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Full Length Research Paper

Nutrition recovery with Spirulina diet improves body growth and muscle protein of protein – restricted rats

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The present study aimed to evaluate the effects of *Spirulina maxima* as the sole dietary source of protein on muscle protein and body growth of rats recovering from protein malnutrition. Young (30 days) male Wistar rats were randomly separated into 5 groups: (I) Casein 17% (C17; 30 to 150 days of age); (II) Spirulina 17% (S17; 30 to 150 days); (III) Casein 6% (C6; 30 to 150 days); (IV) Casein 6% (30 to 90 days) and Spirulina 17% (91 to 150 days) (C6/S17) and V- Casein 6% (30 to 90 days) and Casein 17% (91 to 150 days) (C6/C17). Muscle total protein and DNA contents as well as the protein synthesis and degradation rates were investigated to infer on muscle growth and on muscle protein, respectively. The protein malnourished group (C6) presented lower total protein and DNA contents in the soleus muscle if compared to other groups. The nutritional recovery, using both diets, re-established these parameters. Spirulina and casein diets reduced the protein degradation and increased the protein synthesis in the soleus muscle of the previously malnourished rats. Spirulina proved to be an adequate protein source for recovery of body weight and muscle protein of protein malnourished rats.

Key words: Muscle protein, spirulina, rats, protein malnutrition.

INTRODUCTION

There are several numbers of forms of malnutrition; marasmus and kwashiorkor are clinical manifestations of severe protein-calorie malnutrition. Protein malnutrition provokes deleterious effects in a great number of organ systems, leading to accentuated metabolic disturbances, which may alter food processing when feeding resumes. To this day, with the continuing low level of available protein food all over the world and increasingly urgent need for low-cost food of good nutritional value, the exploration of biomasses as an alternative protein sources became a matter of general interest. The use of algae (seaweed) in human alimentation is ancient. In the East, in particular, such source of food material has been tried extensively, in the hope of correcting the widespread protein deficiency which characterizes the nutritional status of less favored populations (Simpore et al., 2006).

Spirulina is a helicoidal shaped blue green alga with length of 0.2 to 0.3 mm (Costa et al., 2006; Hadenshog and Hofsten, 1979). Spirulina's special merit as a food source is that, it contains 65 to 70% protein on dry weight basis, which is higher than any other natural food and has all eight essential amino acids to men (Li et al., 2006).

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It normally grows in naturally alkaline lakes located in arid zones. Although the alkaline water from such lakes cannot be used for irrigation, it can be used for cultivation of Spirulina (Kay, 1991; Simpore et al., 2006). Since this alga has a rapid reproduction rate, dividing three times a day, a pond devoted totally to the growth of Spirulina can produce 125 times as much protein as the same amount area devoted to corn, 70 times as much protein as to fish and 600 times as much as cattle (Branger et al., 2003; Furst, 1978).

According to previous evaluations, Spirulina seems to be a good alimentary protein source for human subjects. It has adequate acceptance and does not appear to exert any toxic effects, although it has slightly reduced digestibility (Sautier and Tremolieres, 1975; Simpore et al., 2005). The most detailed studies on the nutritional value of Spirulina have been conducted in rodents, mostly rats. The rodent studies covered a variety of parameters, such as body growth (Salazar et al., 1996; Tranquille et al., 1994), protein efficiency ratio (PER) and net protein utilization (NPU) (Narayan et al., 2005), sexual maturation (Contreras et al., 1979), reproductive performance (Salazar et al., 1996), hematological status (Kapoor and Metha, 1998), among others. Spirulina proved to maintain all these physiological makers at normal levels and did not produce adverse effects after chronic treatment.

Skeletal muscle is susceptible to protein malnutrition because it is one of the body's most important protein stores. Therefore, when there is a dietary protein deficiency, this tissue becomes the target of depletion (Ihemelandu, 1985). Thus, the present study was designed to evaluate the effects of Spirulina as the sole dietary protein source in rats recovering from malnutrition on body growth, as well as on skeletal muscle protein.

