	0.67 ± 0.23	1.17 ± 0.6	1.17 ± 0.23	1.17 ± 0.6	0.3	0.5939	0.3	0.5939	0.3	0.5939
2	0.42 ± 0.11	0.58 ± 0.28	0.17 ± 0.11	0 ± 0.28	0	1	3.75	0.0767	0.6	0.4536
3	0.67 ± 0.26 a	32.7 ± 0.68 b	1.59 ± 0.26 a	1.17 ± 0.68 a	945.01	0.0001	886.11	0.0001	995.53	0.0001
4	0.25 ± 0.14 a	24.53 ± 0.36 b	0.08 ± 0.14 a	3.21 ± 0.36 c	2529.19	0.0001	1554.05	0.0001	1506.15	0.0001
5	0.5 ± 0.13 a	26.86 ± 0.35 b	1 ± 0.13 a	6.13 ± 0.35 c	3562..66	0.0001	1470.16	0.0001	1619.26	0.0001
6	0.67 ± 0.18 a	28.32 ± 0.47 b	0.08 ± 0.18 a	6.42 ± 0.47 c	2306.34	0.0001	1008.75	0.0001	906.67	0.0001
7	0.5 ± 0.2 a	28.03 ± 0.54 b	1.33 ± 0.2 a	3.21 ± 0.54 c	1294.34	0.0001	861	0.0001	984.96	0.0001
8	1.5 ± 2.55 a	27.45 ± 6.74 bc	3.42 ± 2.55 a	2.04 ± 6.74 ac	5.82	0.0328	5.32	0.0398	7.2	0.0199
9	3.42 ± 1.98 a	24.82 ± 5.23 bc	2.09 ± 1.98 a	3.21 ± 5.23 ac	8.11	0.0147	8.42	0.0133	6.57	0.0248
10	6.09 ± 2.79 ab	27.16 ± 7.37 b	1.29 ± 2.79 a	4.09 ± 7.37 ab	4.58	0.0536	6.25	0.028	2.69	1.1272
11	6.97 ± 3.09	26.86 ± 8.17	3.21 ± 3.09	4.67 ± 8.17	2.99	0.1093	4.41	0.0574	2.23	0.1613
12	8.57 ± 3.31	29.2 ± 8.76	3.21 ± 3.31	5.26 ± 8.76	2.93	0.1127	4.85	0.048	1.97	1.1857
13	11.6 ± 3.57	28.03 ± 9.45	7.72 ± 3.57	4.96 ± 9.45	0.92	0.3569	3.56	0.0836	1.81	0.2039
14	15.18 ± 3.94	34.16 ± 10.4	2.75 ± 3.94	1.46 ± 10.4	1.26	0.2834	8.21	0.0142	1.66	0.2223
15	12.81 ± 3.72	7.01 ± 9.85	5.01 ± 3.72	1.17 ± 9.85	0.42	0.53	0.84	0.3779	0.02	0.8975

abc Within day comparisons of individual means.
Means with different letters are significantly different at $p<0.05$ with Tukey's Test.

Table A14.3 : Average absolute intake of protein (least square means kcal±SEM) in slow learning (SL) and fast learning (FL) rats fed a choice between high protein powder and high carbohydrate granular (HPP-HCG) diets during the 4 h early, middle and late dark phases of the diurnal cycle.

	early dark		middle dark		late dark		group		phase		interaction	
							df (1,18)		df (2,18)		df (2,18)	
day	SL (n=7)	FL (n=5)	SL (n=7)	FL (n=5)	SL (n=7)	FL (n=5)	F value	p	F value	p	F value	p
1	0.17 ± 0.11	0 ± 0.29	0.17 ± 0.11	0 ± 0.29	0.33 ± 0.11	1.17 ± 0.29	0.84	0.3705	6	0.0101	3.37	0.0569
2	0.08 ± 0.08	0 ± 0.22	0.33 ± 0.08	0 ± 0.22	0 ± 0.08	0.58 ± 0.22	0.17	0.6879	1.13	0.3464	4.04	0.0355
3	0.33 ± 0.11 a	5.84 ± 0.28 b	0.25 ± 0.11 a	15.48 ± 0.28 c	0.08 ± 0.11 a	11.39 ± 0.28 d	3686.4	0.0001	246.79	0.0001	257.64	0.0001
4	0.08 ± 0.11 a	3.8 ± 0.28 b	0.17 ± 0.11 a	8.76 ± 0.28 c	0 ± 0.11 a	11.97 ± 0.28 d	2117	0.0001	180.02	0.0001	185.79	0.0001
5	0.17 ± 0.09 a	7.3 ± 0.24 b	0.33 ± 0.09 a	12.26 ± 0.24 c	0 ± 0.09 a	7.3 ± 0.24 b	3404.2	0.0001	133.27	0.0001	108.93	0.0001
6	0.08 ± 0.1 a	4.67 ± 0.27 b	0.42 ± 0.1 a	15.48 ± 0.27 c	0.17 ± 0.1 a	8.18 ± 0.27 d	3170	0.0001	401.85	0.0001	354.4	0.0001
7	0.17 ± 0.09 a	6.13 ± 0.24 b	0.33 ± 0.09 a	11.68 ± 0.24 c	0 ± 0.09 a	10.22 ± 0.24 d	3712.5	0.0001	125.51	0.0001	118.36	0.0001
8	0.38 ± 0.54 a	4.96 ± 1.42 ac	0.88 ± 0.54 a	13.72 ± 1.42 b	0.25 ± 0.54 a	8.76 ± 1.42 bc	97.24	0.0001	9.42	0.0016	7.4	0.0045
9	1.79 ± 1.06 a	5.55 ± 2.8 ac	0.38 ± 1.06 a	11.39 ± 2.8 bc	1.25 ± 1.06 a	7.88 ± 2.8 ac	17.01	0.0006	0.55	0.5857	1.49	0.2522
10	1.33 ± 1.67	6.42 ± 4.42	1.59 ± 1.67	13.14 ± 4.42	3.17 ± 1.67	7.59 ± 4.42	6.62	0.0192	0.55	0.5885	0.69	0.5124
11	3.38 ± 1.63	7.3 ± 4.31	0.92 ± 1.63	16.94 ± 4.31 *	2.67 ± 1.63	2.63 ± 4.31	6.22	0.0226	1.87	0.183	3.3	0.0602
12	1.53 ± 1.74	9.05 ± 4.6	3.95 ± 1.74	11.97 ± 4.6	3.09 ± 1.74	8.18 ± 4.6	5.88	0.026	0.35	0.7116	0.1	0.9021
13	5.63 ± 1.98	9.05 ± 5.25	1.55 ± 1.98	18.4 ± 5.25	4.42 ± 1.98	0.58 ± 5.25	2.86	0.1079	1.82	0.1899	3.5	0.0519
14	5.13 ± 2.06	9.64 ± 5.45	4.76 ± 2.06	13.14 ± 5.45	5.3 ± 2.06	11.39 ± 5.45	3.53	0.0764	0.07	0.9297	0.11	0.8947
15	6.84 ± 2.2	7.01 ± 5.83	4.63 ± 2.2	15.18 ± 5.83	3.84 ± 2.2	6.13 ± 5.83	1.45	0.2434	0.63	0.5421	0.78	0.4752

abcd Within day comparisons of individual means.
Means with different letters are significantly different at $p<0.05$ with Tukey's Test.

* Within phase and day comparisons of individual means are significantly different at $p<0.05$ with Tukey's Test.

