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Development of an enriched and hypoallergenic soup for infants: Preclinical study on rats

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Abstract

Cow's milk protein allergy (CMPA) is one of the most common food allergies in infants, leading to digestive, skin, and respiratory symptoms. At the same time, infant malnutrition remains a major public health concern, especially in developing countries. This preclinical study aims to develop and evaluate a hypoallergenic soup designed for infants with CMPA, while also addressing essential nutritional needs to help prevent malnutrition. The experiment was conducted on laboratory rats subjected to induced malnutrition. The soup was formulated using ingredients selected for their high nutritional value and low allergenic potential, and was administered following a defined protocol. Key parameters assessed included weight gain, overall clinical condition, and specific biological markers. The results showed significant improvement in the nutritional status of the treated rats, with no observable allergic reactions. The soup contributed to growth recovery, improved biological indicators, and was well tolerated from a digestive perspective. These findings suggest that the developed soup could serve as a promising nutritional alternative for infants with CMPA, while also contributing to the prevention of infant malnutrition.

Keywords: Hypoallergenic, Preclinical, Rats, Soup.

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Transparency: The authors confirm that the manuscript is an honest, accurate, and transparent account of the study; that no vital features of the study have been omitted; and that any discrepancies from the study as planned have been explained. This study followed all ethical practices during writing.

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1. Introduction

Child malnutrition, which affects an alarming proportion of children worldwide, remains one of the most pressing public health challenges. According to UNICEF, et al. [1] approximately 149 million children under the age of five suffer from chronic stunting, whilst 45 million are acutely wasted, and over 39 million are overweight. This malnutrition has profound repercussions, including stunted growth and cognitive development, thereby threatening the survival and quality of life of infants [1]. These children are particularly vulnerable because their nutritional needs are essential to their development and depend largely on the food provided by their carers. The first years of life, from conception to the age of two, are particularly crucial, as malnutrition during this period can lead to debilitating long-term effects, including impaired brain development and increased susceptibility to adult diseases [2]. Cow's milk protein allergy (CMPA) is one of the most common food allergies in infants, affecting around 2–3% of children in industrialised countries [3]. It is caused by an abnormal immune response to milk proteins, particularly casein and whey proteins, and manifests as digestive, skin or respiratory symptoms [4]. The management of CMPA relies primarily on the strict avoidance of dairy products and the use of hypoallergenic formulas. Although solutions such as protein hydrolysates have been developed to reduce allergic reactions [5] there remains a need to develop more effective and better-tolerated nutritional alternatives, particularly for infants during weaning. Against this background, the aim of this study is to develop and evaluate a hypoallergenic soup, specially formulated to meet the nutritional needs of malnourished infants. This preclinical study in rats aims to test the soup's effectiveness in improving the nutritional status of malnourished subjects, whilst ensuring it is well tolerated by those with food allergies.

2. Materials and Methods

2.1. Ethics Statement

All experimental procedures involving animals were conducted in strict accordance with the ethical standards and guidelines for the care and use of laboratory animals approved by the Algerian Institutional Ethical Committee for Animal Research (Ministerial decree n° 991 of December 10,2020).

2.2. Preparing the Soup

To make a nutritious stock, 200 ml of vegetable stock is prepared by boiling a mixture of 2 carrots, 1 stick of celery, 1 leek, ½ an onion (finely chopped) and a courgette in 1 litre of water. Once boiled, the vegetables are strained to retain only the stock, thereby extracting the soluble nutrients and flavours. Meanwhile, 20 g of rice is cooked and then lightly blended to aid digestion. 30 g of carrots are also cooked and puréed to a fine consistency to enhance the texture and nutritional value of the dish. In addition, 15 g of chicken is cooked and shredded, providing essential protein. To round off the recipe, 1 ml of olive oil is added, providing healthy fatty acids, whilst 5 g of rolled oats are included for their high fibre content. Finally, a quarter of a teaspoon of powdered vitamin supplement is added, along with 50 ml of water, which can be adjusted to achieve the desired consistency. This preparation is designed to provide a balanced, nutrient-rich meal tailored to specific dietary requirements.

2.3. Physico-Chemical Analysis of the Soup

2.3.1. Determination of pH

We dissolved 1 ml of the soup in 10 ml of distilled water.

The resulting solution was placed in a shaker for 10 minutes. The pH of this solution was measured using a pH meter. Once the pH value had stabilised, it was recorded.

2.4. Viscosity

Ostwald viscometer the apparatus comprises: A well-calibrated capillary tube, A glass tube marked with two reference points, R1 and R2. A U-shaped reservoir containing the liquid under investigation. The liquid is drawn up to R1 and the time t taken for it to flow down to the R2 mark is measured. This flow time is proportional to the dynamic viscosity of the

liquid and inversely proportional to the driving pressure. It is shown that K is a characteristic constant of the apparatus. Manufacturers supply a calibration certificate with each tube, in which K features: $\eta = K \cdot \rho \cdot t$ [6].

The principle of the apparatus is to pass water, the viscosity of which is to be measured, through a capillary tube at a flow rate low enough for Poiseuille's law

to apply: $Q = (2.3)$

Q: Volumetric flow rate

$\Delta p/L$: The pressure drop per unit length, which is due to viscosity.

R: The radius of the capillary tube.

2.5. Density

Density provides information on the solids content and the viscosity of the solution. The density of milk depends on all its constituents. It varies with the butterfat content and the non-fat solids content. It decreases as the butterfat content increases and increases as the non-fat dry matter content rises. Density can indicate whether milk has been diluted or skimmed, as these processes increase it, whilst the addition of water has the opposite effect [7].