MATERIALS AND METHODS

Animals

All experiments involving animals followed both the specific Brazilian resolutions of the bioethics of experiments with animals (law No 6.638 of May 8th 1979; Decree no. 24.645 of July 10th 1934, Brazilian College of Animal Experimentation) and the internationally accepted principles for laboratory animal use and care in the European Community guidelines (EEC Directive of 1986; 86/609/EEC). Young (30 days old at the beginning of the experiment) male Wistar rats, weighing 119.5 ± 12.7 g and measuring (nose-to-anus length) 19.1 ± 1.2 cm, obtained from the animal facilities of the UNESP – São Paulo State University, Botucatu, SP, Brazil, were used.

Diets

Semi-purified diets, containing 17% of protein represented by casein (powdered protein free diet plus casein - powdered milk protein), 6% of protein represented by casein, and 17% of protein represented by Spirulina (powdered protein free diet plus Spirulina - powdered *Spirulina maxima* sold commercially by All Chemistry do Brasil Ltda.), as described in Table 1, were employed. The Spirulina powder composition was as follows. General analysis (%): protein 64.7, carbohydrates 15, lipids 6, minerals (ash) 7, fiber 8. Minerals (mg/10 g of protein): calcium 70, iron 15, phosphorus 80, magnesium 40, zinc 0.3, manganese 0.5, sodium 90, potassium 140; minerals (mcg/10 g of protein): selenium 10, copper 120, chromium 25. Vitamins (per 10 g of protein): vitamin A 23000 IU, beta carotene 14 mg, vitamin D 1200 IU, vitamin E 1.0 mg, vitamin K 200 mcg, biotin 0.5 mcg, inositol 6.4 mg, thiamine 0.35 mg, riboflavin 0.4 mg, niacin 1.4 mg, pyridoxine 80 mcg, folate 1mcg, cianocobalamine 20 mcg, pantothenic acid 10 mcg. Table 2 shows Spirulina and casein amino acids composition.

A concern in the use of plant protein source is the presence of antinutritional factors, which if not removed or processed may likewise contribute to the low growth of several animal species. In this study however, Spirulina protein source used were properly processed and were assumed not to contain any of these antinutritional factors (as reported by the supplier / All Chemistry, São Paulo, Brazil).

Design and experimental groups

Young male Wistar rats were randomly separated into 5 groups (n=8/group), according to the diet received during the experiment:

(I) Casein 17% (C17) from 30 to 150 days of age;
(II) Spirulina 17% (S17) from 30 to 150 days;
(III) Casein 6% (C6) from 30 to 150 days;
(IV) Casein 6% from 30 to 90 days and Spirulina 17% from 91 to 150 days (C6/S17);
(V) Casein 6% from 30 to 90 days and casein 17% from 91 to 150 days (C6/C17).

During the experiment, the rats had free access to food and water and were housed on a 12 h light/dark cycle at room temperature of 25°C. Food intake was monitored daily and body weight and length were measured (nose-to-anus length) once a week. In addition, the food efficiency (body weight gain [g] / food ingestion [g]) and protein efficiency (body weight gain [g] / protein ingestion [g]) ratios were also calculated.

Tissue extraction

At the end of the experiment, the animals belonging to all experimental groups were anesthetized by intraperitoneal injection of pentobarbitone sodium (60 mg/kg body weight) (Nembutal; Bomac Laboratories, Asquith, Australia), and further sacrificed by decapitation method. Blood samples were collected for serum glucose, total protein, albumin and free fatty acid (FFA) measurements. Samples of the liver were taken for total lipids and glycogen (Si and Taylor, 1970) determinations.

Left soleus muscle was excised, weighed and analyzed for total protein (Lowry et al., 1951) and DNA (Giles and Meyers, 1961) contents as well as protein/DNA ratio, to infer on growing of skeletal muscle. Longitudinal strips (70 mg) from the right soleus muscle were obtained for protein synthesis and degradation assays.