Table A15.1 : Number of meals consumed over 24 h in groups of rats fed a choice between high protein powder and high carbohydrate granular (HPP-HCG) diets or high protein granular and high carbohydrate powder (HPG-HCP) diets.

	number 24h		dietary group df (1,5)	
day	HPP-HCG (n=12)	HPG-HCP (n=12)	F value	p
1	10.33 ± 1.23	8 ± 1.06	2.06	0.2108
2	7.67 ± 2.06	8.25 ± 1.78	0.05	0.8387
3	9.67 ± 2.5	9.25 ± 2.16	0.02	0.9045
4	9.33 ± 2.39	9.5 ± 2.07	0	0.96
5	8.67 ± 2.23	10 ± 1.93	0.2	0.6704
6	9.67 ± 1.84	10 ± 1.59	0.02	0.8963
7	8 ± 3.17	11.75 ± 2.75	0.8	0.4122
8	10 ± 1.95	11.25 ± 1.68	0.24	0.6477
9	7 ± 1.12	13.25 ± 0.97 *	17.86	0.0083
10	8.67 ± 0.7	11.75 ± 0.61 *	10.99	0.0211
11	9.33 ± 2.28	12.5 ± 1.97	1.11	0.341
12	10 ± 1.23	12.75 ± 1.07	2.85	0.1522
13	11 ± 0.97	10 ± 0.84	0.61	0.4694
14	9.67 ± 2.4	10 ± 2.08	0.01	0.9206
15	12.67 ± 1.76	10 ± 1.53	1.31	0.3049

Values represent least square mean±SEM.

* Within day comparisons of individual means are significantly different at $p<0.05$.

Table A15.2 : Number of meals consumed during the 12 h light and dark phases in groups of rats fed a choice between high protein powder and high carbohydrate granular (HPP-HCG) diets or high protein granular and high carbohydrate powder (HPG-HCP) diets.

	number		number		dietary group		phase		interaction	
	12h dark		12h light		df (1,10)		df (1,10)		df (1,10)	
day	HPP-HCG (n=12)	HPG-HCP (n=12)	HPP-HCG (n=12)	HPG-HCP (n=12)	F value	p	F value	p	F value	p
1	8 ± 0.94 *	8 ± 0.82 *	2.33 ± 0.94	0 ± 0.82	1.75	0.2153	60.04	0.0001	1.75	0.2153
2	5.33 ± 1.48	7 ± 1.29 *	2.33 ± 1.48	1.25 ± 1.29	0.04	0.8378	9.93	0.0103	0.98	0.3453
3	6 ± 1.64	7.5 ± 1.42	3.67 ± 1.64	1.75 ± 1.42	0.02	0.8945	6.96	0.0248	1.24	0.2907
4	7 ± 1.9	7.75 ± 1.64	2.33 ± 1.9	1.75 ± 1.64	0	0.9635	9.02	0.0133	0.14	0.7153
5	6.33 ± 1.71	7.5 ± 1.48	2.33 ± 1.71	2.5 ± 1.48	0.17	0.685	7.95	0.0182	0.1	0.7605
6	7 ± 1.93	8.5 ± 1.03 *	2.67 ± 1.93	1.5 ± 1.03	0.02	0.8842	25.8	0.0005	1.43	0.2596
7	6.67 ± 2	9.75 ± 1.73 *	1.33 ± 2	2 ± 1.73	1	0.34	12.22	0.0058	0.42	0.533
8	7 ± 1.43	9.5 ± 1.24 *	3 ± 1.43	1.75 ± 1.24	0.22	0.6514	19.16	0.0014	1.95	0.1926
9	5 ± 0.81 a	10.75 ± 0.7 b	2 ± 0.81 a	2.5 ± 0.7 a	16.95	0.0021	54.93	0.0001	11.96	0.0061
10	7 ± 0.72 b	9.75 ± 0.62 b	1.67 ± 0.72 a	2 ± 0.62 a	5.29	0.0443	95.17	0.0001	3.25	0.1017
11	7.67 ± 1.45	9.25 ± 1.25 *	1.67 ± 1.45	3.25 ± 1.25	1.37	0.2693	19.64	0.0013	0	1
12	7.33 ± 0.82 *	9.75 ± 0.71 *	2.67 ± 0.82	3 ± 0.71	3.23	0.1026	55.63	0.0001	1.85	0.2034
13	9.33 ± 0.88 *	7 ± 0.76 *	1.67 ± 0.88	3 ± 0.76	0.37	0.558	50	0.0001	4.94	0.0505
14	7.67 ± 1.49	7.5 ± 1.29	2 ± 1.49	2.5 ± 1.29	0.01	0.9072	14.67	0.0033	0.06	0.8159
15	9.33 ± 1.17 *	7.75 ± 1.01 *	3.33 ± 1.17	2.25 ± 1.01	1.49	0.2498	27.76	0.0004	0.05	0.8234

Values represent least square mean ±SEM.

abc Within day comparisons of individual means.
Means with different letters are significantly different at $p<0.05$ with Tukey's Test.

* Within group and day comparisons of individual means are significantly different at $p<0.05$ with Tukey's Test.

Table A16.1 : Average duration of meals consumed over 24 h in groups of rats fed a choice between high protein powder and high carbohydrate granular (HPP-HCG) diets or high protein granular and high carbohydrate powder (HPG-HCP) diets.

	time (min) 24 h		dietary group df (1,5)	
day	HPP-HCG (n=12)	HPG-HCP (n=12)	F value	p
1	4.73 ± 0.37	4.7 ± 0.32	0	0.9516
2	5.59 ± 0.35	4.74 ± 0.31	3.29	0.1292
3	5.76 ± 0.31 *	3.81 ± 0.27	22.36	0.0052
4	5.48 ± 0.39 *	3.79 ± 0.33	10.9	0.0214
5	5.21 ± 0.77	3.69 ± 0.66	2.24	0.1945
6	5.29 ± 0.61	3.85 ± 0.53	3.19	0.134
7	5.11 ± 0.91	4.43 ± 0.79	0.32	0.5955
8	5.09 ± 0.64	4.25 ± 0.56	0.99	0.3664
9	4.06 ± 0.5	3.67 ± 0.43	0.35	0.5812
10	3.99 ± 0.41	4.33 ± 0.35	0.4	0.5561
11	3.59 ± 0.12 *	4.16 ± 0.1	13.31	0.0148
12	3.86 ± 0.34	4.04 ± 0.29	0.15	0.7136
13	3.76 ± 0.25	4.3 ± 0.22	2.65	0.1643
14	3.7 ± 0.29	4.16 ± 0.25	1.47	0.2792
15	3.91 ± 0.28	4.1 ± 0.24	0.29	0.6135

Values represent least square mean±SEM.

* Within day comparisons of individual means are significantly different at $p<0.05$.

Table A16.2 : Average duration of meals consumed during the 12 h light and dark phases in groups of rats fed a choice between high protein powder and high carbohydrate granular (HPP-HCG) diets or high protein granular and high carbohydrate powder (HPG-HCP) diets.

	time (min)		time (min)		dietary group		phase		interaction	
	12h dark		12h light		df (1,4)		df (1,4)		df	
day	HPP-HCG (n=12)	HPG-HCP (n=12)	HPP-HCG (n=12)	HPG-HCP (n=12)	F value	p	F value	p	F value	p
1	4.99 ± 0.29	5 ± 0.29	5 ± 0.49	3.83 ± 0.17	0	0.9725	0	0.9817	-	-
2	5.53 ± 0.21	4.39 ± 0.21	6.5 ± 0.37	4.45 ± 0.43	14.52	0.0189	5.3	0.0827	-	-
3	5.92 ± 0.23	3.91 ± 0.23	6.67 ± 0.4	3.53 ± 0.27	37.58	0.0036	2.6	0.1824	-	-
4	6.06 ± 0.57	4.26 ± 0.57	4.33 ± 0.99	3.79 ± 0.35	4.94	0.0903	2.27	0.2063	-	-
5	5.81 ± 1.25	4.16 ± 1.25	5.33 ± 2.17	4.23 ± 0.5	0.87	0.4038	0.04	0.858	-	-
6	5.66 ± 0.84	4.24 ± 0.84	4.5 ± 1.46	4.96 ± 1.07	1.41	0.3002	0.47	0.5296	-	-
7	5.49 ± 1.12	4.98 ± 1.12	4 ± 1.95	4.03 ± 0.48	0.1	0.7634	0.44	0.543	-	-
8	5.08 ± 0.78	4.32 ± 0.78	6.25 ± 1.36	5 ± 0.44	0.47	0.5298	0.56	0.4967	-	-
9	4.67 ± 0.74	3.92 ± 0.74	3 ± 1.28	4.58 ± 0.56	0.51	0.514	1.27	0.3221	-	-
10	3.97 ± 0.39	4.84 ± 0.39	3 ± 0.67	3.69 ± 0.23	2.49	0.1899	1.6	0.2752	-	-
11	3.64 ± 0.21	4.28 ± 0.21	3.5 ± 0.37	4.14 ± 0.28	4.5	0.1011	0.12	0.7496	-	-
12	4.06 ± 0.32	4.33 ± 0.32	4 ± 0.55	4.14 ± 0.49	0.34	0.5917	0.01	0.9254	-	-
13	3.63 ± 0.24	4.66 ± 0.24	6 ± 0.42	4.33 ± 0.4	9.02	0.0398	23.78	0.0082	-	-
14	3.58 ± 0.32	4.31 ± 0.32	4.33 ± 0.55	3.82 ± 0.31	2.66	0.1783	1.41	0.3005	-	-
15	3.89 ± 0.27	4.17 ± 0.27	4 ± 0.48	4.31 ± 0.32	0.5	0.5167	0.04	0.8541	-	-

Values represent least square mean ±SEM.
- Not available due to insufficient number of observations.

