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Inulin fortified maize-based fermented beverage (*Rab*) affects lipid profile and blood pressure levels in Indian hyperlipidaemic subjects

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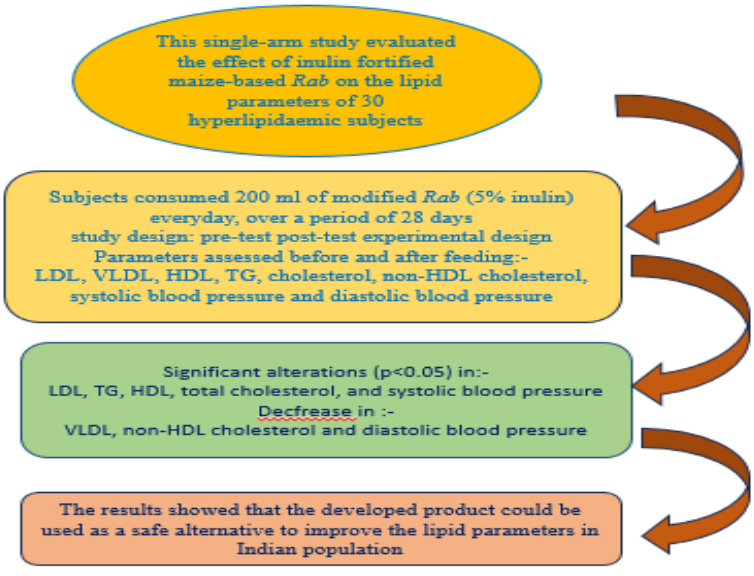
Abstract— *This study evaluated the effect of inulin-fortified maize-based Rab on the lipid parameters of 30 hyperlipidemic subjects. The subjects consumed 200 ml of modified Rab (5% inulin) for 28 days. Anthropometric measurements, blood pressure, and lipid parameters were assessed at the beginning and end of the intervention. The data showed that the LDL, total cholesterol, and triglyceride levels were significantly reduced ($p<0.05$), HDL levels also increased significantly at the end of the intervention period ($p<0.05$). The results showed that the developed product could be used as a safe alternative to improve the lipid parameters in Indian population.*

Keywords— ***prebiotics, inulin, modified Rab***

Practical application: Adding inulin to traditional beverage would increase the adaptation and reach of the product. It might be an effective tool to prevent and manage dyslipidemia in rural and urban Rajasthan and connected regions



Graphical abstract

I. INTRODUCTION

Changes in lifestyle, dietary patterns, high-fat food, low level of physical activity, and sedentary lifestyle are the important factors that pose a fatal threat to human beings in the form of hyperlipidaemia, a common cardiovascular disease. Dyslipidaemia is the most important atherosclerotic risk factor. A review of population-based studies in India shows increasing mean total cholesterol levels. South Asians (SA) are at a higher risk for stroke and vascular dementia due to the disproportionate burden of diabetes, hypertension, and dyslipidemia. (Enas, Yusuf and Mehta 1992; Misra, Wasir, and Pandey 2005, Gupta and Gupta 2009, Singh, Dhamoon, and Alladi 2018)

Recent studies have reported that in India, high cholesterol is present among 25-30 per-cent of urban and 15-20 per-cent of rural subjects. This prevalence is lower than in high-income countries. The most common dyslipidaemia in India is borderline high LDL cholesterol, low HDL cholesterol, and high triglycerides (Shahi and Ranga 2000). Studies have reported that over a twenty-year period total cholesterol, LDL cholesterol, and triglyceride levels have increased among urban populations. Case-control studies have reported that there is a significant association of coronary events with raised apolipoprotein-B, total cholesterol, LDL cholesterol and non-HDL cholesterol and an inverse association with high apolipoprotein-A and HDL cholesterol. An increasing pattern with age was observed for hypercholesterolemia among urban males, females and rural females. The pervasiveness and magnitude of dyslipidemia in India is very high, urging for crucial lifestyle intervention strategies to avert and manage this important cardiovascular risk factor. In order to reduce the burden of this epidemic, it is essential to inculcate healthy lifestyle right from childhood (Enas 2001, Joshi et al 2024, Rao et al, 2015, Gupta 2017).