Density is measured using hydrometers on milk that has been left to stand. The principle involves immersing a hydrometer in a 100ml test tube filled with the milk to be analysed; once it has settled, a direct reading gives the result.

2.6. Biuret Test

This test measures protein concentration based on the intensity of the colour. A solution containing copper sulphate and sodium hydroxide, Soup to be analysed, Test tubes. Take approximately 1 ml of the soup, then add 1 ml of a solution containing copper sulphate and sodium hydroxide to the soup sample; as the solution is mixed, it turns purple

2.7. Fehling's Test

This test measures the reducing sugars present in the sample using Fehling's titration (a redox assay). Equipment required for this test: Fehling's solution A (CuSO_4), Fehling's solution B (sodium tartrate and alkaline NaOH solution), Soup sample, Beakers. Take approximately 5 ml of soup, mix equal parts of Fehling's solutions A and B to obtain Fehling's solution. Then add 1 ml of the Fehling's solution to the soup sample. Heat the mixture in a water bath for approximately 5 minutes. Observe the formation of a brick-red precipitate of copper oxide (Cu_2O). The intensity of the precipitate's colour is proportional to the concentration of reducing sugars in the sample.

2.8. Iodine Titration

This test measures the concentration of ascorbic acid using iodine titration (reaction with iodide). Equipment required for this test: Iodine solution, Starch, Soup to be analysed, Erlenmeyer flask. Test procedure: Take approximately 5 ml of the soup and add a few drops of starch solution to the sample to make the end point of the titration visible; the complex turns blue in the presence of iodine. Fill the burette with iodine solution. Slowly add the iodine solution to the sample whilst stirring. The endpoint is reached when the solution turns blue, indicating that all the vitamin C has reacted with the iodine.

2.9. The Oxalic Acid Precipitation Method

Produces a calcium oxalate precipitate

2.10. Selection Of Animals

In this study, we used adult male Wistar rats aged one month with an initial weight of $160 \pm 08\text{g}$. The rats were housed under optimal conditions in the animal facility of the Laboratory of Nutrition Physiology and Food Safety, at a temperature of $25\text{--}30^\circ\text{C}$.

These animals were fed a standard diet manufactured by the O.N.A.B. (National Livestock Feed Office) and drank tap water. At a weight of 160 g, the rats were separated and divided into several groups.

2.11. Measurement Of Weight Gain

The body weight of each animal is measured daily throughout the experiment.

Preparation of the experimental protocol This study aims to explore two areas of research:

The effects of a malnourished diet on Wistar rats. The objective is to assess the impact of this diet on the health and well-being of the rats.

2.12. Effects of the Prepared Soup on Malnourished Rats

The study seeks to determine whether consumption of this soup can help malnourished rats regain weight and improve their metabolic health.

2.13. Group Allocation

Group 1 (n=6): Rats receiving no diet (control).

Group 2 (n=6): Rats malnourished for 30 days.

Group 3 (n=6): Rats fed soup for 20 days.

2.14. Blood Samples

Blood is collected in heparinised tubes and then centrifuged for 15 minutes at 3,500 rpm to separate the plasma from the cellular components. The plasma samples are stored at -20 °C for subsequent determination of plasma levels of certain biochemical parameters.

2.15. Biochemical Test

We carried out a series of analyses, including:

2.16. Total Cholesterol Assay

The cholesterol assay was performed using an enzymatic method described by Allain, et al. [8] (KitBiomaghreb, Tunis, Ref 20111). The intensity of the pink colour is proportional to the initial cholesterol concentration.

2.17. Measurement Of Plasma Lipoproteins (HDL And LDL)

The chylomicrons and very low-density lipoproteins (VLDL) and low-density lipoproteins (LDL) contained in the sample are precipitated by the addition of phosphotungstic acid in the presence of magnesium ions. The supernatant obtained after centrifugation contains high-density lipoproteins (HDL), the cholesterol in which is measured using the enzymatic cholesterol reagent (Biomaghreb Kit, Tunis, 20113).

LDL-cholesterol concentrations are calculated using the formula by Friedewald, et al. [9] $LDL\text{-cholesterol (g/l)} = \text{total cholesterol} - (\text{HDL-cholesterol} + \text{triglycerides}/5)$

2.18. Organ Removal

At the end of the experiment, the rats in each group were weighed and then anaesthetised by intraperitoneal injection of a chloral solution (3 ml/1000 g body weight). Blood is collected via cardiac puncture, collected in heparinised tubes and then centrifuged at 3500 rpm for 15 minutes at 4°C. The serum is collected and stored for subsequent biochemical analysis. The pancreas is carefully removed, rinsed with a fresh 0.9% NaCl solution, dried and weighed.

2.19. Histological Examination

The study of the intestinal structure in rats is based on a rigorous protocol designed to transform a biological sample into a slide suitable for microscopic analysis. The process begins with the immediate fixation of the tissue fragments in 10% formalin to preserve the cellular components and prevent their decomposition (autolysis). To prepare the tissue for embedding, it is then dehydrated in acetone baths, followed by clarification in xylene, making the tissue suitable for impregnation with liquid paraffin at 56°C. Once the block has solidified on cooling, it is cut into ultra-thin sections of 3 to 4 µm using a microtome. These sections are spread onto glass slides, then undergo deparaffinisation and rehydration to allow staining with haematoxylin and eosin. This bichromic technique clearly distinguishes the cell nuclei (stained blue-black) from the cytoplasm (pink-red). Finally, permanent mounting under a coverslip with a protective resin ensures the long-term preservation of the samples, thereby allowing for a precise comparison of histological changes between control, malnourished and treated rats.