Table 1. Diets composition (g/kg).

Components	Casein 17%*	Spirulina 17%	Casein 6%**
Spirulina			
(65% protein)***	-	280.0	-
Casein			
(84% protein)****	202.2	-	71.5
Cornstarch	397.0	386.0	480.0
Dextrinized			
cornstarch	130.5	130.5	159.0
Sucrose	100.0	100.0	121.0
Soybean oil	70.0	70.0	70.0
Fiber			
(microcellulose)	50.0	50.0	50.0
Mineral mix	35.0	35.0	35.0
Vitamin mix	10.0	10.0	10.0
L-cystine	3.0	3.0	3.0
Choline			
Hydrochloride	2.5	2.5	2.5

* Diet for growth phase, pregnancy and lactation of rodents – AIN – 93G; ** Diet for malnutrition induction; *** Corrected values due to protein content in Spirulina; **** Corrected values due to protein content in casein.

Gastrocnemius muscle strips (100 to 200 mg) were collected to determine the alkaline phosphatase enzyme activity.

Protein synthesis

The soleus muscle strips were preincubated for 30 min in RPMI 1640 medium (with glutamine and without red phenol and sodium bicarbonate), supplemented with bovine serum albumin fatty acid free (BSA) [1 g/L] and insulin (100 U/ml), and saturated with 95% O2/5% CO2 gas mixture. They were then transferred into a fresh RPMI 1640 medium with the same supplementation containing L-(1 to 14 C) phenylalanine (0.05 µ Ci/ml) (Merck, Nottingham, UK) and incubated for 2 h. At the end of the incubation, the muscle strips were homogenized in 5% trichloroacetic (TCA) and centrifuged at 750 x g for 15 min at 4°C. TCA-insoluble material was washed 3 times with 5% TCA.

The resultant pellet was solubilized in 10% sodium dodecyl sulfate (SDS) at room temperature for 30 min aiming at the determination of protein content and radioactivity incorporated to muscle proteins. Muscle protein was determined by the folin phenol method (Lowry et al., 1951) and the protein bound radioactivity was measured using scintillation counting (Packard Tri-Carb 2100 TR). Protein synthesis was calculated by dividing the protein-bound radioactivity by the specific activity of the free phenylalanine in the incubation medium and expressed as nanomoles of phenylalanine incorporated per mg of protein per 2 h.

Protein degradation

Tyrosine release from isolated muscle in the presence of cyclohexamide was used as an indicator of protein degradation, as previously described (Fulks et al., 1957). This method makes use of the fact that, the amino acid tyrosine is neither synthesized nor degraded by skeletal muscle. The soleus muscle strips were pre-incubated for 30 min in Krebs Ringer buffer (NaCl 1.2 mmol/L; KCl 4.8 mmol/L; $NaHCO_3$ 25 mmol/L; $CaCl_2$ 2.5 mmol/L; KH_2PO_4 1.2 mmol/L and $mgSO_4$ 1.2 mmol/L; pH 7.4), supplemented with glucose (5.5 mmol/L), BSA (1.0 g/L), insulin (5 U/ml) and cyclohexamide (5 mmol/L), and saturated with 95% O_2/5%CO_2 gas mixture. They were then transferred into a fresh medium of the same composition and incubated for 2 h. At the end of the incubation, samples of the incubation medium were used for the assay of tyrosine (Waalkes and Udenfriend, 1957).