A study on the cholesterol levels among tribal population of Rajasthan state showed that 21.1% had borderline high cholesterol and 9.4% had high cholesterol. It was observed that males have higher cholesterol level as compared to females and working group has high level as compared to non-working group. Prevalence of low HDL-C level was found among urban females in Rajasthan (Bandana 2012, Agrawal, Varma and Gupta 2015).

Inulin is a non-digestible polysaccharide which break down in large intestine by particular gut microorganisms and proved to be beneficial for the growth and metabolism of gut microflora; specially, *Lactobacillus* and *Bifidobacteria*. In food industry it is used as fat replacer, sweet replacer, bulking agent, texture modifier, foaming agent, functional ingredient. It is generally commercialized in white coloured powder form, has no particular flavour or smell. Due to moderate water solubility, it is suitable for beverage industry. (Abou-Arab, Talaat and Abu-Salem 2011, Leyva-Porras et al 2014, Shams and Wadhawan 2021)

The study showed that addition of 2 percent inulin improved the viscosity, and melting properties of the yogurt significantly. It also significantly enhanced the viability of probiotic bacteria Lactobacillus acidophilus and Bifidobacterium lactis. (Rezaei, Khomeiri and Kashaninejad 2014)

Data have suggested that consumption of inulin in Human subjects improved the lipid profile. It was suggested that inulin supplementation 10g/day for 3 weeks could reduce triglyceride levels by 16% (Letexier, Diraison and Beylot 2003); 15g/day for 20 days could increase in 2.8% HDL-cholesterol (Alles et al 1999) whereas 5.5g/day for 10 weeks period did not significantly improve in lipid profile (Vulevic 2008). The consumption of inulin rich diet positively modulate total cholesterol, LDL -C and triglyceride levels in plasma of hyperlipidemic individuals but did not altered the plasma lipid profile in normolipidemic subjects (Guo et al 2012).

Hypertension is characterized by abnormally high blood pressure and regarded as one of the major public health issues worldwide. It is associated with the development of medical conditions like CVDs, myocardial infarction, cardiac failure, stroke, renal disease. In lower middle-income countries (LMICs) an increasing trend in prevalence of hypertension is observed. Being an LMIC, the scenario of hypertension in India is evidently crucial as 207 million persons were hypertensive and in 2016 around 1.63 million deaths in India were hypertension-related; therefore, called a silent killer. According to WHO World Health statistic Report 2012, 21 per-cent adult population has raised blood pressure. Hypertension contributes to 4.5 per-cent of the current global disease load, accounting for approximately 31 per-cent of global deaths (Kumar, Sharma and Sain 2017). In India, a representative study was performed on 1.3 million adults aged eighteen or above. The prevalence of hypertension in rural India ranged from 14.6 per-cent to 38.8 per-cent and in urban areas ranged from 17.6 per-cent to 62.7 per-cent, nationally. In Rajasthan state, the data showed 18.3 per-cent hypertension prevalence in rural areas and 26.1 per-cent in urban areas (Ghosh and Kumar 2019, Godara et al 2021, Bardhar, Khanna and Bardhar 2022, Longkumer et al 2023).

A cross-sectional study was performed in Udaipur city, Rajasthan, with aim of evaluating the prevalence of

hypertension in Udaipur, Rajasthan. The data showed that 32.67 percent urban and 18.67 per-cent rural population had elevated levels of blood pressure. Among urban population, 87.76 per-cent led a sedentary lifestyle, 45.92 per-cent were overweight and 14.28 per-cent were obese (Godara et al 2021). A study performed by Patidar (2015) on a sample size of 600 in Udaipur city, Rajasthan suggested that 30.6 per-cent of the total population has hypertension.

