

## **DEVELOPMENT AND EVALUATION OF RENAL-FRIENDLY HYDRATION CUBES USING FLAXSEED MUCILAGE FOR NUTRITIONAL AND FUNCTIONAL APPLICATIONS**

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### **ABSTRACT**

Chronic Kidney Disease (CKD) must be tightly controlled in terms of fluid and electrolyte intake, which usually leads to constant thirst, dehydration, and low quality of life. The objective of the study was to formulate renal-friendly hydration cubes by using flaxseed mucilage as a natural hydrocolloid to give controlled and sustained hydration with lower electrolytes load. The formulation of hydration cube was based on flax seed mucilage, agar, reverse osmosis water, honey and lemon juice, and the agar concentration (1.5, 1.8 and 2 percent) varied to reach optimal gel strength. The sensory analysis showed that formulation F3 (2% agar) had the best overall score (7.5) in acceptability, appearance, texture, taste, and flavor. Physicochemical examination revealed an improvement in the moisture content (82.2%), water holding capacity (86.6%), swelling index (3.07%), and in-vitro swelling (2.61%), which indicated high hydration potential. It was found in distilled water (5.07%) and simulated gastric fluid (6.1%), and reduced syneresis (4.1%) validated that gel stability was enhanced. Mineral analysis showed that sodium, potassium, calcium, and phosphorus were low, which are appropriate in renal diets. The microbiological analysis revealed acceptable values of total plate count and yeast and mold. The researchers conclude that hydration cubes made of flaxseed mucilage provide a new safe and effective method of controlled hydration among CKD patients to enhance adherence and quality of life.

Keywords: Chronic Kidney Disease, Hydration Cubes, Flaxseed mucilage, Hydrogel, Controlled hydration.

## 1. Introduction

Chronic Kidney Disease (CKD) is a long-lasting and irreversible condition which is marked by a progressive deterioration in the renal functioning over a prolonged period of time. The kidneys handle critical physiological processes such as the blood filtration, elimination of waste products in the body, electrolyte balance regulation, acid-base balance, and fluid homeostasis. In the event of kidney malfunction, these homeostatic mechanisms are ineffective and the result is the build-up of toxic metabolites, electrolyte imbalances and fluid homeostasis. These complications are associated with high morbidity and mortality of CKD patients.

CKD has become a significant global health issue and its prevalence is on the rise because of the growing rate of non-communicable diseases like diabetes mellitus, high blood pressure, heart diseases, and obesity. The epidemiological researches propose that a considerable percentage of the population has CKD, and many of them are not diagnosed until the late stages because the disease develops without symptoms at the initial stages. The prevalence of CKD is especially high in such countries as India because of several factors such as ineffective access to healthcare, late diagnosis, and poor awareness of disease management and preventive measures.

Treatment of CKD is a complex process, involving pharmacological, lifestyle, and nutritional control. Dietary management is one of these and is vital in delaying the course of the disease and complications. Often, patients are asked to adhere to regulated protein, sodium, potassium and phosphorus intake. Besides these dietary limitations, fluid control is another important aspect of CKD management especially among patients in the later stages of the condition or patients under dialysis.

One of the clinical challenges in CKD patients is to maintain optimal hydration. On the one hand, sufficient hydration is required to sustain physiological functions, blood flow and metabolic activities. Conversely, when fluids are administered in excessive amounts, it may cause fluid overload that causes edema, high blood pressure, pulmonary congestion, and cardiovascular risk. Consequently, patients are generally prescribed to maintain a strict fluid limit that can be commonly computed depending on the urine excretion and clinical status.

Nevertheless, fluid restriction is often related to incessant thirst, dry mouth, decreased salivary secretion, and overall discomfort. These symptoms may have severe impacts on the quality of life of the CKD patients and cause lack of adherence to dietary advice. Thirst is not only a physiological reaction but also a psychological and behavioural reaction and thus patients find it hard to regulate the amount of fluid they take. This brings to the fore the necessity of new ways to deal with thirst but in a way that will not lead to fluid imbalance.

Conventional hydration strategies, including simply taking plain water, fail to deliver controlled hydration and can result in a rapid intake of fluids raising chances of fluid overload. On the same note, the drinks containing electrolytes, despite their usefulness in some situations, are not applicable to CKD patients since they contain high levels of sodium and potassium. These restrictions highlight the importance of finding alternative methods which may provide hydration in a well-regulated and sustained form, without having a negative impact on electrolyte equilibrium.