Muscle alkaline phosphatase

The physiological role of alkaline phosphatase enzyme (APE) can be associated to transport systems and to cellular activity (Calhau et al., 1999). For this reason, this enzyme was measured in the muscle tissue of the animals. Gastrocnemius muscle strips (100 to 200 mg) were excised and homogenised by sonication during 40 s in 500 µl of distilled water. The homogenised muscle strips were centrifuged (750 x g / 5 min) and the supernatant was separated to

Table 2. Spirulina and casein amino acids composition (mg/g of protein)*

Spirulina			
Essential			
Isoleucine	350.0	Phenylalanine	280.0
Leucine	540.0	Threonine	320.0
Lysine	290.0	Valine	400.0
Methionine	140.0	Tryptophan	90.0
Non essential			
Alanine	470.0	Glycine	320.0
Arginine	430.0	Histidine	100.0
Aspartatic acid	610.0	Proline	270.0
Cystine	60.0	Serine	320.0
Glutamic acid	910.0	Tyrosine	300.0
Casein			
Essential			
Isoleucine	38.2	Phenylalanine	104.8
Leucine	90.6	Threonine	45.1
Lysine	82.7	Valine	44.6
Methionine	32.7	Tryptophan	13.3
Non essential			
Alanine	34.6	Proline	108.5
Arginine	36.6	Glutamic acid	181.7
Aspartatic acid	91.0	Histidine	28.8
Serine	59.4	Glycine	20.7

*As reported by the supplier (All Chemistry, São Paulo, Brazil).

measure the alkaline phosphatase by colorimetric method (Labtest Diagnóstica®, Lagoa Santa, Minas Gerais, Brazil).

Statistical analysis

The results were expressed as mean ± SD for the number of rats (n) indicated. In the protein synthesis and degradation assays, as well as in the APE assay, n indicated the muscle strips number. The Shapiro Wilk's W test was used to verify the normality of samples. Then, the results were statistically analyzed by analysis of variance (two way ANOVA). When necessary, the Bonferroni post-hoc test was used. In all cases, the level of significance was pre-set at 5%. The software used was Statistica 7.0®.

RESULTS

Body weight and length gains and serum protein, albumin and FFA concentrations were lower in the protein malnourished group (C6) when compared to the C17 and S17 normal protein groups and to the recovered groups (C6/C17 and C6/S17). Nevertheless, liver total lipid concentrations appeared higher, whereas liver glycogen concentrations appeared lower in the protein malnourished group (C6) in comparison to the other groups. No differences were detected in relation to food intake and protein efficiency ratio when all groups were compared, whereas the food efficiency ratio was lower in the protein malnourished group (C6) if compared to the other groups (Table 3).

The total protein and DNA contents as well as the protein/DNA ratio in the soleus muscle were decreased in the animals previously submitted to protein restriction (C6). These effects were counteracted by feeding both the casein and the Spirulina balanced diets for 8 weeks, since the results observed for the recovered groups (C6/C17 and C6/S17) were similar to those from the normal protein groups (C17 and S17) (Table 4). Protein synthesis decreased significantly, whereas protein degradation increased significantly in the protein deficient group (C6) when compared to the other groups (Figures 1 A and B). After 8 weeks of balanced casein diet or Spirulina diet treatment, the rates of protein synthesis (Figure 1A) were re-established in the recovered groups (C6/C17 and C6/S17) if compared to C17 and S17 normal protein groups. The same was observed in relation to protein degradation (Figure 1B). The alkaline phosphatase activity in gastrocnemius muscle of the protein deficient animals (C6) was higher if compared to the other groups (Figure 2).

DISCUSSION

There is a great interest in developing more effective procedures for protein malnutrition treatment, mainly in the poor countries. These include the employment of new sources of protein in the diet, for instance the blue-green algae named Spirulina, in order to avoid and/or to recovery from malnutrition. Spirulina demonstrated to be both efficient to attenuate the arterial hypertension in rats (Hernández et al., 2001) and in the treatment of some diseases, such as cancer (Nagasawa et al., 1989), mal-nutrition (Fica et al., 1984; Simpore et al., 2006) and HIV-positive (Simpore et al., 2005). In the present study, we verified the effects of this alga on skeletal muscle protein as well as on body growth of young rats previously submitted to dietary protein restriction.