Table A17.1: Average size of meals consumed over 24 h in groups of rats fed a choice between high protein powder and high carbohydrate granular (HPP-HCG) diets or high protein granular and high carbohydrate powder (HPG-HCP) diets.

	size (g) 24h		dietary group df (1,5)	
day	HPP-HCG (n=12)	HPG-HCP (n=12)	F value	p
1	1.38 ± 0.11	1.06 ± 0.09	5.5	0.0659
2	1.54 ± 0.07 *	1.06 ± 0.06	25.76	0.0039
3	1.48 ± 0.11 *	0.84 ± 0.09	20.94	0.006
4	1.5 ± 0.11 *	0.81 ± 0.09	23.45	0.0047
5	1.34 ± 0.19	0.81 ± 0.17	4.44	0.089
6	1.41 ± 0.16	0.89 ± 0.14	5.83	0.0605
7	1.36 ± 0.23	1 ± 0.2	1.43	0.2857
8	1.35 ± 0.16	1 ± 0.14	2.61	0.1668
9	1.26 ± 0.14	0.95 ± 0.12	2.98	0.1451
10	1.17 ± 0.11	1.02 ± 0.09	1.12	0.3377
11	1.04 ± 0.08	0.96 ± 0.07	0.62	0.4656
12	1.16 ± 0.13	0.95 ± 0.12	1.52	0.2731
13	1.26 ± 0.1	1.02 ± 0.09	3.49	0.1205
14	1.25 ± 0.11	0.96 ± 0.09	4.21	0.0954
15	1.27 ± 0.11	0.95 ± 0.1	4.33	0.0921

Values represent least square mean±SEM.

* Within day comparisons of individual means are significantly different at $p<0.05$.

Table A17.2 : Average size of meals consumed during the 12 h light and dark phases in groups of rats fed a choice between high protein powder and high carbohydrate granular (HPP-HCG) diets or high protein granular and high carbohydrate powder (HPG-HCP) diets.

	size (g) 12h dark		size (g) 12h light		dietary group df (1,4)		phase df (1,4)		interaction df	
day	HPP-HCG (n=12)	HPG-HCP (n=12)	HPP-HCG (n=12)	HPG-HCP (n=12)	F value	p	F value	p	F value	p
1	1.42 ± 0.1	1.13 ± 0.1	1.75 ± 0.18	0.97 ± 0.02	4.03	0.1151	2.53	0.1872	-	-
2	1.45 ± 0.06	1 ± 0.06	2.05 ± 0.11	1.02 ± 0.1	23.36	0.0073	22.08	0.0093	-	-
3	1.59 ± 0.09	0.88 ± 0.09	1.73 ± 0.15	0.83 ± 0.08	34.07	0.0043	0.68	0.4546	-	-
4	1.7 ± 0.15	0.92 ± 0.15	1.13 ± 0.27	0.86 ± 0.09	12.92	0.0229	3.44	0.1371	-	-
5	1.6 ± 0.36	0.93 ± 0.36	1.17 ± 0.63	1.02 ± 0.15	1.71	0.2615	0.35	0.5835	-	-
6	1.57 ± 0.22	1.03 ± 0.22	1 ± 0.38	1.11 ± 0.26	3.11	0.1528	1.72	0.2603	-	-
7	1.48 ± 0.28	1.16 ± 0.28	0.8 ± 0.49	0.88 ± 0.13	0.63	0.4728	1.43	0.2975	-	-
8	1.39 ± 0.17	1.06 ± 0.17	1.63 ± 0.29	1.17 ± 0.15	1.96	0.234	0.52	0.5122	-	-
9	1.41 ± 0.1	0.97 ± 0.1	0.9 ± 0.18	1.2 ± 0.16	9.37	0.0376	6.21	0.0674	-	-
10	1.2 ± 0.08	1.16 ± 0.08	1 ± 0.14	0.87 ± 0.06	0.11	0.7599	1.51	0.2865	-	-
11	1.08 ± 0.09	1.02 ± 0.09	1.35 ± 0.15	0.95 ± 0.08	0.2	0.6754	2.53	0.1868	-	-
12	1.21 ± 0.14	1.04 ± 0.14	1.33 ± 0.24	0.95 ± 0.11	0.76	0.4323	0.18	0.6904	-	-
13	1.21 ± 0.08	1.17 ± 0.08	2.15 ± 0.13	1.01 ± 0.11	0.16	0.7138	36.98	0.0037	-	-
14	1.24 ± 0.11	1.04 ± 0.11	1.4 ± 0.2	0.91 ± 0.07	1.67	0.2662	0.48	0.5282	-	-
15	1.29 ± 0.14	1 ± 0.14	1.23 ± 0.24	0.99 ± 0.06	2.22	0.2105	0.04	0.8552	-	-

Values represent least square mean ±SEM.
- Not available due to insufficient number of observations.

Table A18.1: Average protein compositon of meals consumed over 24 h in groups of rats fed a choice between high protein powder and high carbohydrate granular (HPP-HCG) diets or high protein granular and high carbohydrate powder (HPG-HCP) diets.

	protein composition (g) 24h		dietary group df (1,5)	
day	HPP-HCG (n=12)	HPG-HCP (n=12)	F value	p
1	0.01 ± 0.13	0.49 ± 0.11 *	7.61	0.0399
2	0 ± 0.11	0.28 ± 0.09	3.87	0.1062
3	0.12 ± 0.13	0.27 ± 0.11	0.84	0.4027
4	0.09 ± 0.13	0.37 ± 0.11	2.62	0.1667
5	0.14 ± 0.11	0.33 ± 0.1	1.44	0.2843
6	0.12 ± 0.08	0.26 ± 0.07	1.7	0.2485
7	0.13 ± 0.09	0.37 ± 0.08	4.43	0.0892
8	0.21 ± 0.08	0.28 ± 0.07	0.42	0.5475
9	0.16 ± 0.13	0.39 ± 0.11	1.92	0.2243
10	0.33 ± 0.11	0.28 ± 0.1	0.14	0.7276
11	0.32 ± 0.08	0.33 ± 0.07	0.01	0.9105
12	0.32 ± 0.09	0.39 ± 0.08	0.34	0.5846
13	0.32 ± 0.11	0.41 ± 0.09	0.37	0.572
14	0.2 ± 0.15	0.42 ± 0.13	1.22	0.3202
15	0.45 ± 0.06	0.37 ± 0.05	0.88	0.3908

Values represent least square mean±SEM.

* Within day comparisons of individual means are significantly different at $p<0.05$.