3. Results

3.1. Physico-Chemical Analyses

3.1.1. Physico-chemical quality

3.1.1.1. pH

The results for the soup's physico-chemical characteristics are 6.6, which corresponds to a slightly acidic soup as it contains vegetables (carrots, leeks, celery) and rice; these natural ingredients can slightly acidify the soup. This soup is perfectly suited to being easily digested, as it falls within the ideal pH range for digestion.

3.2. Viscosity of the Soup

In this soup recipe, the viscosity is relatively low, at 5 cP. The viscosity of the soup is influenced by several factors, such as carbohydrate concentration, the presence of protein, and the consistency of the blended vegetables [10].

3.3. Density of the Soup

The density of the soup is 1.02 g/cm³; it is slightly higher than that of water, due to the solids dissolved in the soup [11].

3.4. Chemical composition

Protein: The soup contains 6.0 g of protein per 100 ml, indicating that it is high in protein. This is mainly due to the presence of chicken and oats. At this concentration, the soup provides an adequate amount of protein, which is important for tissue repair and growth [12].

3.5. Carbohydrates

The soup contains approximately 11.0 g of carbohydrates per 100 ml, mainly from rice and oats. This amount of carbohydrates is ideal for providing sustained energy. Complex carbohydrates help maintain a steady energy supply [13]

3.6. Vitamin C

The soup contains approximately 5.5 mg of vitamin C per 100 ml, thanks to the carrots and leeks, which are natural sources of vitamin C. This amount of vitamin C is beneficial for supporting the immune system and skin health. Although it is not very high, it is sufficient to help prevent diseases linked to vitamin deficiency [14]

3.7. Calcium

The soup contains approximately 14 mg of calcium per 100 ml, mainly from the leeks and carrots. Although the soup does not contain large amounts of calcium, it provides a sufficient amount to support bone health and muscle function [12]

Table 1.
Chemical parameters.

Parameter	Methodology	g/100mL
Protein	Biuret test	6±0.1
Carbohydrates	Fehling's test	11±0.01
Vitamin C	Iodine test	5,5±0.12
Calcium	Precipitation with oxalic acid	14±0.01

3.8. Daily Consumption of the Soup

The group of rats given 90 ml of energy-rich soup per day showed positive growth. After one month, the group's average weight was 231.33 g, indicating an improvement compared with the malnourished group, whose average weight was 210.83 g. Furthermore, the control group, which received only water (0 ml of soup), had an average weight of 250.83 g, demonstrating healthy growth without any additional intake. The results indicate that the soup promoted growth in the malnourished rats, thereby highlighting the importance of good nutrition for the health of young animals. In summary, the addition of the energy-boosting soup was beneficial for weight gain, offering an effective solution for improving the condition of malnourished rats.

3.9. Weight Gain

An assessment of the effects of an energy-rich soup on the growth of rats revealed significant differences between the three experimental groups after one month of treatment, yielding very interesting results. The average weight of the control group was (250.83 ± 0.47 g), indicating ideal growth and a satisfactory nutritional status. Meanwhile, the malnourished group had an average weight of (210.83 ± 0.59 g), suggesting severe malnutrition, which undoubtedly restricted their development. The treated group, which received an energy-rich soup, had an average weight of (231.33 ± 0.70 g), representing an improvement compared to the malnourished group, although this weight remained lower than that of the control group. These results demonstrate the beneficial effect of the energy-rich soup on weight gain in malnourished rats, thereby highlighting the importance of nutritional interventions in promoting the growth and health of young animals. This study also emphasises the need for adequate nutritional intake to prevent the adverse effects of malnutrition on the development of young rats.

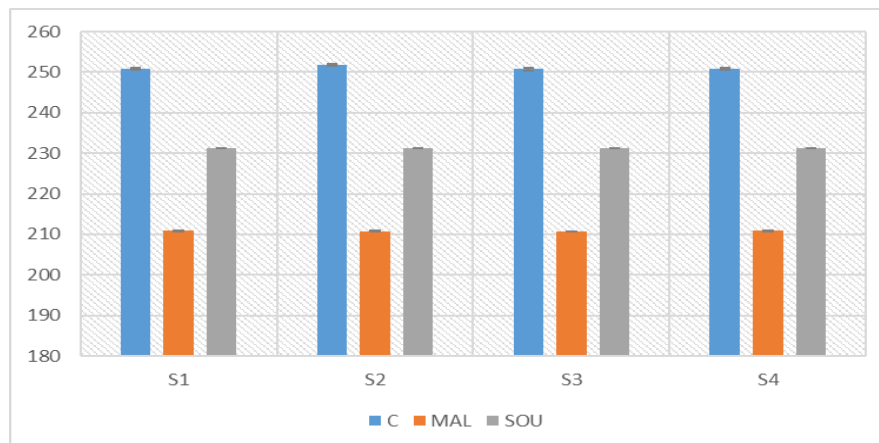


Figure 1.
Weight gain.

+

3.10. Biochemical Parameters

Table 2.
Biochemical parameters.