The nutritional status of the animals fed casein (6 or 17%) or Spirulina (17%) was assessed by measuring the body weight and length and serum total protein and albumin levels, which are the traditional nutritional assessment indices for human subjects and also

Table 3. Body weight and length gains; food intake; food efficiency ratio (body weight gain [g] / ingestion [g]) and protein efficiency ratio (body weight gain [g] / protein ingestion [g]); serum protein, albumin and FFA concentrations; and liver total lipids and glycogen (both expressed per wet weight) contents of the animals at the end of the experiment.

Parameters	Groups				
	C17	S17	C6	C6/C17	C6/S17
Body weight gain (g)	438±22	437±39	233±32*	435±33	435±25
Body length gain (cm)	11.7±0.4	11.9±0.4	7.2±0.4*	11.3±0.3	11.2±0.2
Food intake (g /100 g of body weight)	12.6±0.9	12.0±0.5	12.5±0.8	11.1±0.7	11.6±0.5
Food Efficiency Ratio	5.3±0.3	5.1±0.5	2.2±0.3*	5.2±0.4	5.0±0.3
Protein Efficiency Ratio	3.4±0.4	3.4±0.5	3.3±0.3	3.2±0.4	3.3±0.2
Serum Protein (g/dl)	7.5±0.2	7.4±0.3	4.5±0.3*	7.3±0.2	7.5±0.4
Serum Albumin (µmol/L)	1072±58	1087±72	551±58*	1101±72	1130±43
Serum FFA (µmol/L)	382±12	380±8	170±19*	386±10	381±7
Liver total lipids (mg/100 mg)	4.4±0.5	4.5±0.5	12.0±1.2*	4.6±0.4	4.3±0.3
Liver glycogen (mg/100 mg)	7.2±0.2	7.3±0.3	5.7±0.5*	7.2±0.4	7.0±0.3

Results expressed as mean ± SD from 8 rats per group, C17= Casein diet 16 weeks 17%; S17= *Spirulina* diet 16 weeks 17%; C6=Casein diet 16 weeks 6%; C6/C17=Casein diet 8 weeks 6% and Casein diet 8 weeks 17%; C6/S17=Casein diet 8 weeks 6% and *Spirulina* diet 8 weeks 17%. * Significantly different ($p<0.05$, ANOVA two-way test) from the other groups.

Table 4. Protein (g/100 g) and DNA (g/100 g) contents, protein to DNA ratio and weight (g) of the soleus muscle of the animals at the end of the experiment.

Parameters	Groups				
	C17	S17	C6	C6/C17	C6/S17
Protein	3.5±0.3	3.5±0.4	1.4±0.2*	3.2±0.2	3.1±0.3
DNA	0.148±0.012	0.147±0.009	0.139±0.014*	0.145±0.013	0.149±0.014
Protein/DNA	23.9±3.2	24.0±3.5	10.2±2.4*	21.9±2.3	22.4±3.1
Weight	0.076±0.002	0.079±0.005	0.070±0.002	0.077±0.003	0.078±0.004

Results expressed as mean ± SD from 8 rats per group. C17= Casein diet 16 weeks 17%; S17= Spirulina diet 16 weeks 17%; C6=Casein diet 16 weeks 6%; C6/C17=Casein diet 8 weeks 6% and Casein diet 8 weeks 17%; C6/S17=Casein diet 8 weeks 6% and Spirulina diet 8 weeks 17%. * Significantly different ($p<0.05$, ANOVA two-way test) from the other groups.

frequently used in animal studies. Several studies have demonstrated that, low body growth in the presence of low serum albumin is often associated with medical complications (Jeejeebhoy, 2000), including protein malnutrition. Impaired body weight and body length gains, hypoalbuminemia, hyproteinemia and high liver lipid and glycogen contents, as observed in our experimental rats maintained with the low protein diet are features commonly found in infantile kwashiorkor (Torun and Chew, 1994) and in protein malnourished experimental animals. This indicates the adequacy of the animal model of protein malnutrition used in the present work.