Indian rural population depends on locally available food for nutrition and health. In India, 1000 of major and minor ethnic/ traditional foods and beverages are produced diversly. One of such beverages is called as *Rab* which is made up of combination of buttermilk and cereals like maize, pearl millet, wheat etc. It is served as cold or hot drink mainly as a breakfast in summer as well as winter season. *Rab* is a traditional fermented cereal-based soup like beverage of Rajasthani cuisine; prepared by cooking maize grits and flour in buttermilk for a long period (2 to 3 h). In rural areas of Rajasthan *Rab* is prepared and kept stored for 2 or 3 days in an earthen pot for consumption purposes. Investigations have been performed to standardize different cereal- based Rabs including maize-based (Soni and Arora 2000) sorghum-based (Pintu and Verma 2019), pearl millet-based (Dhankher and Chauhan 1987), wheat-based (Gupta and Nagar 2014, Gupta and Khetarpaul 1993), barley-based *Rabs* (Gupta, Khetarpaul and Chauhan 1992), soybean-based (Gupta and Nagar 2008).

Prior, studies have suggested the beneficial effect of inulin on the hyperlipidaemic subjects. But no scientific studies are focussed on the combination of traditional beverage (*Rab*) and inulin. Besides, there is no research work available that investigate the effect of the consumption of inulin fortified *Rab* on the lipid profile of hyperlipidaemia. Thus, the present study primarily concentrated on the effect of inulin fortified maize based Rab on the lipid parameters of hyperlipidaemic individuals.

II. METHODOLOGY

Subjects: This study was approved by the "Institutional Ethical Committee of Human Research", Maharana Pratap University of Agriculture and Technology, Udaipur, Rajasthan, India. Written informed consent was obtained from all participants before inclusion.

Screening and inclusion

In total 30 hyperlipidaemic subjects from Udaipur city, Rajasthan, were identified and selected for the feeding intervention. The intervention was done for four weeks (28 days). Both male and female subjects participated in the study in 60:40 ratio. The inclusion criteria for the selection of the subject: willingness to participate and cooperate; age (>35 to < 55 year); serum cholesterol level >= 200mg/dl; no other degenerative diseases; and persons who are not taking any medication for hyperlipidemia.

Tool for personal interview

A well-structured interview schedule was prepared for this purpose. The schedule included background information, anthropometric measurement, blood pressure, food habits, biochemical parameters.

Intervention

All the participants were asked to consume 200 ml of modified maize-based *Rab* containing 5 percent inulin, daily for 28 days in the morning time during breakfast. No special diet modification or lifestyle modification was prescribed.

Blood pressure: a certified, automates, calibrated blood pressure measuring device was used to measure the systolic and diastolic blood pressure of all the participants before and after the commencement of the feeding period.

Pre and post blood analysis

Lipid parameters: cholesterol total, Low-Density Lipoprotein (LDL), High-Density Lipoprotein (HDL), Triglycerides (TG), Very Low-Density Lipoprotein (VLDL) and Non-HDL Cholesterol were checked a day prior to intervention. Post intervention testing of lipid parameters was done on the very next day of completion of intervention.

Statistical analysis for biochemical properties Mean+ SD values were calculated and to analyze the effect of consumption of modified Rab on the lipid profile and blood pressure paired 't' test was applied.

III. RESULTS

The age of the selected participants ranged from 35 to 55 years. All the participants were non-smoker and non-alcoholic. None of the participants exercise daily. None of the participants had diabetes or any known heart disease. Ten of the subjects had family history of hyperlipidaemia. The pre-intervention, estimated mean value for LDL was 123.58 mg/dL, HDL was 35.21 mg/dL, TG, was 137.30mg/dL, VLDL mean value was 27.78 mg/dL, mean cholesterol total was 223.05 mg/dL, and mean of non- HDL cholesterol for 30 subjects was 152.31 mg/dL (Table 3). The post-intervention estimated mean value of LDL was calculated as 122.75 mg/dL, HDL as 35.78 mg/dL, TG as 136.62 mg/dL, Cholesterol total as 222.48 mg/dL, VLDL as 27.71 mg/dL, and Non-HDL cholesterol as 151.86 mg/dL (Table 3)

When the pre- and post-intervention values were compared, there was a significant decline in the values of LDL, triglycerides and total cholesterol at 1 per-cent level of significance (Table 3). The increase in the value of HDL was also found to be significant at 5 percent level of significance. The reduction in the values of VLDL and non-HDL cholesterol were found to be non-significant.