Table A18.2 : Average protein composition of meals consumed during the 12 h light and dark phases in groups of rats fed a choice between high protein powder and high carbohydrate granular (HPP-HCG) diets or high protein granular and high carbohydrate powder (HPG-HCP) diets.

	protein composition (g) 12h dark		protein composition (g) 12h light		dietary group df (1,4)		phase df (1,4)		interaction df	
day	HPP-HCG (n=12)	HPG-HCP (n=12)	HPP-HCG (n=12)	HPG-HCP (n=12)	F value	p	F value	p	F value	p
1	0 ± 0.06	0.62 ± 0.06	0 ± 0.1	0.42 ± 0.28	58.23	0.0016	0	1	-	-
2	0 ± 0.08	0.37 ± 0.08	0 ± 0.13	0.41 ± 0.18	11.48	0.0276	0	1	-	-
3	0.17 ± 0.15	0.32 ± 0.15	0 ± 0.25	0.34 ± 0.11	0.53	0.5066	0.33	0.5971	-	-
4	0.09 ± 0.08	0.47 ± 0.08	0 ± 0.15	0.38 ± 0.13	10	0.0341	0.3	0.6104	-	-
5	0.13 ± 0.1	0.34 ± 0.1	0 ± 0.17	0.23 ± 0.08	2.11	0.2199	0.44	0.5433	-	-
6	0.11 ± 0.11	0.28 ± 0.11	0 ± 0.19	0.17 ± 0.09	1.26	0.3251	0.28	0.6249	-	-
7	0.13 ± 0.11	0.29 ± 0.11	0 ± 0.18	0.3 ± 0.11	1.22	0.3318	0.35	0.5865	-	-
8	0.2 ± 0.11	0.33 ± 0.11	0.43 ± 0.19	0.06 ± 0.03	0.72	0.4451	1.05	0.3641	-	-
9	0.09 ± 0.08	0.3 ± 0.08	0.9 ± 0.14	0.5 ± 0.24	3.26	0.1455	24.58	0.0077	-	-
10	0.41 ± 0.1	0.37 ± 0.1	0 ± 0.18	0.41 ± 0.11	0.1	0.772	4.09	0.113	-	-
11	0.36 ± 0.11	0.35 ± 0.11	0 ± 0.18	0.31 ± 0.1	0.01	0.9188	2.95	0.1612	-	-
12	0.31 ± 0.13	0.43 ± 0.13	0.27 ± 0.22	0.34 ± 0.11	0.48	0.5274	0.02	0.8848	-	-
13	0.38 ± 0.1	0.49 ± 0.1	0 ± 0.16	0.35 ± 0.11	0.72	0.4428	4.47	0.102	-	-
14	0.24 ± 0.14	0.56 ± 0.14	0.2 ± 0.25	0.38 ± 0.09	2.5	0.189	0.02	0.9018	-	-
15	0.48 ± 0.07	0.42 ± 0.07	0.27 ± 0.13	0.32 ± 0.11	0.23	0.6555	1.96	0.2344	-	-

Values represent least square mean ±SEM.
- Not available due to insufficient number of observations.

Table A19.1: Average carbohydrate compositon of meals consumed over 24 h in groups of rats fed a choice between high protein powder and high carbohydrate granular (HPP-HCG) diets or high protein granular and high carbohydrate powder (HPG-HCP) diets.

	carbohydrate composition (g) 24h		dietary group df (1,5)	
day	HPP-HCG (n=12)	HPG-HCP (n=12)	F value	p
1	1.38 ± 0.08 *	0.57 ± 0.07	61.35	0.0005
2	1.54 ± 0.17 *	0.78 ± 0.15	11.04	0.021
3	1.36 ± 0.15 *	0.57 ± 0.13	16.36	0.0099
4	1.41 ± 0.14 *	0.44 ± 0.12	28.74	0.003
5	1.2 ± 0.26	0.48 ± 0.23	4.31	0.0926
6	1.3 ± 0.22	0.64 ± 0.19	4.97	0.0761
7	1.23 ± 0.3	0.63 ± 0.26	2.33	0.1873
8	1.14 ± 0.2	0.72 ± 0.17	2.45	0.1783
9	1.11 ± 0.11 *	0.56 ± 0.09	15.69	0.0107
10	0.84 ± 0.1	0.74 ± 0.08	0.54	0.4967
11	0.72 ± 0.11	0.63 ± 0.09	0.43	0.5424
12	0.84 ± 0.17	0.55 ± 0.15	1.7	0.2488
13	0.94 ± 0.13	0.61 ± 0.11	3.6	0.1163
14	1.04 ± 0.22	0.54 ± 0.19	3.16	0.1358
15	0.82 ± 0.13	0.58 ± 0.12	1.83	0.2343

Values represent least square mean±SEM.

* Within day comparisons of individual means are significantly different at $p<0.05$.

Table A19.2 : Average carbohydrate composition of meals consumed during the 12 h light and dark phases in groups of rats fed a choice between high protein powder and high carbohydrate granular (HPP-HCG) diets or high protein granular and high carbohydrate powder (HPG-HCP) diets.

	carbohydrate composition (g) 12h dark		carbohydrate composition (g) 12h light		dietary group df (1,4)		phase df (1,4)		interaction df	
day	HPP-HCG (n=12)	HPG-HCP (n=12)	HPP-HCG (n=12)	HPG-HCP (n=12)	F value	p	F value	p	F value	p
1	1.42 ± 0.07	0.5 ± 0.07	1.75 ± 0.12	0.55 ± 0.29	85.27	0.0008	5.47	0.0795	-	-
2	1.45 ± 0.13	0.63 ± 0.13	2.05 ± 0.22	0.61 ± 0.2	21.23	0.01	5.65	0.0762	-	-
3	1.42 ± 0.27	0.57 ± 0.27	1.73 ± 0.27	0.48 ± 0.16	15.57	0.0169	1.01	0.3722	-	-
4	1.61 ± 0.22	0.45 ± 0.22	1.13 ± 0.38	0.49 ± 0.15	13.89	0.0204	1.17	0.3394	-	-
5	1.47 ± 0.43	0.59 ± 0.43	1.17 ± 0.75	0.79 ± 0.18	2.04	0.2265	0.12	0.7482	-	-
6	1.46 ± 0.3	0.74 ± 0.3	1 ± 0.52	0.94 ± 0.31	2.8	0.1697	0.58	0.4904	-	-
7	1.35 ± 0.38	0.87 ± 0.38	0.8 ± 0.65	0.58 ± 0.16	0.82	0.4162	0.54	0.5049	-	-
8	1.18 ± 0.26	0.73 ± 0.26	1.2 ± 0.44	1.11 ± 0.15	1.58	0.2771	0	0.9773	-	-
9	1.32 ± 0.13	0.67 ± 0.13	0 ± 0.23	0.7 ± 0.15	11.9	0.026	24.35	0.0078	-	-
10	0.79 ± 0.12	0.8 ± 0.12	1 ± 0.21	0.46 ± 0.16	0	0.972	0.75	0.4359	-	-
11	0.71 ± 0.13	0.68 ± 0.13	1.35 ± 0.22	0.64 ± 0.13	0.05	0.8412	6.37	0.0651	-	-
12	0.91 ± 0.21	0.61 ± 0.21	1.07 ± 0.36	0.62 ± 0.18	1.03	0.3677	0.15	0.7194	-	-
13	0.83 ± 0.13	0.68 ± 0.13	2.15 ± 0.22	0.65 ± 0.19	0.7	0.4491	26.71	0.0067	-	-
14	1 ± 0.25	0.47 ± 0.25	1.2 ± 0.43	0.53 ± 0.12	2.25	0.2083	0.15	0.7175	-	-
15	0.81 ± 0.2	0.57 ± 0.2	0.97 ± 0.36	0.66 ± 0.13	0.68	0.4558	0.14	0.7244	-	-

Values represent least square mean ±SEM.

- Not available due to insufficient number of observations.

Table A20.1: Average intermeal interval over 24 h in groups of rats fed a choice between high protein powder and high carbohydrate granular (HPP-HCG) diets or high protein granular and high carbohydrate powder (HPG-HCP) diets.

