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Nutritional and Healthier Dietary Fiber Enriched Cookies from Sugarcane Bagass

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Abstract*: Innovation forms the essence in bringing about economic and social development; specifically, eco-friendly innovation that not only triggers production but also promote efficient use of natural resources as well. As a result of changing economic, political, and ecological conditions in the world, innovations now enable higher value in unprocessed raw material within a chain; processing, packaging, storage, delivery and distribution of food after production and food safety. Consequently, use of technology towards efficient utilization of by-products accelerates growth and development of the entire system as a whole giving due diligence to effective production throughout the chain. The ultimate impact of technology use and innovation can be achieved in decreasing poverty through rural development as well as improving the standards of living of the urban sector as well. With the aim to develop nutritionally and functionally improved cookies, sugarcane bagasse derived dietary fibre was used in formulation. The prepared biscuits were analysed for their physiochemical properties such as spread ratio, diameter, thickness, fat content, moisture content, crude fibre content, dry matter, ash content etc. The physiochemical chemical properties were also adjudged against commercially available products. It is also pertinent to mention that the product's sensory qualities were not negatively influenced with the incorporation of sugarcane bagasse derived dietary fibre thereby opening possibilities to use the bagasse derived dietary fibre in biscuits as well as in other bakery products.

***Keywords*: Nutrition, dietary fibre, sugarcane bagasse, eco-friendly, food safety.**

1. Introduction

Agriculture forms the backbone of the Indian economy supporting more than 2/3rd of the total population of the country and also contributing significantly to the GDP of the country. Therefore, agriculture holds a significant stature in social, political and economic affairs. Sugarcane is one of the major cash crop in India where more than 50 million farmers are directly or indirectly dependent on the sugar or sugar based industries. India is second in line for production of sugar around 30 MMT (crushing season 2020-2021) next to Brazil. In spite of many bigs, this industry often encounters issues of economic sustainability to the extent that the issues of pending cane prices arrears become a burning issue attracting the government. The importance of by-product utilization has been realized by the industry as merely depending upon revenues from sugar alone to a greater extend does not sound as a profitable venture in times to come and hence better management of by-products could be a promising asset to the sugar industry as a whole. The by-products of the sugar industry whose potential have not been explored to its maximum, have huge scope to be converted in to value- added products through innovative approach and thereby would yield more income to the industry through sale and marketing of such innovative and attractive products rather than sugar. The potential of revenue generation through utilization of various by-products viz. Bagasse, filter cake and molasses is to be taken up in an innovative manner besides developing technologies for converting huge amount of surplus water into good quality manner to meet human needs and earn revenue. Being the second largest agro-based industry in the country, sugar industry generates various solid wastes such as sugarcane trash, bagasse, filter cake and bagasse fly ash. These by-products of the industry can either be considered as waste, affecting the environment, or can be looked upon as a resource when put to proper use through implementation of appropriate valorization technology. [1]

Consumers' concerns regarding healthy diet and convenience foods have significantly increased in the last decade. Nowadays, consumers are interested not only in the quality but also in the nutritive value and safety of the products they eat. Dietary fiber (DF) is considered as one of the food ingredients with a significant contribution to health. Since 1998, the food agriculture organization (FAO) of the United Nations (UN) and the World Health Organization (WHO) have developed global strategies for bettering diet, physical activity and health of the common masses. Particularly, a diet with low glycemic Index can be beneficial in the control of diabetes even in healthy subjects. [2]

The Global dietary fiber market exhibited strong growth during 2015-2020. Looking forward, International Market Analysis Research and Consulting (IMARC) Group expects the market to grow at a compound annual growth rate (CAGR) of around 8 % during 2021-2026. Keeping in the mind

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uncertainties of COVID-19, continuous efforts are being made for tracking and evaluating the direct as well as the indirect influence of the pandemic and efforts are being made to make healthier product such as dietary fiber enriched cookies with goodness of jaggery which would help boosting consumers' immunity and overall health profile. [3]