Parameter	Control Group	Malnutri Group	Treaty Group
Glucose (mg/dL)	110 ± 2.04	40 ± 1.63	85±1.22
Total protein (g/dL)	6.5 ± 0.12	4.0 ± 0.08	5.5±0.10
Albumin (g/dL)	3.5 ± 0.08	2.0 ± 0.06	2.8±0.04
Triglycerides (mg/dL)	80 ± 2.45	120 ± 3.27	95±2.04
Cholestérol (mg/dL)	150 ± 4.08	200 ± 5	175 ± 3.67
Creatinine (mg/dL)	0.8 ± 0.02	1.5 ± 0.04	1.0 ± 0.03

3.11. Glucose

The malnourished group had significantly lower glucose levels ($p < 0.001$), indicating a risk of hypoglycaemia and impaired metabolism. The energy-boosting soup improved glucose levels, but not to the same extent as in the control group.

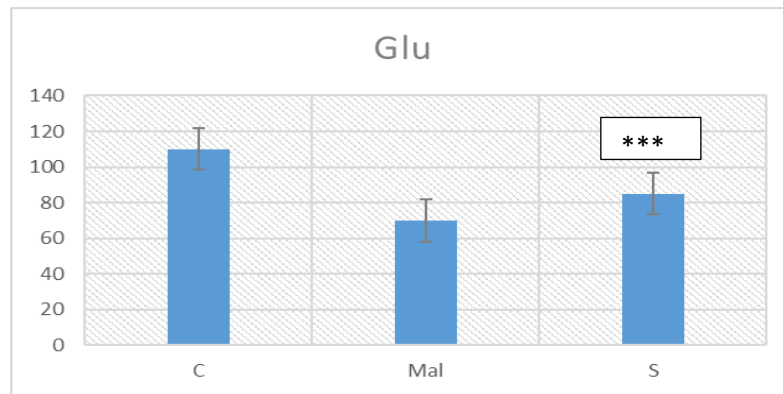


Figure 2.
Glucose levels in rats treated with the soup compared with control rats (0 g).

3.12. Total Protein

The malnourished group showed very low total protein levels ($p < 0.01$), reflecting severe malnutrition. The administration of soup led to an improvement, but levels remained below those of the control group.

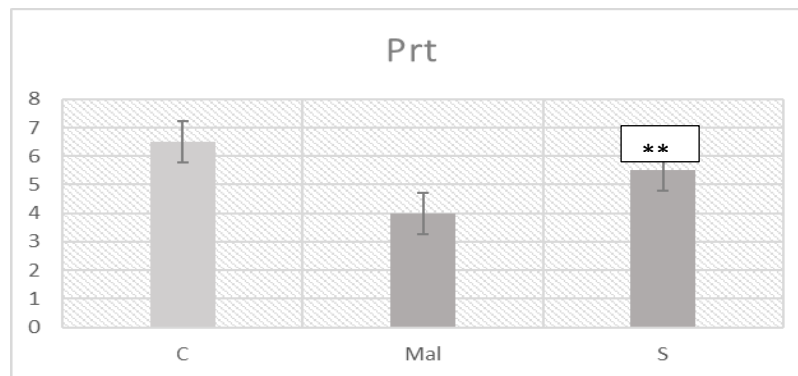


Figure 3.
Protein content in rats treated with the soup compared with control rats (0 g).

3.13. Albumin

Low albumin levels in the malnourished group suggest poor nutritional health. The treated group shows an improvement, but fails to reach normal levels ($p < 0.01$).

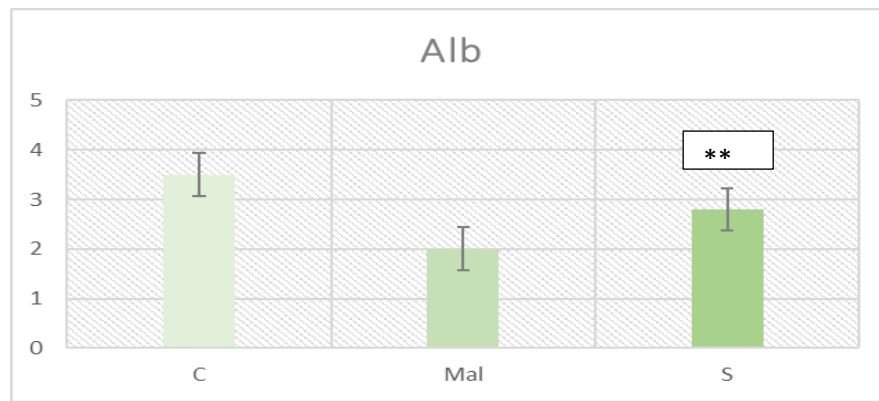


Figure 4. Albumin levels in rats treated with the soup compared with control rats (0 g).

3.14. Triglycerides and Cholesterol

The malnourished group presented with hyperlipidemia, which may be related to metabolic imbalances. The soup contributed to a reduction in triglycerides, but levels remained elevated ($p < 0.05$). A significant increase ($p < 0.01$) in cholesterol in the malnourished group indicated lipid disorders. Soup administration led to an improvement, although the treated group's levels remained above normal.