	Intermeal interval (min) 24h		dietary group df (1,5)	
day	HPP-HCG (n=12)	HPG-HCP (n=12)	F value	p
1	88.6 ± 17.4	75.9 ± 15.1	0.3	0.6081
2	170.3 ± 51.4	118.1 ± 44.5	0.59	0.4777
3	128 ± 25.9	106.9 ± 22.4	0.38	0.565
4	110.7 ± 36.7	111.8 ± 31.8	0	0.9827
5	130.4 ± 44.4	128.7 ± 38.5	0	0.978
6	143.4 ± 21	80.3 ± 18.2	5.15	0.0725
7	105.5 ± 34.7	114.6 ± 30	0.04	0.8507
8	135.5 ± 37.3	100.9 ± 32.3	0.49	0.5146
9	153 ± 15.3 *	80.5 ± 13.2	12.86	0.0158
10	107.6 ± 13.4	85 ± 11.6	1.61	0.2602
11	144.8 ± 24.5	99.7 ± 21.2	1.93	0.2231
12	120.5 ± 11.3	98 ± 9.8	2.27	0.1925
13	100.2 ± 12.7	107.3 ± 11	0.18	0.6902
14	97.7 ± 32.1	127.2 ± 27.8	0.48	0.5176
15	93.6 ± 19.5	99.3 ± 16.9	0.05	0.8329

Values represent least square mean±SEM.

* Within day comparisons of individual means are significantly different at $p<0.05$.

Table A20.2 : Average intermeal interval during the 12 h light and dark phases in groups of rats fed a choice between high protein powder and high carbohydrate granular (HPP-HCG) diets or high protein granular and high carbohydrate powder (HPG-HCP) diets.

	intermeal interval (min) 12h dark		intermeal interval (min) 12h light		dietary group df (1,4)		phase df (1,4)		interaction df	
day	HPP-HCG (n=12)	HPG-HCP (n=12)	HPP-HCG (n=12)	HPG-HCP (n=12)	F value	p	F value	p	F value	p
1	83 ± 16.5	82.5 ± 16.5	143.2 ± 19.6	39.5 ± 28.9	0	0.9853	-	-	-	-
2	151.1 ± 29.3	66.9 ± 29.3	189 ± 44.5	202 ± 49.4	4.13	0.112	-	-	-	-
3	105.4 ± 6.8	67.2 ± 6.8	174.2 ± 49.9	174.1 ± 30.8	15.84	0.0164	-	-	-	-
4	100.9 ± 13.9	70.2 ± 13.9	110.8 ± 32.1	152.2 ± 26.2	2.44	0.1935	-	-	-	-
5	120.5 ± 29.9	83.1 ± 29.9	154.5 ± 32.8	126.8 ± 14.6	0.78	0.4271	-	-	-	-
6	119.7 ± 18.1	68.8 ± 18.1	192.3 ± 46.6	134.4 ± 48.8	3.95	0.1177	-	-	-	-
7	107.9 ± 24.9	68.6 ± 24.9	131.2 ± 67.7	148.3 ± 48.9	1.25	0.3264	-	-	-	-
8	120.7 ± 14.7	59.2 ± 14.7	137.3 ± 37.6	196.9 ± 50.5	8.78	0.0414	-	-	-	-
9	142 ± 11	64.4 ± 11	150.9 ± 41.5	136.8 ± 44.3	24.78	0.0076	-	-	-	-
10	111.5 ± 13.6	71.5 ± 13.6	161.9 ± 54.8	160.2 ± 45.6	4.29	0.107	-	-	-	-
11	132.2 ± 10.5	62.6 ± 10.5	264.8 ± 57.4	174.4 ± 40.3	22.07	0.0093	-	-	-	-
12	125.9 ± 17.3	72.2 ± 17.3	231.5 ± 64.9	206.9 ± 39.6	4.82	0.0932	-	-	-	-
13	82.4 ± 10.2	84 ± 10.2	236.9 ± 64	198.1 ± 32.5	0.01	0.9187	-	-	-	-
14	93.9 ± 27.8	102.8 ± 27.8	86.4 ± 30.7	159.8 ± 39.5	0.05	0.8309	-	-	-	-
15	83.5 ± 9.4	68.8 ± 9.4	122.6 ± 32	168.1 ± 30.4	1.22	0.3312	-	-	-	-

Values represent least square mean ±SEM.
- Not available due to insufficient number of observations.

Table A21.1: Number of meals consumed over 24 h in two subgroups
[high protein powder high carbohydrate granular slow learners (HPP-HCG-SL)
and high protein powder high carbohydrate granular fast learners (HPP-HCG-FL)]
of rats fed a choice between high protein powder and high carbohydrate granular diets.

	number 24h		group df (1,1)	
day	HPP-HCG-SL (n=7)	HPP-HCG-FL (n=5)	F value	p
1	10 ± 2	11 ± 2.8	0.08	0.8211
2	9 ± 1	5 ± 1.4	5.33	0.2601
3	11 ± 2	7 ± 2.8	1.33	0.4544
4	9 ± 1	10 ± 1.4	0.33	0.6667
5	7 ± 1	12 ± 1.4	8.33	0.2123
6	8.5 ± 1.5	12 ± 2.1	1.81	0.4065
7	7.5 ± 1.5	9 ± 2.1	0.33	0.6667
8	8.5 ± 0.5	13 ± 0.7	27	0.121
9	7.5 ± 1.5	6 ± 2.1	0.33	0.6667
10	9 ± 1	8 ± 1.4	0.33	0.6667
11	10.5 ± 0.5	7 ± 0.7	16.33	0.1544
12	9.5 ± 0.5	11 ± 0.7	3	0.3333
13	11 ± 0	11 ± 0	-	-
14	9.5 ± 0.5	10 ± 0.7	0.33	0.6667
15	12.5 ± 2.5	13 ± 3.5	0.01	0.9268

Values represent least square mean±SEM.
- Not available due to insufficient number of observations.
* Within day comparisons of individual means are significantly different at $p<0.05$.

Table A21.2 : Number of meals consumed during the 12 h light and dark phases in two subgroups [high protein powder high carbohydrate granular-slow learners (HPP-HCG-SL) and high protein powder high carbohydrate granular-fast learners (HPP-HCG-FL)] of rats fed a choice between high protein powder and high carbohydrate granular diets.

	number		number		group		phase		interaction	
	12h dark		12h light		df (1,2)		df (1,2)		df (1,2)	
day	HPP-HCG-SL (n=7)	HPP-HCG-FL (n=5)	HPP-HCG-SL (n=7)	HPP-HCG-FL (n=5)	F value	p	F value	p	F value	p
1	7 ± 1	10 ± 1.41	3 ± 1	1 ± 1.41	0.17	0.7226	28.17	0.0337	4.17	0.178
2	6 ± 0.71	4 ± 1	3 ± 0.71	1 ± 1	5.33	0.1472	12	0.0742	0	1
3	6.5 ± 1.12	5 ± 1.58	4.5 ± 1.12	2 ± 1.58	2.13	0.2816	3.33	0.2094	0.13	0.75
4	5.5 ± 0.5	10 ± 0.71 *	3.5 ± 0.5	0 ± 0.71	0.67	0.5	96	0.0103	42.67	0.0226
5	4 ± 0.71	11 ± 1 *	3 ± 0.71	1 ± 1	8.33	0.102	40.33	0.0239	27	0.0351
6	5.5 ± 0.79	10 ± 1.12	3 ± 0.79	2 ± 1.12	3.27	0.2124	29.4	0.0324	8.07	0.1048
7	5.5 ± 0.79	9 ± 1.12	2 ± 0.79	0 ± 1.12	0.6	0.5196	41.67	0.0232	8.07	0.1048
8	5.5 ± 0.79	10 ± 1.12	3 ± 0.79	3 ± 1.12	5.4	0.1458	24.07	0.0391	5.4	0.1458
9	5.5 ± 0.79	4 ± 1.12	2 ± 0.79	2 ± 1.12	0.6	0.5196	8.07	0.1048	0.6	0.5196
10	7 ± 1.58	7 ± 2.24	2 ± 1.58	1 ± 2.24	0.07	0.8204	8.07	0.1048	0.07	0.8204
11	9 ± 0.35 *	5 ± 0.5	1.5 ± 0.35	2 ± 0.5	16.33	0.0561	147	0.0067	27	0.0351
12	6.5 ± 0.35 *	9 ± 0.5 *	3 ± 0.35	2 ± 0.5	3	0.2254	147	0.0067	16.33	0.0561
13	9.5 ± 0.5 *	9 ± 0.71 *	1.5 ± 0.5	2 ± 0.71	0	1	150	0.0066	0.67	0.5
14	8 ± 1.27	7 ± 1.8	1.5 ± 1.27	3 ± 1.8	0.03	0.8875	11.31	0.0782	0.64	0.5073
15	8.5 ± 1.46	11 ± 2.06	4 ± 1.46	2 ± 2.06	0.02	0.9015	14.29	0.0634	1.59	0.3347

Values represent least square mean ±SEM.