Dietary fibers, or roughage, are indigestible complex carbohydrates that are present in various food products. such as fruits, vegetables, nuts lentils and grains. There are primarily two kind of dietary fibers, soluble and non-soluble, which aids n maintaining the proper functioning of the digestive system. The soluble fibers give a feeling of satiety, facilitate weight loss and control cholesterol and blood sugar levels in the body. On the other hand, insoluble fibers absorb water to normalize bowel movements and ensure the proper functioning of the stomach and intestines. They also aid in preventing duodenal ulcers, irritable bowel syndrome (IBS), hemorrhoids and constipation. Due to the pandemic consumer inclination towards proactive healthcare and maintaining a healthy life style is increasing which is also one of the key factors driving the market growth for nutritious and high fiber food commodities. Today consumer is well aware of the benefits of incorporating fibers in their daily diets through foods, nutritional supplements and beverages.

To further exploit the potential of by-product (bagasse figure 1) of the sugar industry for developing value added products, the present study aims at utilizing sugarcane bagasse derived dietary fiber to produced healthier nutritive cookies.

Fig. 1. Sugarcane Bagasse

As it is rightly said, "nutrition is a basic prerequisite to sustain a healthier lifestyle", being aware of the importance of dietary fiber required by all age group, such healthier nutritive cookies are formulated that suits every individual need of all age group. Keeping this in view, this paper presents the progress of the work carried out at the institute in providing a novel by way of making nourishing cookies from sugarcane bagasse fiber.

2. Preparation of Nutritive Baked Product from Dietary Fiber

It is important for baked food material to be delicious as well as nutritious. Development of functional foods has generated the necessity to use new ingredients which might play a pivotal role in improving the health of consumers. Considering one such ingredient namely 'dietary fiber' whose position was reassessed by evaluating its physiological role. Bakery product are most consumed foods of all the time by all age groups, their evolution has experienced various stages of enlargement, reaching today a growing diversity. The current drift is to create that product which are favorable to health. Table 1 gives a fair idea about recommended requirement of dietary fiber.

Table 1
How much fiber is needed?

Adult	Gm/day
1 - 3 year	
Boys	25 gm/day
Girls	19 gm/day
4 – 13 years	
Boys	31 gm/day
Girls	26 gm/day
14 - 50 year	
Men	38 gm/day
Women	25 gm/day
> 50 year	
Men	30 gm/day
Women	21 gm/day

3. Material and methods

1) Raw material

Sugarcane bagasse was taken from Experimental Sugar Factory of National Sugar Institute. All chemicals used during the analytical procedure were of analytical grade.

2) Preparation of dietary fiber from sugarcane bagasse

Sugarcane bagasse as received from the factory was analyzed for various parameters viz. moisture content, cellulose, hemicellulose and lignin content, ash content as detailed in table no. 2. The bagasse as received was soaked in luke warm distilled water in order to remove adhering dirt. Sugarcane bagasse after soaking for 20-30 minutes was subjected to drying in an oven at 50-60 ˚C. In the process of preparing dietary fiber from bagasse two different methods were used and the same has been discussed below.

Methods for preparing dietary fiber from sugarcane bagasse:

1. Dietary fiber preparation using Microwave Aided Alkali Treatment
2. Dietary fiber preparation using Autoclave Aided Alkali Treatment

B. Explanation of the process

1) Dietary fiber preparation using Microwave Aided Alkali Treatment

The alkaline treatment of the fibers was performed using NaOH (Aldrich, 99.99% of purity). However, before the chemical treatment, sugarcane bagasse was washed with distilled water, milled in a laboratory crusher. Sugarcane bagasse was further screened using a 40 & 60 mesh sieves. Sample of sieved SCB fiber was then placed in a 1000 ml beaker and mixed with 0 .1 N NaOH in the ratio of 1:15 (on solid basis). The sample was mixed properly and maintained at room temperature for 10-15 minutes. The microwave aided alkali process was carried out in a home-made oven at 600 W, 2400 MHz, for 5 min, after the chemical process the fibers were washed with distilled water until a neutral pH is obtained. Thereafter, the fibers were dried at 50 - 60˚C (24h) and were kept for further characterization. The sample was analyzed for moisture content, water holding capacity, oil absorption capacity, crude fiber content, cellulose, hemi-cellulose, lignin content as discussed in subsequent paragraphs. The so prepared dietary fiber from sugarcane bagasse was kept in room temperature in sealed packed pouches for further use. Figure 2 represents a process flow diagram detailing various steps involved in obtaining sugarcane bagasse derived dietary fiber by this method.