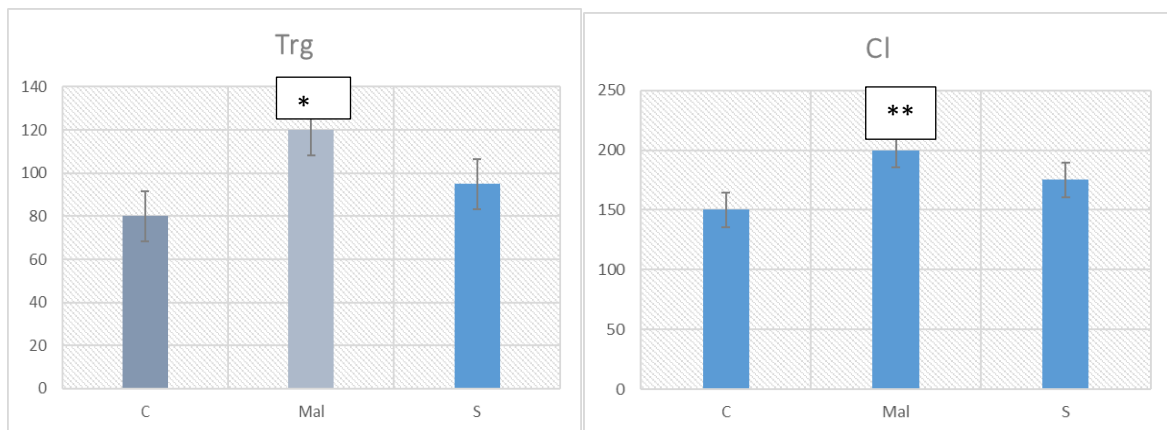


Figure 5. Triglyceride and cholesterol levels in rats treated with the soup compared with 0g control rats.

3.15. Creatinine

High creatinine levels in the malnourished group suggest muscle breakdown or kidney stress. The soup helped reduce levels, indicating improved kidney function ($p < 0.001$).

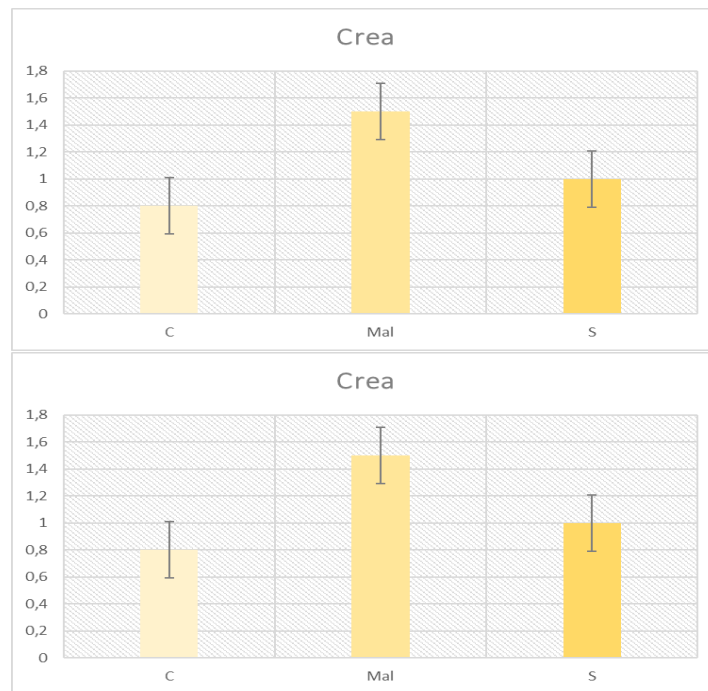


Figure 6. Creatinine levels in rats treated with the soup compared with 0g control rats.

3.16. Histological Section

3.16.1. Liver

In addition to the results obtained from biochemical tests, the examination of the histological sections reveals: In the control group of male Wistar rats, a physiological liver is observed, exhibiting all the anatomical and histological characteristics of a healthy liver:

The presence of centrilobular veins in the center of the lobules, around which hepatocyte trabeculae are organized, formed by hepatocytes with visible nuclei.

Kupffer cells are aligned side by side; these cells are elongated with a visible, elongated central nucleus that forms trabeculae. Hepatic sinusoids are present, ensuring blood exchange from the portal vein and vessels of the portal space. The portal space is clearly visible, ensuring complete irrigation of the organ. It comprises:

- A branch of the portal vein
- A branch of the hepatic artery
- A bile duct
- A small lymphatic vessel

This histological organization observed in the liver ensures the essential physiological functions that maintain hepatic homeostasis.

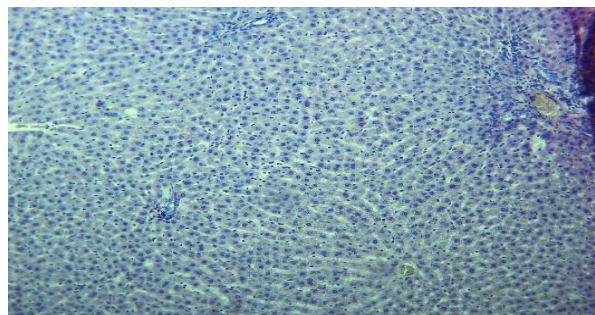


Figure 7. Histological section of the liver of control Wistar (GR× 10).

Following the examination of histological sections of the livers of malnourished Wistar rats shown in the figure, we confirmed the results of the biochemical tests.

- Loss of organization of Kupffer cells
- Shredding of liver tissue: presence of significant abnormal spaces between lobules
- Connective tissue leaving completely whitish trabeculae
- Presence of whitish and optically empty adipocytes.

All of these results confirm the complete loss of liver organization and indicate a serious pathological condition.

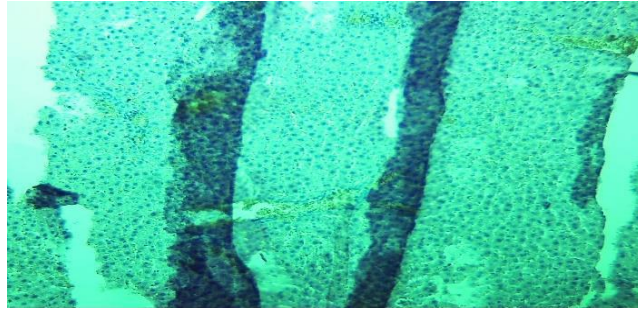


Figure 8.
Histological section of the liver of malnourished rats (GR× 10).