The use of hydrogel-based systems in food science has been receiving special interest in the recent years as a possible solution to controlled hydration. Hydrogels are three-dimensional frameworks of hydrophilic polymers that may incorporate and keep significant quantities of water inside their system. These systems can also discharge water at a slow pace depending on the environmental conditions and this makes them applicable in a long-term hydration system. The use of hydrogels in food items is a new way of solving hydration issues among the clinical population.

Natural hydrocolloids are of special interest to develop hydrogel-based food systems because they are safe, biodegradable and versatile in terms of functionality. Flaxseed mucilage has been one of the promising candidates out of these, because it has good water-binding property, viscosity and gel-forming property. Soluble polysaccharides make up the bulk of flaxseed mucilage, and are what allow it to form stable gel networks, which can hold large volumes of water.

Besides its functional characteristics, flax seed mucilage has nutritional value; it contains a high level of soluble dietary fiber and has a potential antioxidant effect. These properties can be used in addition to other health benefits like better gastrointestinal functioning and metabolism. Flaxseed mucilage use in food preparations is in line with current trends in making functional foods which are not only beneficial in terms of nutrition, but also therapy.

The idea of creating hydration cubes with the help of hydrocolloids is a new strategy in the management of fluids in CKD patients. With water being trapped in a gel matrix, one can have a controlled and slow release of water when consuming and digesting. This method can aid in decreasing the feeling of thirst, avoiding the rapid fluid consumption, and enhancing the compliance with fluid limitations.

Thus, the current research was conducted with the goal of creating renal-friendly hydration cubes with flaxseed mucilage as a natural hydrocolloid. The objectives of the study are to optimize the formulation, test the sensory and physicochemical properties, and determine the appropriateness of the product in controlled hydration in CKD patients. This study combines concepts of food science, nutrition, and clinical management in an effort to resolve a vital issue in renal health and in the effort to pioneer the creation of creative dietary interventions in the treatment of chronic illnesses.

## 2. Materials and Methods

### 2.1 Raw Material Procurement

The choice of raw materials was informed by both the functional and nutritional factors pertaining to the management of CKD. The flaxseeds have been selected as the main source of mucilage because of their large amount of soluble dietary fibers and good hydrocolloid properties. Agar is a polysaccharide that is naturally occurring and is a by-product of seaweed; it was chosen as a gelling agent because it is capable of creating strong and firm gels at comparatively low concentrations.

Honey was used as a natural sweetener to enhance palatability and lemon juice was used to enhance flavor and to give the product a slight acidic condition which could help in product stability. All ingredients were sources of good local sources to be of good quality and fresh. Analytical-grade chemicals were used for laboratory analyses to maintain accuracy and reliability of results.

### 2.2 Extraction of Flaxseed Mucilage

A hot water extraction method was used in the extraction of the flaxseed mucilage, which is known to be efficient and simple. Flax seeds were combined with distilled water at a ratio of 1:20 and heated within the 80-90 C range of temperature over 30-45 minutes. The process was continuously stirred to facilitate even extraction and avoid the local overheating.

The mucilage which was in the outer coat of the flaxseeds was discharged into the water around them during heating, and produced a viscous solution. The mixture was then filtered using muslin cloth to remove the mucilage, and the residues of the seeds. The mucilage obtained was left to dry to room temperature and then stored under refrigerated conditions to maintain its functional qualities and to avoid the growth of microbes.

### 2.3 Preparation of Hydration Cubes

The optimal gel strength and stability of hydration cubes were established by three different formulations with varying agar concentration (1.5, 1.8, and 2%). Agar was dissolved in water by heating until it was completely dissolved. The flaxseed mucilage was subsequently extracted, and added to the agar solution and stirred thoroughly to form a homogenous mixture.

Honey and lemon juice were added to the mixture in moderated amounts to improve the sensory properties without changing the nutritional content of the composition to a great extent. The resulting mixture was cast in molds of the same size and left to cool at room temperature and then refrigerated to help the gel to set.

After the gel formation was done, the cubes were delicately demolded and kept in hygienic conditions to

be analysed. The ready samples were identified by the concentration of agar as F1, F2, and F3.



Fig 1: Formulation 1



Fig 2: Formulation 2



Fig 3: Formulation 3

### 2.4 Sensory Evaluation

The acceptability of the developed hydration cubes was checked using sensory evaluation. Semi-trained panelists rated the samples on a 9-point hedonic scale with a range of scores ranging between dislike extremely and like extremely. Parameters assessed were on appearance, texture, taste, flavor and overall acceptability.