2) Dietary fiber preparation using Autoclave Aided Alkali Treatment

The sugarcane bagasse fibers were washed with distilled water, milled in a laboratory crusher Sugarcane bagasse was further screened using a 40 & 60 mesh sieve. Sample of sieved SCB fiber was then placed in a 1000 ml beaker and mixed with 0 .1 N NaOH in the ratio of 1:15 (on solid basis). The sugarcane bagasse sample was mixed properly and maintained at room temperature for 10-15 minutes. Thereafter the sugarcane bagasse sample was subjected to autoclave for 30 minutes for further sterilization. Therefore, the fibers were washed with distilled water until a neutral pH is achieved. The fibers were then dried at 50 - 60˚C for 24h and was kept for further characterization. The sample was analyzed for moisture content, water holding capacity, oil absorption capacity, crude fiber content, cellulose, hemi-cellulose, lignin content which is detailed below. The so prepared dietary fiber from sugarcane bagasse kept in room temperature in sealed packed pouches for further use. Figure 2 represents a process flow diagram detailing various steps involved in obtaining sugarcane bagasse derived dietary fiber.

3) Preparation of sugarcane bagasse derived dietary fiber enriched nutritional cookies

Nutritional cookies enriched with sugarcane bagasse derived dietary fiber were prepared using 10% (on solid basis) of the dietary fiber so prepared as detailed above. A detailed flow diagram illustrating various steps involved in cookie preparation is given as figure no. 3

4) Material & methods:

In the process of analysis for weighing, electronic weighing balance (Labman make readability 0.1 mg) was used.

Following analysis was carried for dietary fiber derived from sugarcane bagasse using two different approaches as mentioned in the paper above.

1. *Determination of Cellulose, Hemi-cellulose and Lignin* – The Cellulose, Hemi-cellulose and Lignin content of the sugarcane bagasse derived dietary fiber was carried out using NREL Laboratory Analytical Procedures for standard biomass analysis.
2. *Determination of Moisture-* The moisture content of bagasse sample (as received) and sugarcane bagasse derived dietary fiber was carried out using ICUMSA official method GS 2/1/3/9-IS (2007).
3. *Determination of conductivity Ash-* The conductivity ash of the bagasse samples (as received) was carried out using ICUMSA official method GS 2/3/9-17 (2011).
4. *Determination of fat content:* The fat content of sugarcane bagasse derived dietary fiber enriched cookies was analyzed by soxhlet extraction method.
5. *Determination of ash content*: The ash content was determined by placing the sample in a muffle furnace at about 550°C for 4-5 hrs. the final weight of the sample after incineration was noted and % ash content was calculated.
6. *Determination of dry matter and moisture content*: The dry matter and moisture content of sugarcane bagasse derived dietary fiber enriched cookies was analyzed by drying the sample in an air over at about 100 °C to constant weight.

4. Result and Discussion

On the basis of data contained in table 1 following has been inferred.

A. Chemical characterization

1) Sugarcane bagasse

The chemical composition of untreated sugarcane bagasse shown in table 1 indicates that the moisture content and ash content was 21.95 %, 3.3 % respectively. The cellulose, hemicellulose and lignin content of the bagasse was 47.50 %, 18.79 % and 20.92 % respectively. The values obtained in the study are comparable with the data provided by other authors as per literature [4].

2) Dietary fiber obtained in the study.

The chemical composition of received dietary fiber shown in table 2. Amongst the two methods used in the study it was observed that the microwave aided technique used for obtaining dietary fiber was better as compared to the autoclave aided technique. From table 2 it is evident that the lignin content is reduced in microwave aided method (13.74%) as compared with autoclave aided method in which the lignin content was relatively high (16.73 %). As we are well aware that lignin reduces the digestibility of cellulose, using microwave aided method for obtaining dietary fiber helped in increasing the cellulose content by breaking the ester bond between lignin and cellulose through hydrolysis reaction. This type of reaction breaks the bond between lignin and carbohydrate thereby releasing cellulose from the encapsulation of lignin and hence making cellulose more easily available. Humans are unable to digest cellulose, in-spite of that it forms an important part of a healthy diet of an individual. Since cellulose forms a major part of dietary fiber which helps in proper bowel movement, this cellulose passes through a human system unchanged and therefore increases fecal bulk and frequency of stool movement down the system. Therefore, for a healthy gut, such dietary fiber is of great importance.