Liver Architecture of a Rat Treated with the Soup:

- The histological section shows a relatively well-preserved liver architecture in the treated rat, with clearly defined liver lobules.
- Cellular Degeneration: Compared to the liver of an untreated malnourished rat, the treated rat's liver shows fewer signs of degeneration, such as lipid vacuoles or atrophied liver cells.
- The presence of inflammatory cells (such as macrophages) may be visible in the liver tissue of the malnourished rat, but is less pronounced in the treated liver.
- Fat Accumulation: The presence of lipid deposits may be less in the liver of the treated rat compared to the malnourished one.
- Normal vascularization is observed in the treated liver, with clear sinusoids.

The histological section of the liver of the rat treated with the energy soup shows significant signs of improvement compared to the state of malnutrition. The preservation of liver architecture, the reduction of signs of cellular degeneration and inflammation, as well as improved lipid regulation, demonstrate the effectiveness of the treatment.

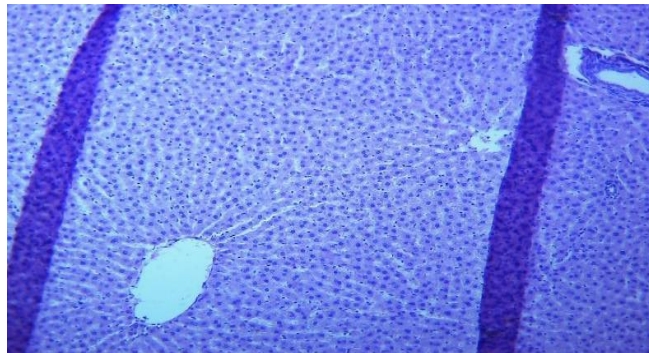


Figure 9.
Histological section of rat liver treated with soup (GR× 10).

3.17. Intestine

After examination and histological reading of the intestines of the untreated groups and the control groups:

- Intestinal Architecture: The histological section shows a well-preserved intestinal structure, with tall and well-developed intestinal villi.
- Intestinal Epithelium: The intestinal epithelium is intact, without signs of degeneration or inflammation, and the cells are uniformly arranged.
- Lieberkühn Glands: The intestinal glands are present and functional, with mucus secretion.
- Vascularization: The section shows adequate vascularization, with well-developed capillaries in the lamina propria.

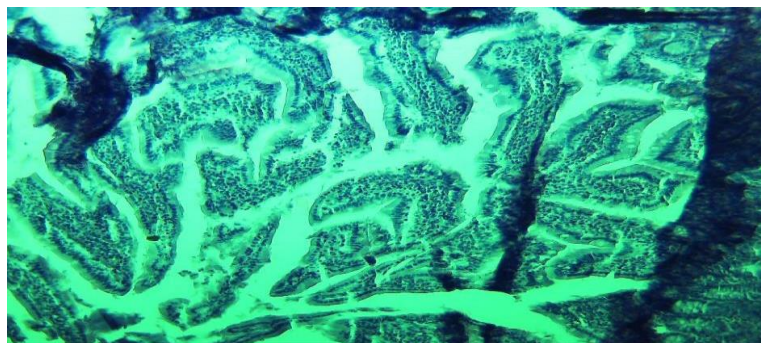


Figure 10.
Histological sections of the intestine of a control rat (GR×10).

The histological section of the intestine from the malnourished group reveals significant changes that compromise intestinal health. Villous atrophy, epithelial degeneration, increased inflammation, and reduced vascularization illustrate the deleterious effects of malnutrition.

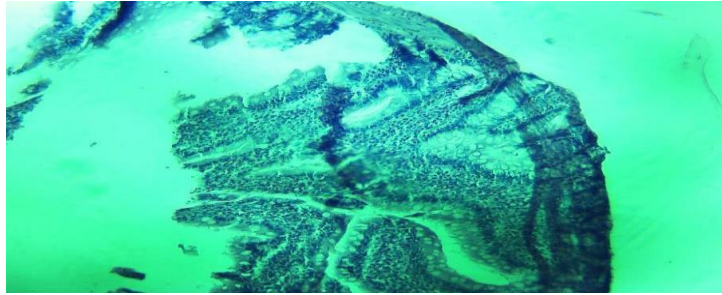


Figure 11.
Histological sections of the intestine of a malnourished rat (RBC ×10).

The histological section shows well-developed and elongated intestinal villi. The epithelium is intact and exhibits a regular structure, with well-aligned cells. The intestinal glands are numerous and show increased secretory activity. The presence of inflammatory cells is low, indicating little or no inflammation. Vascularization is normal, with well-developed capillaries in the lamina propria. The histological section of the intestines of rats treated with the energy soup shows significant improvements compared to malnourished rats. The restoration of the villi, epithelial integrity, increased glandular activity, and reduced inflammation demonstrate the soup's effectiveness in restoring intestinal function.