The test was conducted in a controlled environment to reduce extraneous factors. Coded samples were used to eliminate bias among the panelists. The statistical analysis of the results was carried out to determine the most acceptable formulation.

### 2.5 Physicochemical Analysis

The physicochemical characteristics of the hydration cubes were measured to ascertain their functional performance. Standard drying procedures were used to determine the moisture content of the product, which gave the indication of the hydration potential of the product. The ability of the gel matrix to withstand

pressure of water was measured to determine water holding capacity.

The water absorption capacity of the cubes at simulated conditions was studied by carrying out swelling index and in-vitro studies of swelling. These parameters are essential in the behavior of the product in the gastrointestinal environment.

The measure of syneresis was used to establish how much water came out of the gel during storage, an indicator of gel stability. The pH of the samples was also determined to ascertain whether it was suitable to eat and also to determine whether it would impact on stability.

### 2.6 Mineral Analysis and Microbiological Analysis

The mineral analysis was conducted to establish the levels of sodium, potassium, calcium, and phosphorus because the electrolytes are important and should be regulated in the CKD patients. The correct measurement was ensured through the use of standard analytical techniques.

Microbiological analysis was done; Total Plate Count and Yeast and Mold Count were determined to determine the safety and quality of the product. These tests were carried out in accordance with the standard procedures to adhere to the food safety standards.

## 3. Results and Discussion

### 3.1 Sensory Evaluation

The results of the sensory evaluation showed that the formulations had significant difference in terms of acceptability. The highest overall score of acceptability was in formulation F3 which had 2% agar, which implies better consumer preference. The agar concentration helped in improving the strength of the gel leading to a firmer texture which was found more desirable by the panelists.

The look of the cubes was observed to be more homogeneous and pleasing on the F3 that could be explained by the quality of gel network formation. The aspect of texture was very important in terms of acceptability because there must be a balance between firmness and softness to allow easy consumption. Honey and lemon juice presence helped to balance the taste and flavor profile by covering the mucilage flavor inherent, and increasing palatability.

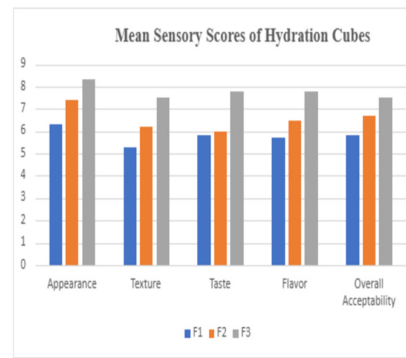


Fig 4: Sensory Evaluation of Hydration Cubes

### 3.2 Physicochemical Properties

The physicochemical test revealed that the hydration cubes had a high content of moisture, which is a requirement in their usage as hydration aids. The higher the concentration of agar, the better was the water holding capacity and this means that the gel network was stronger and more stable to hold more water.

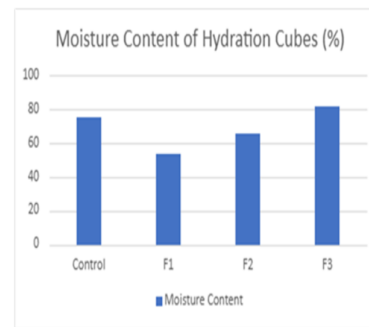


Fig 5: Moisture Content of Hydration Cubes

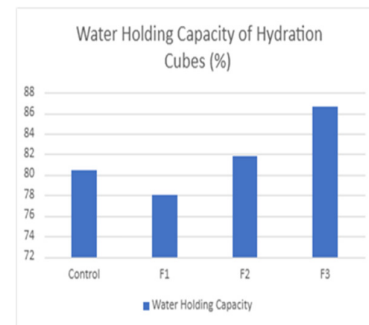


Fig 6: Water Holding Capacity of Hydration Cubes

Agar concentration led to an increase in the swelling index indicating an augmented water uptake ability. This is beneficial to regulated hydration, since cubes can slowly dissipate water with time. Swelling experiments in-vitro also verified that the cubes could be structurally intact and absorb water, which is a sign that they would be suitable in gastrointestinal environments.

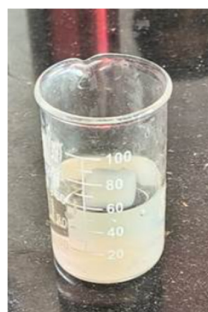


Fig 7: Estimation of In-vitro Swelling Index

### 3.3 Controlled Water Release Behavior

The water flow control measured in the hydration cubes is one of the main functional characteristics that make them stand out in comparison to the traditional hydration techniques. The slow leakage of water in the distilled water and in simulated gastric conditions suggests that the product is capable of hydrating a person on a long-term basis.