B. Physio chemical composition

1) Sugarcane bagasse

The physio chemical composition of sugarcane bagasse as received is illustrated in table 3 below which indicates that the water absorption capacity and oil absorption capacity of sugarcane bagasse as received from the factory was 6.92 g/g & 4.04 g/g respectively.

Table 2
Chemical characteristics of sugarcane bagasse and dietary fiber obtained in the study

S.No	Test	Sugarcane bagasse (as received)	Dietary fiber	
			Using microwave (0.1 NaOH)	Using autoclave (0.1 NaOH)
1.	Moisture	21.95 %	0.73 %	0.72 %
2.	Cellulose	47.50 %	49.85 %	48.52 %
3.	Hemicellulose	18.79 %	14.84 %	16.9 %
4.	Lignin	20.92 %	13.74 %	16.73 %
5.	Ash content	3.3	3.29	3.28

2) Dietary fiber obtained using microwave aided and alkali aided methods

The physio chemical composition of Dietary as obtained using microwave aided or autoclave aided methods is shown in below table 3. The water absorption capacity and oil absorption capacity of dietary fiber as obtained using two methods as mentioned above was 7.47 g/g, 5.17 g/g by microwave method and 5.14 g/g, 8.08 g/g by autoclave method.

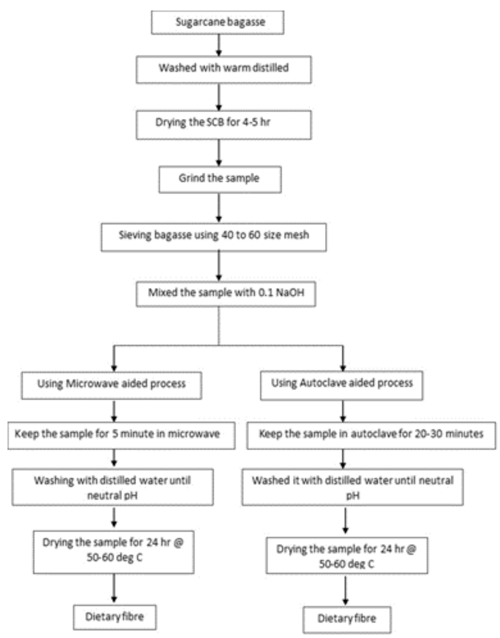

Fig. 2. Flow diagram of dietary fiber from sugarcane bagasse

The water absorption capacity of dietary fiber is an indicator of the ability of the fiber to alter stool weight in the diet. Whereas oil absorption capacity is indicative of physical entrapment of fat in fiber. The study has been undertaken to quantify the amount of oil the fiber can retain per gram of dry material in the presence of excess oil. The results indicate that the received bagasse has lower water and oil absorption capacity (6.92 g/g & 4.04 g/g resp.) as compared to the dietary fiber obtained from the two techniques in the present study. High water and lower oil absorption capacity of fiber is the best combination for a healthier dietary fiber option in the diet of an individual. Amongst the two methods employed for obtaining the dietary fiber it was observed that the microwave aided technique gave better results in comparison to the autoclave aided technique used. Therefore, to conclude, the dietary fiber obtained from microwave aided technique has better water absorption (7.47 g/g) and oil absorption (5.17 g/g) capacity as compared to autoclave aided technique.