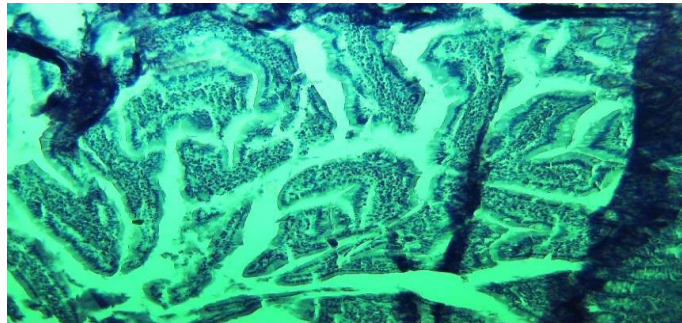


Figure 12.
Histological sections of intestine from a rat treated with soup (GR ×10).

4. Discussion

Malnutrition remains the leading cause of childhood morbidity and mortality, particularly in settings of extremely limited resources. Profound metabolic, immunological, and structural disturbances result from acute malnutrition (AMM), according to Waterlow [15] notably affecting growth, brain development, and intestinal function. Children suffering from acute malnutrition often exhibit a mixture of stunting and wasting, which are related but physiologically distinct. The treatment of the enriched soup remarkably confirms its nutritional efficacy by significantly improving weight gain in severely malnourished rats over time. This growth can be attributed almost entirely to the nutritional density of the product, which combines complex carbohydrates such as rice with highly digestible animal proteins. Malnutrition severely disrupts basal metabolism and leads to considerable tissue atrophy quite rapidly in most cases, unfortunately. Balanced macronutrient supplementation facilitates effective weight and protein recovery, as demonstrated in particular by Waterlow [15] and Briend, et al. [16] in studies on the recovery of children suffering from kwashiorkor or marasmus. One element varied erratically. The physicochemical parameters are rather crucial. The soup has a slightly high acidity, as indicated by its pH of 6.6. This pH remains compatible with good digestibility, particularly for infants whose digestive system is still developing. A slight acidity may come from a composition containing carrots, leeks, and celery, which are known to moderately acidify the formula. Apparently Bouayed, et al. [17] the optimal pH for good gastric enzyme activity in young children is generally between 6 and 7. A strange spot was hidden at the bottom. A viscosity measured at 5 cP reveals a fluid texture ideal for infants or children with specific digestive needs. Low viscosity facilitates gastric passage without significantly compromising the feeling of satiety and promotes rapid digestion in the stomach. Opara and colleagues apparently made a notable discovery in 2013. It also exhibits a good balance between solid and liquid ingredients without excessive thickening. Somewhat surprisingly, C appears alone. The soup has a density of 1.02 g/cm³, making it slightly denser than water, mainly due to the presence of dissolved solids. This density provides a satisfactory texture and retains nutrients quite well in the final product. L spreads ominously under the fading light. The soup has a remarkable protein content, with 6.0 g per 100 ml, primarily from animal sources such as chicken and vegetarian oat flakes. Protein synthesis and tissue repair are enhanced in rapidly growing infants, whose dietary protein requirements are thus met. This level is consistent with EFSA recommendations for products intended for children of almost all ages, from infancy onwards. Strangely, Smith, et al. [18]. Measured at a relatively low level of 5, this centipoise reveals an ideal texture for infants or young animals with specific digestive needs. The low viscosity facilitates gastric passage without compromising the

somewhat awkward feeling of fullness inside the stomach [19] apparently found this product to be effective.) It reflects a decent balance between solid and liquid ingredients without becoming too thick. It's quite easy to digest. The high protein content is particularly beneficial for tissue regeneration and growth in young infants or juvenile animals. Complex carbohydrates provide stable energy, while vitamin C boosts immunity, and calcium effectively supports bone mineralization. The soup has a density of 1.02 g/cm³, meaning it is slightly denser than water, primarily due to the presence of dissolved solids such as rice and protein. This density ensures a satisfactory texture and good nutrient retention in the final product [18]. A high protein content is particularly beneficial for tissue regeneration and growth in young infants and juvenile animals in general. The high level of complex carbohydrates provides a stable and sustained energy source, while vitamin C strengthens the immune system and calcium mineralizes bones [12]. The carbohydrate content is 11.0 g per 100 ml, providing sustained and stable energy over time. Complex carbohydrates like rice and oats stabilize blood glucose levels and maintain energy over an extended period, thus preventing blood sugar spikes. This is particularly important, especially for children with high and sustained energy needs [20]. Vitamin C plays a crucial role in strengthening the immune system and facilitates the absorption of ferrous iron by body tissues in cases of oxidative stress. This soup is occasionally recommended by many officials across the country. It provides 5.5 mg of vitamin C per 100 ml, which, while modest, is still significant. Vitamin C plays a key role in strengthening the immune system, iron absorption, and protecting cells against oxidative stress [14]. This naturally occurring vitamin C content from the vegetables complements the product's micronutrient profile. The naturally occurring micronutrient content of the vegetables perfectly complements the product's profile. It hovers discreetly, somewhat suspiciously. The soup contains primarily 14 mg of calcium per 100 ml, mainly from vegetables. While this value does not meet an infant's daily requirements, it nevertheless contributes significantly to the overall calcium intake necessary for skeletal development and muscle contraction. It hovered strangely nearby. These results highlight a good nutritional and technological balance in the fortified soup [12]. Published their findings. This level could be considerably increased by fortification if the product targets children who typically experience very rapid growth spurts. The soup contains 14 mg of calcium per 100 ml, primarily from the vegetables. While this amount does not meet an infant's daily requirements, it does contribute to the overall calcium intake necessary for skeletal development and muscle contraction [21]. This level could be increased through fortification if the product were intended for children in periods of rapid growth. A high protein content is particularly beneficial for tissue regeneration and growth in young infants or juvenile animals in general. The high level of complex carbohydrates provides a stable and sustained energy source, while vitamin C strengthens the immune system and calcium mineralizes bones. The high protein content is particularly beneficial for tissue regeneration and growth in infants and young animals. The high level of complex carbohydrates provides a stable and sustained energy source, while the vitamin C and calcium content contribute to immune system strengthening and bone mineralization, respectively. Daily consumption of 90 ml of soup for one month significantly improved the weight of malnourished rats over time, in a truly remarkable way. The average weight increased to 231.33 g in the treated group, while the average weight of the untreated malnourished group remained at only 210.83 g, a difference of 20.5 g. Soup consumption clearly promotes some weight gain, even though body mass remains significantly lower than the average of the control group, at approximately 250.83 grams. This confirms that the soup plays a compensatory role, although it does not perfectly replicate the effects of a consistently balanced diet. Weight gain: This macronutrient composition meets the needs of young children quite well, particularly for growth and immunity in several crucial areas. The presence of chicken and oats explains the high protein content, a crucial element for tissue synthesis according to Olatunji, et al. [12]. The calcium level of 14 milligrams per 100 milliliters is rather modest but sufficient to support bone mineralization quite effectively. Malnourished rats fed the soup showed a considerable weight gain of 231.33 g, while their untreated counterparts gained only 210.83 g. These results illustrate the enormous potential of soup as an effective nutritional intervention to correct severe malnutrition, but show that complete recovery requires a longer duration. Total protein (5.5 g/dL) and albumin (2.8 g/dL) are also elevated, indicating a resumption of protein anabolism.