As there was no significant difference both in food intake and protein efficiency ratio (PER) between rats fed the normal (C17) and the low casein (C6) diets, the model represents protein deficiency and not protein-energy deficiency (Ennouri et al., 2006). On the other hand, the food efficiency ratio (FER) appeared lower in the protein restricted group (C6) in relation to the C17 and S17 control groups. The serum FFA concentration of the protein deficient rats (C6) of the present study was significantly lower in relation to animals fed the normal protein diets (C17 and S17). Studies using experimental animals showed that the 6-desaturase, a key enzyme in the synthesis of essential FA, appears inhibited in fasting and in insulin, protein and zinc deficiencies, conditions often observed in malnourished children (Golden and Golden, 1981).

In relation to liver lipid content, there was a significant increase in the protein restricted rats (C6) when compared to normal protein groups (C17 and S17) and seems to occur as a consequence of deficient transport of lipids to outside of the liver in protein-deficient organisms (Coward and Whitehead, 1972). Body weight

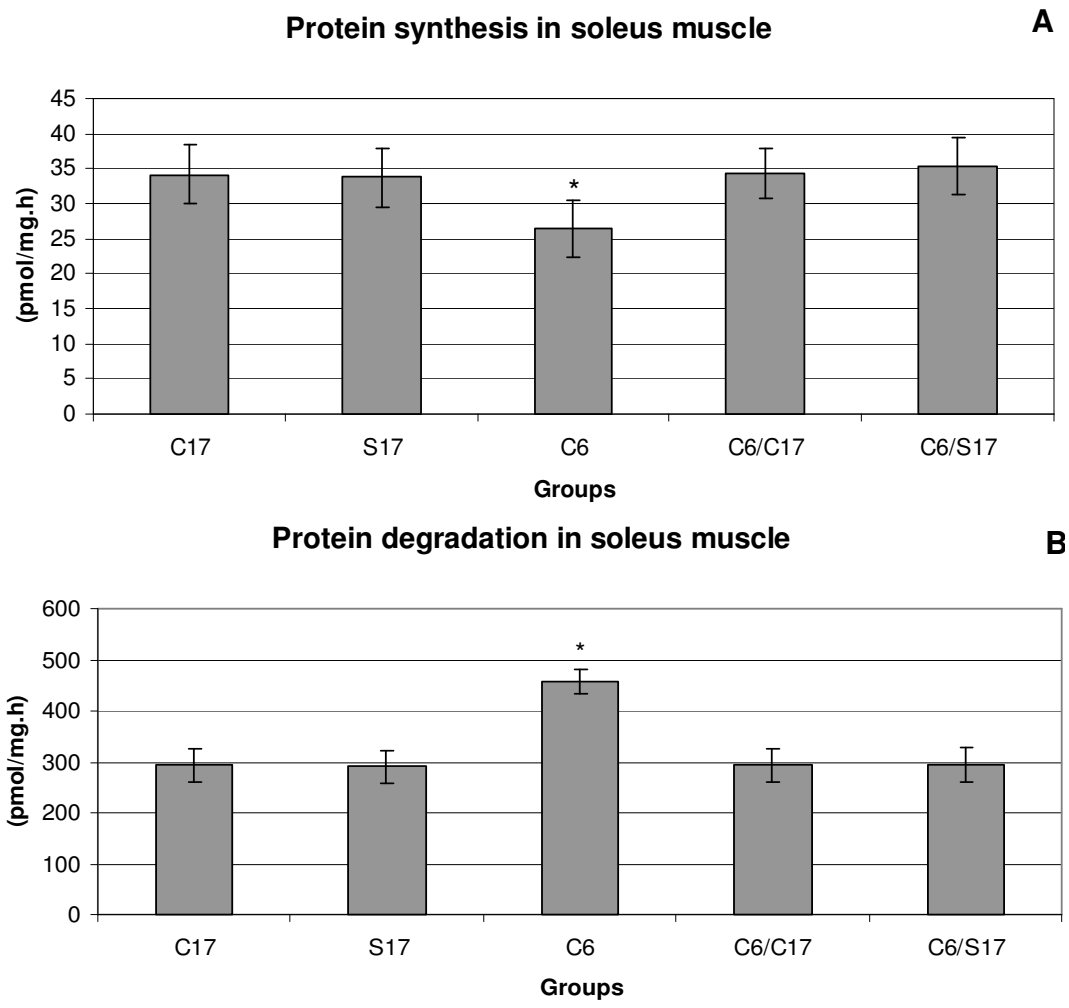

Figure 1. Protein (A) and degradation (B) rates in the Soleus Muscle of the animals (n=8/group) at the end of the experiment. C17= Casein diet 16 weeks 17%; S17= Spirulina diet 16 weeks 17%; C6=Casein diet 16 weeks 6%; C6/C17=Casein diet 8 weeks 6% and Casein diet 8 weeks 17%; C6/S17=Casein diet 8 weeks 6% and Spirulina diet 8 weeks 17%. *Significantly different ($p<0.05$, ANOVA two-way test) from the other groups.

and length gains, serum protein, albumin and FFA concentrations, as well as liver glycogen and total lipid contents were restored by both casein and Spirulina balanced diets in the recovered groups (C6/C17 and C6/S17). These positive effects of Spirulina as protein source, similar to those of casein protein, for the recovery from protein malnutrition, reinforce the nutritional value of this alga.

The total number of cells in an organ can be estimated by determining total organ DNA content whereas the cell size can be estimated by calculating the weight/DNA or the protein/DNA ratios (Winick et al., 1972). Nutritional alterations during the period of hyperplasic and/or hypertrophic growth may result in altered number and/or size of cells in this tissue. Studies of the size of the muscles of animals submitted to postnatal malnutrition have revealed that, this reduction is primarily attributable to a reduction in the volume of the fibers (hypotrophy) rather than to a reduction in the total number of fibers in the tissue (hypoplasia) (Rowe, 1968). However, in the present study, total protein and DNA contents as well as the protein/DNA ratio in the soleus muscle were decreased in the animals, previously submitted to protein malnutrition if compared to C17 and S17 groups,