Fig. 3. Flow diagram of sugarcane bagasse derived dietary fiber enriched nutritional cookies

Table 3
Physio chemical characteristic of sugarcane bagasse (as received) and dietary fiber obtained in the study

S.No	Test	Dietary fiber	
		Using microwave (0.1 NaOH)	Using autoclave (0.1 NaOH)
1.	Water absorption capacity	7.47 g/g	5.14 g/g
2.	Oil absorption capacity	5.17 g/g	8.08 g/g

3) Structural characterization of dietary fiber obtained in the present study

Structural characterization of sugarcane bagasse was done by Fourier Transform Infrared Spectroscopy (FTIR) spectra obtained on a Bruker ALPHA-T FT-IR spectrometer using KBr-disk method (figure 4). A broad-spectrum band in the region 3600 – 3000 cm-1 with a peak centered at 3474 cm-1 corresponds to the characteristic hydroxyl stretching vibration of xylans as well as to the hydrogen bond of the hydroxyl groups. The band at 2859 cm-1 represents C-H stretching vibrations of –CH2. Absorption bands of protein observed at 1638 cm-1 and 1418 cm-1 are attributed to amide I and amide II groups, respectively. The sharp band at 1039 cm-1 is assigned to C-O, C-C stretching and hence to the glycosidic (C-O-C) contributing to the AX backbone. The low intensity shoulders at 1099 and 1148 cm-1 are attributed to arabinose substitution at C-3 of xylose residues. A small sharp peak at 620 cm-1 evidences the presence of β – glycosidic linkages between the xylose units. The remaining signals in the spectra, at 1477, 1438, 1371 and 1210 cm-1, relate to C-H and O-H bending and C-C stretching [5].

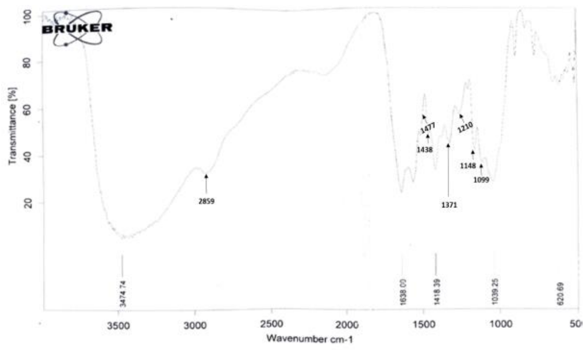

Fig. 4 FTIR spectra of Dietary fiber of Sugarcane Bagasse after treatment with 0.1 NaOH by Microwave aided alkali method

C. Physical characterization of dietary fiber enriched cookies

The physical characterization of dietary fiber incorporated cookies were assessed and presented in below (table 4). The diameter, thickness and spread ratio, weight was 34 mm, 4.6 mm, 7.39, 20.18 gm respectively. The results in the present study are comparable with those reported by other authors. [6].

Table 4
Physical characterization of cookies

S. No	Test	Parameter
1.	Diameter	34 mm
2.	Thickness	4.6 mm
3.	Spread ratio	7.39
4.	Weight	20.18 gm

1) Chemical characteristics of dietary fiber enriched cookies

The chemical characteristics of cookies was assessed and presented in below table 4. The comparison of dietary fiber enriched cookies as per the present study and commercially available cookies in the market indicates that the moisture content of the prepared cookies in the present study was around 4.5 % which when compared with that of commercially available biscuits was less (4.81 %), this is indicative of good shelf life of the product as higher moisture content may trigger microbial activities. Crude fat which is important for maintenance of human health and brain development, it was observed that the crude fat content of the prepared cookies and those commercially available biscuits was comparable with moderate variation in the values (0.5 % for prepared cookies in the present study & 0.85 % for commercial biscuits). The higher crude fiber content in the commercial biscuits could be due to a greater of animal fat used in the preparation of commercial biscuits. The values for fat content in the prepared cookies in the study and that which are available in the market had no significant change (13.6 % & 13.5 % respectively). Also there was no significant difference in the ash content values for the prepared cookies in the study and the commercially ones [7].

Table 5
Chemical characterization of cookies

S.No	Test	Parameter	
		Dietary fiber enriched cookies (from the present study)	Commercial Cookies (from the market)
1.	Moisture	4.5 %	4.81 %
2.	Dry matter	94 %	95.19 %
3.	Crude fiber	0.5 %	0 .85 %
4.	Fat	13.6 %	13.54 %
5.	Ash	1 %	1.16 %

5. Conclusion

Sugarcane bagasse can be an excellent source for production of dietary fiber, use of which is being advocated to mitigate health issues. It can be cheaper as well considering the prices of bagasse and should be considered as another value added product from the sugar industry. As such or as an important ingredient it can be used in many bakery and other food products offering nutritive and healthier options to the conventional products.

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