* Within group and day comparisons of individual means are significantly different at $p<0.05$ with Tukey's Test.

Table A22.1: Average duration of meals consumed over 24 h in two subgroups [high protein powder high carbohydrate granular slow learners (HPP-HCG-SL) and high protein powder high carbohydrate granular fast learners (HPP-HCG-FL)] of rats fed a choice between high protein powder and high carbohydrate granular diets.

	time (min) 24h		group df (1,1)	
day	HPP-HCG-SL (n=7)	HPP-HCG-FL (n=5)	F value	p
1	4.92 ± 0.33	4.36 ± 0.47	0.92	0.5137
2	5.49 ± 0.39	5.8 ± 0.55	0.22	0.7226
3	5.65 ± 0.8	6 ± 1.13	0.07	0.8403
4	5.68 ± 0.58	5.1 ± 0.81	0.33	0.6667
5	6.02 ± 1.15	3.58 ± 1.62	1.51	0.435
6	5.98 ± 0.88	3.92 ± 1.24	1.84	0.4048
7	6.11 ± 0.56	3.11 ± 0.79	9.72	0.1976
8	5.79 ± 0.46	3.69 ± 0.65	6.99	0.2302
9	4.42 ± 1.13	3.33 ± 1.61	0.31	0.6784
10	4.11 ± 0.51	3.75 ± 0.72	0.17	0.7532
11	3.67 ± 0.03	3.43 ± 0.04	18.9	0.1439
12	4.02 ± 0.58	3.55 ± 0.82	0.23	0.717
13	3.95 ± 0.14	3.36 ± 0.19	6.26	0.2421
14	3.79 ± 0.09	3.5 ± 0.13	3.24	0.3228
15	4.17 ± 0.03 *	3.38 ± 0.05	183.48	0.0469

Values represent least square mean±SEM.

* Within day comparisons of individual means are significantly different at $p<0.05$.

Table A22.2 : Average duration of meals consumed during the 12 h light and dark phases in two subgroups [high protein powder high carbohydrate granular-slow learners (HPP-HCG-SL) and high protein powder high carbohydrate granular-fast learners (HPP-HCG-FL)] of rats fed a choice between high protein powder and high carbohydrate granular diets.

	time (min)		time (min)		group		phase		interaction	
	12h dark		12h light		df (1,1)		df (1,1)		df (1,1)	
day	HPP-HCG-SL (n=7)	HPP-HCG-FL (n=5)	HPP-HCG-SL (n=7)	HPP-HCG-FL (n=5)	F value	p	F value	p	F value	p
1	5.23 ± 0.1	4.5 ± 0.15	5 ± 0.15	3.5 ± 0.2	16.33	0.1544	1.61	0.4246	-	-
2	5.42 ± 0.25	5.75 ± 0.35	6.5 ± 0.35	4.77 ± 0.65	0.59	0.5823	6.26	0.2421	-	-
3	5.88 ± 0.45	6 ± 0.64	6.67 ± 0.64	5.5 ± 0.5	0.02	0.904	1.01	0.4991	-	-
4	6.53 ± 0.87	5.1 ± 1.23	4.33 ± 1.23	3 ±	0.91	0.5147	2.15	0.3812	-	-
5	6.9 ± 2.1	3.64 ± 2.97	5.33 ± 2.97	3.71 ± 0.29	0.81	0.5344	0.19	0.7411	-	-
6	6.48 ± 1.32	4 ± 1.86	4.5 ± 1.86	3.75 ± 0.25	1.19	0.4729	0.76	0.5443	-	-
7	6.68 ± 0.52	3.11 ± 0.73	4 ± 0.73	4.75 ± 1.25	15.93	0.1563	8.99	0.2049	-	-
8	5.72 ± 1.12	3.8 ± 1.58	6.25 ± 1.58	3.67 ± 0.33	0.98	0.5029	0.08	0.8287	-	-
9	5.25 ± 1.25	3.5 ± 1.77	3 ± 1.77	3.17 ± 0.17	0.65	0.5672	1.08	0.4878	-	-
10	4.03 ± 0.37	3.86 ± 0.52	3 ± 0.52	3.73 ± 0.32	0.08	0.8277	2.65	0.3508	-	-
11	-	-	-	3.67 ± 0.33	-	-	-	-	-	-
12	4.26 ± 0.6	3.67 ± 0.84	4 ± 0.84	3.61 ± 0.45	0.33	0.6667	0.06	0.8416	-	-
13	3.78 ± 0.12	3.33 ± 0.16	6 ± 0.16	3.46 ± 0.21	4.96	0.2687	120.33	0.0579	-	-
14	3.66 ± 0.23	3.43 ± 0.33	4.33 ± 0.33	3.89 ± 0.11	0.33	0.6667	2.86	0.3398	-	-
15	4.11 ± 0.11	3.45 ± 0.16	4 ± 0.16	3.89 ± 0.48	11.64	0.1815	0.33	0.6667	-	-

Values represent least square mean ±SEM.
- Not available due to insufficient number of observations.

Table A23.1: Average size of meals consumed over 24 h in two subgroups [high protein powder high carbohydrate granular slow learners (HPP-HCG-SL) and high protein powder high carbohydrate granular fast learners (HPP-HCG-FL)] of rats fed a choice between high protein powder and high carbohydrate granular diets.

	size (g) 24h		group df (1,1)	
day	HPP-HCG-SL (n=7)	HPP-HCG-FL (n=5)	F value	p
1	1.45 ± 0.05	1.25 ± 0.06	6.91	0.2314
2	1.55 ± 0 *	1.52 ± 0	99999	0.0001
3	1.43 ± 0.27	1.59 ± 0.38	0.11	0.7958
4	1.52 ± 0.21	1.46 ± 0.3	0.03	0.8914
5	1.51 ± 0.35	0.99 ± 0.5	0.74	0.5487
6	1.57 ± 0.24	1.11 ± 0.33	1.26	0.4635
7	1.53 ± 0.26	1.02 ± 0.37	1.26	0.463
8	1.49 ± 0.02	1.07 ± 0.03	98.39	0.064
9	1.31 ± 0.1	1.17 ± 0.15	0.68	0.5601
10	1.15 ± 0.07	1.21 ± 0.1	0.27	0.6959
11	1.08 ± 0.16	0.96 ± 0.23	0.2	0.7332
12	1.21 ± 0.29	1.08 ± 0.42	0.06	0.8485
13	1.32 ± 0.07	1.14 ± 0.1	2.49	0.3596
14	1.29 ± 0.04	1.17 ± 0.06	2.5	0.3588
15	1.35 ± 0.17	1.12 ± 0.25	0.59	0.5821

Values represent least square mean±SEM.

* Within day comparisons of individual means are significantly different at $p<0.05$.