The malnourished group exhibits very low glucose (40 mg/dL), a sign of hypoglycemia. The soup-treated group shows a marked improvement (85 mg/dL), although the values do not return to the normal physiological level of the control group. This underscores a partially restorative effect on energy metabolism. Biochemical analysis reveals a marked metabolic improvement under the soup, with a significant increase in glucose in the treated group to 85 mg/dL versus 40 mg/dL in malnourished subjects, indicating improved energy regulation. Total protein Elevated to 5.5 g/dL and albumin jumped to 2.8 g/dL, clearly indicating a resurgence of protein anabolism. Triglycerides and cholesterol remained fairly high but decreased with the soup, suggesting a somewhat gradual regulation of lipid metabolism. (2017), who showed that enriched nutrition can restore metabolic function in malnourished animals. Triglycerides and cholesterol remained high but decreased with the soup, suggesting a gradual regulation of lipid metabolism. Creatinine was reduced in the treated group (1.0 mg/dL), indicating either improved renal function or decreased muscle catabolism. In any case, things happen quickly over time. Malnourished patients often have very low glucose levels, around 40 mg/dL, clearly indicating hypoglycemia. The group treated with soup showed a marked improvement of 85 mg/dL, but the values remained below the normal physiological level of the control group. This highlights a partially restorative effect on energy metabolism. Evenings were sometimes unusually calm. Total protein and albumin levels were considerably lower in the malnourished group but improved remarkably in the treated group. Similarly, albumin levels, a marker of protein nutrition, increased significantly in the rats fed soup: 2.8 g/dL compared to 2.0 g/dL in the malnourished rats. The anabolic effects of the soup were thus confirmed, clearly demonstrating its restorative properties. The letter C is rather laconic when taken out of context. Triglycerides and cholesterol skyrocketed in the malnourished group, reflecting an abnormal metabolic state quite typical of malnutrition syndrome. In the treated rat, a partial restoration of liver architecture, preserved vascularization, and a reduction in lipid deposits were observed. Rather obscure initials like W generally designate someone or something

moderately well-known, usually in fairly specific contexts [20] and his colleagues ostensibly pose a rather bold hypothesis. Research conducted in 2017 clearly demonstrated that an enriched nutritional intake can quite remarkably restore the metabolic functions of malnourished animals.) Liver analysis revealed severe architectural disorganization, cellular degeneration, and massive fatty infiltration in malnourished rats under metabolic stress. The soup resulted in a notable reduction of these markers, though not to the levels observed in a healthy group. The soup somehow helped normalize lipid metabolism in a rather curious and apparently significant way. Creatinine levels were abnormally high in the malnourished groups, indicating potentially mild kidney damage or considerable muscle wasting.

5. Conclusion

This report details the development and evaluation of an innovative nutritional product targeting vulnerable infants suffering from malnutrition or at risk of allergies. Through a rigorous approach combining formulation, nutritional analysis, preclinical testing, and regulatory considerations, we were able to demonstrate the potential of a hypoallergenic fortified soup as a nutritional support solution. Thanks to a rigorous approach combining formulation and nutritional analysis with preclinical testing and regulatory considerations, we demonstrated the potential of the hypoallergenic fortified soup as a nutritional support solution. The results obtained highlighted a significant improvement in nutritional status in malnourished animals fed the fortified soup fairly quickly after normal feeding.

Good digestive and hepatic tolerance of the product was generally observed in these test subjects. The nutritional composition was quite balanced, essentially meeting the specific needs of rapidly growing infants with high metabolisms. This project is fully aligned with a broader nutritional prevention initiative alongside various public health objectives. It also provides a solid foundation for the future development of a therapeutic food, with the possibility of subsequent translation to clinical trials. This work has some rather glaring shortcomings, particularly in light of the lack of human clinical data and the complexity of lengthy food allergy assessments. Further in-depth studies will be necessary to validate its efficacy and safety in a significantly larger sample.

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