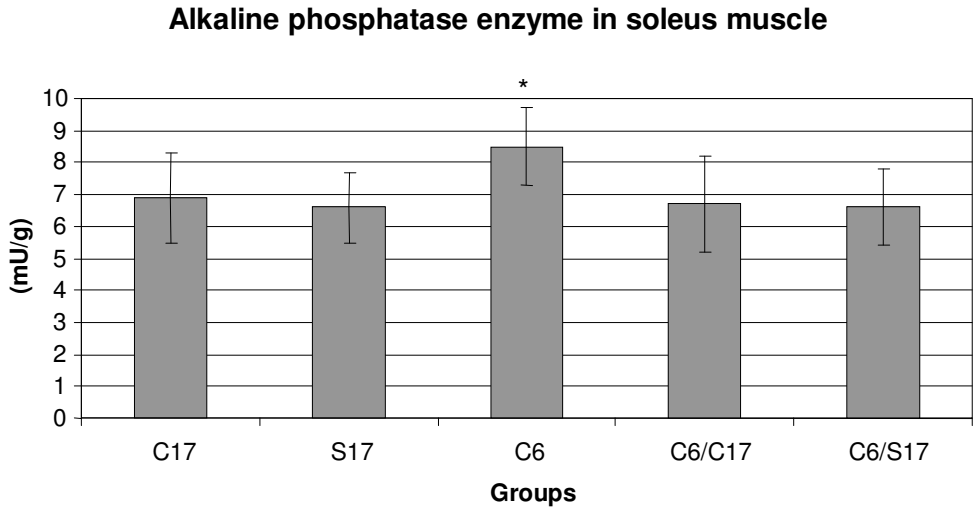

Figure 2. Activity of alkaline phosphatase enzyme in soleus muscle of the animals (n=8/group) at the end of the experiment. C17= Casein diet 16 weeks 17%; S17= Spirulina diet 16 weeks 17%; C6=Casein diet 16 weeks 6%; C6/C17=Casein diet 8 weeks 6% and Casein diet 8 weeks 17%; C6/S17=Casein diet 8 weeks 6% and Spirulina diet 8 weeks 17%. *Significantly different ($p<0.05$, ANOVA two-way test) from the other groups.

suggesting both hypoplasia and hypotrophy in the skeletal muscle. This situation was reverted in the C6/C17 and C6/S17 groups at the end of the experiment, indicating that Spirulina as the sole dietary protein source is adequate to promote hyperplasic and hypertrophic growth in the skeletal muscle of the young rat submitted to protein restriction.

To further analyze the consequences of protein malnutrition followed by a recovery period through ingestion of balanced casein and Spirulina diets on muscle protein, protein synthesis and degradation rates by the soleus muscle of the animals were evaluated *in vitro*. After 16 weeks of diet treatment, being 8 weeks of dietary protein restriction followed by 8 weeks of nutritional recovery, the rates of protein synthesis, which were reduced by the initial dietary protein restriction, were re-established by both casein and Spirulina balanced diets. At the end of the experiment, when analyzed the C6/C17 and C6/S17 groups and compared to C17 and S17 groups, no differences in the protein synthesis were observed. The same was observed in relation to protein degradation, that is these rates, which were increased by the initial protein restriction, returned to values similar to C17 and S17 groups at the end of the experiment. No differences in the muscle protein synthesis and degradation rates were found when the normal protein groups were compared (C17 and S17). In recent studies performed by our group, the Spirulina proved to be adequate to maintain body growth, whereas the muscle protein synthesis rates were increased by the ingestion of the experimental diet in young rats (Voltarelli and Mello, 2008; Voltarelli et al., 2008; Voltarelli et al., 2003).

The alkaline phosphatase enzymes (APE) comprise a heterogeneous group of enzymes that are widely distributed in mammalian cells. They often are associated with cell membranes, but their exact physiologic function is unknown. Despite this, APE is a very useful serum biochemical indicator of liver disease. However, increases in the APE activity in certain tissues may reflect physiologic or pathologic changes beyond those of hepatic origin. For example, nonhepatic increases in tissue APE activity were found in young animals, in pregnant and lactating females, and in association with high fat or low protein diets (Fernandez and Kidney, 2007). In addition, the determination of APE in the skeletal muscle is a useful tool to estimate the cellular activity in this tissue (Calhau et al., 1999). In the present study, the activity of APE was higher in the soleus muscle of the protein malnourished rats (C6) when compared to the normal protein groups (C17 and S17). It may be hypothesized that the increase in the APE activity in soleus muscle of the C6 group might be a consequence, at least in part, of the protein turnover unbalance in this tissue, which was induced by low protein diet. On the other hand, the rats recovering from malnutrition (C6/C17 and C6/S17) had their muscle APE restored to control levels (C17 and S17),

concomitant to the increase of the protein synthesis and the decrease of the protein degradation rates.

In summary, Spirulina proved to be an adequate protein source to aid in the recovery of body weight and length gain of protein malnourished rats. In addition, muscle protein synthesis as well as muscle total protein and DNA contents were increased by the ingestion of the both experimental diets in young rats previously malnourished. Taken together, the results of the present study suggests that:

1. Feeding the rats previously submitted to protein restriction with balanced casein or Spirulina diet showed efficient in counteracting the alterations in body growth and muscle protein induced by the protein restriction;
2. Both diets proved to be equally efficient in this sense. This fact demonstrates the potential value of protein proceeding from algae in protein malnutrition recovery.

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