Table A23.2 : Average size of meals consumed during the 12 h light and dark phases in two subgroups [high protein powder high carbohydrate granular-slow learners (HPP-HCG-SL) and high protein powder high carbohydrate granular-fast learners (HPP-HCG-FL)] of rats fed a choice between high protein powder and high carbohydrate granular diets.

	size (g) 12h dark		size (g) 12h light		group df (1,1)		phase df (1,1)		interaction df (1,1)	
day	HPP-HCG-SL (n=7)	HPP-HCG-FL (n=5)	HPP-HCG-SL (n=7)	HPP-HCG-FL (n=5)	F value	p	F value	p	F value	p
1	1.5 ± 0.09	1.26 ± 0.12	1.75 ± 0.12	1.12 ± 0.04	2.68	0.3492	2.81	0.3425	-	-
2	1.47 ± 0.08	1.43 ± 0.12	2.05 ± 0.12	1.37 ± 0.27	0.08	0.8211	16.33	0.1544	-	-
3	1.53 ± 0.16	1.72 ± 0.22	1.73 ± 0.22	1.31 ± 0.06	0.51	0.6056	0.58	0.5853	-	-
4	1.83 ± 0.28	1.46 ± 0.39	1.13 ± 0.39	0.85 ±	0.59	0.5837	2.11	0.3839	-	-
5	1.89 ± 0.67	1.01 ± 0.95	1.17 ± 0.95	0.91 ± 0.11	0.57	0.587	0.39	0.6453	-	-
6	1.76 ± 0.36	1.19 ± 0.51	1 ± 0.51	0.93 ± 0.23	0.84	0.5285	1.49	0.4374	-	-
7	1.71 ± 0.27	1.02 ± 0.39	0.8 ± 0.39	0.98 ± 0.23	2.09	0.3852	3.67	0.3064	-	-
8	1.53 ± 0.11	1.11 ± 0.15	1.63 ± 0.15	1.07 ± 0.13	5.09	0.2657	0.28	0.6886	-	-
9	1.47 ± 0.05	1.3 ± 0.07	0.9 ± 0.07	0.94 ± 0.14	3.54	0.3111	40.33	0.0994	-	-
10	1.18 ± 0.06	1.24 ± 0.09	1 ± 0.09	0.91 ± 0.07	0.32	0.6737	2.86	0.34	-	-
11	1.08 ± 0.14	1.08 ± 0.2	1.35 ± 0.2	1.18 ± 0.26	0	0.9943	1.18	0.4732	-	-
12	1.29 ± 0.29	1.07 ± 0.4	1.33 ± 0.4	1.27 ± 0.14	0.2	0.7347	0.01	0.9389	-	-
13	1.25 ± 0.03	1.13 ± 0.04	2.15 ± 0.04	1.1 ± 0.14	5.54	0.2558	322.72	0.0354	-	-
14	1.27 ± 0.03	1.19 ± 0.04	1.4 ± 0.04	1.38 ± 0.17	3.23	0.3231	7.05	0.2293	-	-
15	1.37 ± 0.23	1.13 ± 0.33	1.23 ± 0.33	1.22 ± 0.1	0.35	0.6596	0.11	0.7971	-	-

Values represent least square mean ±SEM.
- Not available due to insufficient number of observations.

Table A24.1: Average protein composition of meals consumed over 24 h in two subgroups [high protein powder high carbohydrate granular slow learners (HPP-HCG-SL) and high protein powder high carbohydrate granular fast learners (HPP-HCG-FL)] of rats fed a choice between high protein powder and high carbohydrate granular diets.

	protein composition (g) 24h		group df (1,1)	
day	HPP-HCG-SL (n=7)	HPP-HCG-FL (n=5)	F value	p
1	0.008 ± 0.008	0 ± 0.01	0.33	0.6667
2	-	-	-	-
3	-	-	-	-
4	-	-	-	-
5	-	-	-	-
6	-	-	-	-
7	-	-	-	-
8	0.13 ± 0.13	0.36 ± 0.19	0.98	0.5038
9	0.08 ± 0.08	0.32 ± 0.11	3.46	0.314
10	0.25 ± 0.02	0.5 ± 0.03	41.98	0.0975
11	0.26 ± 0.07	0.43 ± 0.1	1.7	0.4163
12	0.24 ± 0.02	0.49 ± 0.03	67.58	0.0771
13	0.23 ± 0.07	0.5 ± 0.1	5.16	0.2641
14	0.16 ± 0.06	0.29 ± 0.08	1.56	0.4293
15	-	-	-	-

Values represent least square mean±SEM.

- Not available due to insufficient number of observations.

* Within day comparisons of individual means are significantly different at $p<0.05$.

Table A24.2 : Average protein composition of meals consumed during the 12 h light and dark phases in two subgroups [high protein powder high carbohydrate granular-slow learners (HPP-HCG-SL) and high protein powder high carbohydrate granular-fast learners (HPP-HCG-FL)] of rats fed a choice between high protein powder and high carbohydrate granular diets.

	protein composition (g) 12h dark		protein composition (g) 12h light		group df (1,1)		phase df (1,1)		interaction df (1,1)	
day	HPP-HCG-SL (n=7)	HPP-HCG-FL (n=5)	HPP-HCG-SL (n=7)	HPP-HCG-FL (n=5)	F value	p	F value	p	F value	p
1	-	-	-	-	-	-	-	-	-	-
2	-	-	-	-	-	-	-	-	-	-
3	-	-	-	-	-	-	-	-	-	-
4	-	-	-	-	-	-	-	-	-	-
5	-	-	-	-	-	-	-	-	-	-
6	-	-	-	-	-	-	-	-	-	-
7	-	-	-	-	-	-	-	-	-	-
8	-	-	-	-	-	-	-	-	-	-
9	-	-	-	-	-	-	-	-	-	-
10	0.33 ± 0.03	0.57 ± 0.04	0 ± 0.04	0.37 ± 0.14	21.59	0.135	40.33	0.0994	-	-
11	0.27 ± 0.14	0.56 ± 0.2	0 ± 0.2	0.13 ± 0.09	1.37	0.4496	1.14	0.4797	-	-
12	0.16 ± 0.04	0.6 ± 0.06	0.27 ± 0.06	0.04 ± 0.04	37.45	0.1031	2.25	0.3741	-	-
13	0.27 ± 0.07	0.61 ± 0.09	0 ± 0.09	0.06 ± 0.06	9.45	0.2002	5.54	0.2558	-	-
14	0.16 ± 0.06	0.39 ± 0.09	0.2 ± 0.09	0.02 ± 0.02	3.95	0.2966	0.1	0.8024	-	-
15	0.44 ± 0.12	0.55 ± 0.16	0.27 ± 0.16	0.11 ± 0.11	0.28	0.6913	0.76	0.5444	-	-

Values represent least square mean ±SEM.
- Not available due to insufficient number of observations.

Table A25.1: Average carbohydrate composition of meals consumed over 24 h in two subgroups [high protein powder high carbohydrate granular slow learners (HPP-HCG-SL) and high protein powder high carbohydrate granular fast learners (HPP-HCG-FL)] of rats fed a choice between high protein powder and high carbohydrate granular diets.

	carbohydrate composition (g) 24h		group df (1,1)	
day	HPP-HCG-SL (n=7)	HPP-HCG-FL (n=5)	F value	p
1	1.45 ± 0.05	1.25 ± 0.08	4.56	0.2788
2	-	-	-	-
3	1.43 ± 0.27	1.23 ± 0.38	0.19	0.7395
4	1.52 ± 0.21	1.18 ± 0.3	0.86	0.5236
5	1.51 ± 0.35	0.56 ± 0.5	2.46	0.3614
6	1.57 ± 0.24	0.76 ± 0.33	3.93	0.2975
7	1.53 ± 0.26	0.64 ± 0.37	3.87	0.2993
8	1.35 ± 0.11	0.71 ± 0.15	11.69	0.1811
9	1.24 ± 0.03	0.85 ± 0.04	65.33	0.0784
10	0.9 ± 0.05	0.71 ± 0.07	4.69	0.2755
11	0.82 ± 0.09	0.53 ± 0.13	3.52	0.3118
12	0.97 ± 0.31	0.59 ± 0.44	0.49	0.6125
13	1.09 ± 0.14	0.64 ± 0.19	3.7	0.3051
14	1.13 ± 0.02	0.88 ± 0.02	68.69	0.0764
15	0.91 ± 0.17	0.65 ± 0.25	0.71	0.5544

Values represent least square mean±SEM.

'- Not available due to insufficient number of observations.

* Within day comparisons of individual means are significantly different at $p<0.05$.