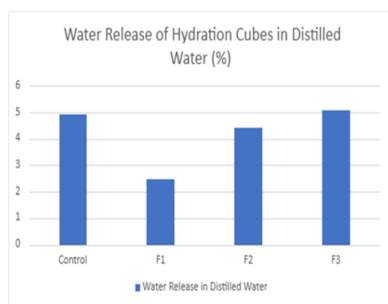


Fig 8: Water Release in Distilled Water

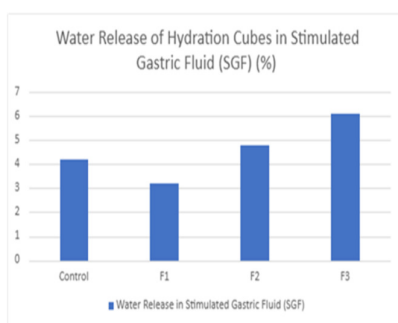


Fig 9: Water Release in SGF (Stimulated Gastric Fluid)

The reduced syneresis values in formulation F3 point to the enhanced stability of the gel and decreased water loss in the course of storage. This indicates that the product can retain functional properties throughout a long period, which is relevant to the practical use.

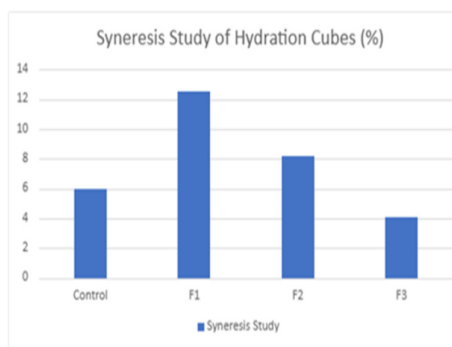


Fig 10: Syneresis Study of Hydration Cubes

### 3.4 Nutritional and Clinical Relevance

The low electrolyte content of the hydration cubes is also a huge plus, as far as the clinical perspective is concerned. The patients of CKD need to maintain a rigid control over the intake of sodium, potassium and phosphorus to avoid complications like fluid retention and electrolyte imbalance. These requirements are satisfied by the developed product and it also offers functional hydration.

As well, soluble dietary fiber content of flaxseed mucilage could provide other health benefits such as better gastrointestinal performance and possible regulation of glycemic response. As these benefits were not the main thrust of the research, they add value to the product as a functional food.

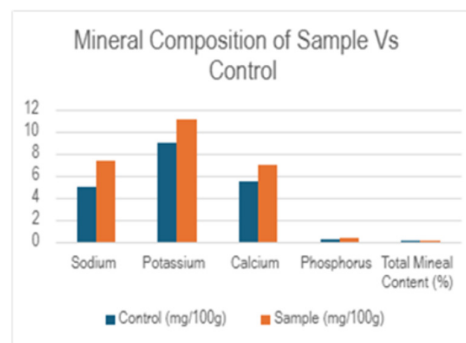


Fig 11: Mineral Composition of Hydration Cubes

## 4. Conclusion

The current research was able to show how renal-friendly hydration cubes could be developed using flaxseed mucilage as an example of a natural hydrocolloid to be used in delivering hydration in a controlled manner. The optimized formulation showed good sensory properties, sufficient structural integrity, and increased physicochemical properties, such as high water holding capacity and better swelling behavior. All these features make the product an effective sustained hydration system.

The regulated discharge of water in the developed hydrogel matrix points to the fact that it can be used in

order to overcome one of the primary issues of Chronic Kidney Disease management, i.e. fluid retention without fluid overload. The fact that the product contains low concentrations of important electrolytes like sodium, potassium, and phosphorus also adds to the appropriateness of the product to the needs of renal diets, which makes the product safe and functional.

Clinically and nutritionally, the developed hydration cubes are a new and convenient way of providing comfort to the patient by decreasing the sensation of thirst and increasing adherence to fluid limitations. Flaxseed mucilage does not only give the product functional advantages but it also delivers nutritional value, which is in line with the increasing need of natural and health-oriented food solutions.

In general, the article focuses on the promise of hydrocolloid-based functional foods in clinical nutrition and the opportunities that exist to incorporate food technology advances in the management of disease. Future studies ought to be done on the shelf-life assessment, package optimization and clinical trials aimed at confirming the efficacy of the product in a real-life setting, which will make it easier to apply to a large scale and commercially.

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