Table A25.2 : Average carbohydrate composition of meals consumed during the 12 h light and dark phases in two subgroups [high protein powder high carbohydrate granular-slow learners (HPP-HCG-SL) and high protein powder high carbohydrate granular-fast learners (HPP-HCG-FL)] of rats fed a choice between high protein powder and high carbohydrate granular diets.

	carbohydrate composition (g) 12h dark		carbohydrate composition (g) 12h light		group df (1,1)		phase df (1,1)		interaction df (1,1)	
day	HPP-HCG-SL (n=7)	HPP-HCG-FL (n=5)	HPP-HCG-SL (n=7)	HPP-HCG-FL (n=5)	F value	p	F value	p	F value	p
1	1.5 ± 0.09	1.26 ± 0.12	1.75 ± 0.12	1.12 ± 0.04	2.68	0.3492	2.81	0.3425	-	-
2	1.47 ± 0.08	1.43 ± 0.12	2.05 ± 0.12	1.37 ± 0.27	0.08	0.8211	16.33	0.1544	-	-
3	1.53 ± 0.16	1.22 ± 0.22	1.73 ± 0.22	1.31 ± 0.06	1.29	0.459	0.58	0.5853	-	-
4	1.83 ± 0.28	1.18 ± 0.39	1.13 ± 0.39	0.85 ±	1.83	0.4049	2.11	0.3839	-	-
5	1.89 ± 0.67	0.61 ± 0.95	1.17 ± 0.95	0.37 ± 0.28	1.21	0.4694	0.39	0.6453	-	-
6	1.76 ± 0.36	0.85 ± 0.51	1 ± 0.51	0.55 ± 0.25	2.13	0.3824	1.49	0.4374	-	-
7	1.71 ± 0.27	0.64 ± 0.39	0.8 ± 0.39	0.2 ± 0.2	5.03	0.2669	3.67	0.3064	-	-
8	1.46 ± 0.18	0.64 ± 0.25	1.2 ± 0.25	1.07 ± 0.13	7.12	0.2282	0.7	0.5557	-	-
9	1.47 ± 0.05	1.03 ± 0.07	0 ± 0.07	0.75 ± 0.14	24.54	0.1268	269.22	0.0388	-	-
10	0.85 ± 0.09	0.67 ± 0.13	1 ± 0.13	0.54 ± 0.16	1.28	0.4607	0.86	0.5247	-	-
11	-	-	-	1.04 ± 0.25	-	-	-	-	-	-
12	1.13 ± 0.24	0.47 ± 0.35	1.07 ± 0.35	1.22 ± 0.17	2.44	0.3623	0.02	0.9092	-	-
13	0.99 ± 0.04	0.52 ± 0.05	2.15 ± 0.05	1.04 ± 0.14	55.01	0.0853	346.28	0.0342	-	-
14	1.11 ± 0.04	0.8 ± 0.05	1.2 ± 0.05	1.36 ± 0.18	23.72	0.1289	2.12	0.3831	-	-
15	0.93 ± 0.35	0.58 ± 0.49	0.97 ± 0.49	1.11 ± 0.16	0.33	0.6699	0	0.9576	-	-

Values represent least square mean ±SEM.
- Not available due to insufficient number of observations.

Table A26.1: Average intermeal interval over 24 h in two subgroups
[high protein powder high carbohydrate granular slow learners (HPP-HCG-SL)
and high protein powder high carbohydrate granular fast learners (HPP-HCG-FL)]
of rats fed a choice between high protein powder and high carbohydrate granular diets.

	intermeal interval (min) 24h		group df (1,1)	
day	HPP-HCG-SL (n=7)	HPP-HCG-FL (n=5)	F value	p
1	100.4 ± 17	64.8 ± 24	1.47	0.4393
2	139 ± 24.9	233 ± 35.2	4.76	0.2735
3	108.2 ± 21.5	167.5 ± 30.5	2.53	0.3576
4	132.2 ± 23.5	67.8 ± 33.3	2.5	0.3591
5	166.3 ± 25.9	58.6 ± 36.6	5.77	0.2512
6	161.9 ± 34.1	106.5 ± 48.2	0.88	0.5203
7	125.5 ± 32.3	65.4 ± 45.6	1.16	0.4767
8	154.7 ± 7.3	97.2 ± 10.3	20.63	0.138
9	139 ± 5.2	181 ± 7.4	21.56	0.135
10	121.8 ± 9.9	79.3 ± 14	6.13	0.2444
11	123.9 ± 2.7	186.5 ± 3.9 *	174.65	0.0481
12	124.1 ± 13.7	113.2 ± 19.4	0.21	0.7264
13	94.7 ± 23.8	111.3 ± 33.7	0.16	0.7563
14	83.9 ± 4.1	125.2 ± 5.7	34.42	0.1075
15	105.4 ± 18.8	69.8 ± 26.6	1.2	0.4715

Values represent least square mean±SEM.

* Within day comparisons of individual means are significantly different at $p<0.05$.

Table A26.2 : Average intermeal interval during the 12 h light and dark phases in two subgroups [high protein powder high carbohydrate granular-slow learners (HPP-HCG-SL) and high protein powder high carbohydrate granular-fast learners (HPP-HCG-FL)] of rats fed a choice between high protein powder and high carbohydrate granular diets.

	intermeal interval (min) 12h dark		intermeal interval (min) 12h light		group df (1,1)		phase df (1,1)		interaction df (1,1)	
day	HPP-HCG-SL (n=7)	HPP-HCG-FL (n=5)	HPP-HCG-SL (n=7)	HPP-HCG-FL (n=5)	F value	p	F value	p	F value	p
1	92 ± 9.1	64.8 ± 12.9	153.1 ± 23.7	118.5 ± 40.5	2.95	0.3355	-	-	-	-
2	110.2 ± 6.7	233 ± 9.4	214 ± 59.8	126.4 ± 19.9	113.16	0.0597	-	-	-	-
3	97.4 ± 9.1	121.4 ± 12.9	136.5 ± 51.8	287.3 ± 111	2.32	0.3701	-	-	-	-
4	117.5 ± 18.1	67.8 ± 25.6	137.7 ± 36.7	43.5 ± 43.5	2.5	0.3589	-	-	-	-
5	151.4 ± 30.2	58.6 ± 42.8	136 ± 39	219 ± 39	3.14	0.3271	-	-	-	-
6	136.4 ± 27.6	86.4 ± 39	263.1 ± 43	103.7 ± 72.4	1.1	0.4854	-	-	-	-
7	129.2 ± 28.6	65.4 ± 40.4	188.6 ± 90	16.5 ± 16.5	1.67	0.4197	-	-	-	-
8	141.1 ± 0.6	79.9 ± 0.78	157.4 ± 53	103.7 ± 54.3	4120.47	0.0099	-	-	-	-
9	132.9 ± 11.4	160.3 ± 16.1	136.2 ± 60.4	175.5 ± 58.5	1.94	0.3962	-	-	-	-
10	127.5 ± 4.1	79.3 ± 5.8	217.8 ± 105	106.1 ± 28.9	45.42	0.0938	-	-	-	-
11	121.8 ± 4.9	153 ± 6.9	286.3 ± 69.8	222 ± 132	13.6	0.1686	-	-	-	-
12	143.4 ± 22.7	91 ± 32.2	196.3 ± 138	266.7 ± 29.1	1.77	0.4103	-	-	-	-
13	75.9 ± 5	95.6 ± 7.1	265.6 ± 111	198.7 ± 51.4	5.17	0.2639	-	-	-	-
14	86 ± 6.1	109.6 ± 8.7	47.3 ± 25.3	184.3 ± 4.3	4.92	0.2697	-	-	-	-
15	91 ± 10.8	68.6 ± 15.2	114.2 ± 51	136.5 ± 27	1.44	0.4426	-	-	-	-

Values represent least square mean ±SEM.
- Not available due to insufficient number of observations.

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IMAGE EVALUATION TEST TARGET (QA-3)

1.0 1.1 1.25 1.4 1.6 1.8 2.0 2.2 2.5 2.8 3.2 3.6 4.0

150mm

6"

APPLIED IMAGE . Inc
1653 East Main Street
Rochester, NY 14609 USA
Phone: 716/482-0300
Fax: 716/288-5989