The decline in values of LDL was 0.67%, triglycerides was 0.80%, total cholesterol was 0.25%, VLDL was 0.25% and non-HDL cholesterol was 0.29%. The increase observed for the HDL was 1.61%. (Table 1)

Systolic Blood Pressure (SBP) data revealed a significant decrease in the post-intervention mean value as compared to the pre-intervention mean value at 0.1 per-cent level of significance, as shown in the Table 3. The mean of post diastolic blood pressure (DBP) slid down as compared to the pre-intervention DBP. Though, the difference between post and pre-intervention DBP mean was not found to be significant, nevertheless, the alteration revealed that the modified maize *Rab* did limit the increase in the DBP in the subjects. Modified maize-*Rab* induced 1 per-cent reduction in mean values of both SBP and DBP.

The post-intervention mean systolic blood pressure was found to be significantly reduced as compared to the pre-intervention mean, whereas the reduction in the post-intervention diastolic BP as compared to pre-intervention was not found to be significantly different. The distribution of the participants according to the blood pressure also changed. The pre-intervention data showed that 26.66 per-cent were in normal BP range, 43.33 per-cent were in prehypertensive stage and 30 per-cent were in the hypertensive stage. The post-intervention data suggested that though there is no change in the hypertensive stage, but there is a fall in the frequency of prehypertensive stage (36.66 per-cent) and increase in the normal range of BP as 33.33 per-cent respondents, post-trail (Table 2).

It is evident that the consumption of the modified *Rab* improves systolic blood pressure. Though it does not reduce the diastolic BP but indeed it prevents the rise in the diastolic blood pressure.

IV. DISCUSSION

In the present study, we imposed that consumption of the inulin-incorporated maize-based Rab (200 mL per day containing 10 g inulin) for 28 days duration did affect the levels of lipid parameters and blood pressure of the hyperlipidemic subjects. The developed beverage effectively reduced the values of low-density lipoprotein, triglycerides, and cholesterol levels, significantly. The level of the high-density lipoprotein also influenced by the consumption of the Rab. It did not significantly influence the VLDL and non-HDL cholesterol values but prevented the increase in these values. The mean SBP value significantly reduced after 28 days intervention period. The decline in the DBP value was not found statistically significant.

Previously, the effect of Inulin-incorporated food products and drinks on lipid profile have been studied in animals and in humans. Russo et al (2008) reported that consumption of inulin-enriched pasta resulted in the significantly altered HDL-cholesterol ($P = 0.004$), total cholesterol/HDL-cholesterol ratio ($P = 0.006$), triglycerides ($P = 0.04$), and Lipoprotein(a) ($P = 0.02$) concentrations. Nassar *et al* (2013), presented work on the assessment of effect of inulin on the metabolic changes produced by fructose rich diet in rats. The results showed significant increase in the serum HDL levels and significant decline in the serum levels of TG, LDL and total cholesterol due to inulin supplementation in the experimental animals concluding that the carbohydrate and lipid metabolic changes produced by the high fructose diet could be corrected by the consumption of inulin.

Yang et al (2018) also suggested the effect of inulin (9%) on the hepatic and total cholesterol levels in healthy mice. Miao et al (2021) also suggested the similar results in their research on the pregnant mice that ingestion of inulin type fructans (ITF) may alleviate the glucose and lipid metabolism disorders.

The study performed by Deng et al (2020) suggested that Inulin Type Fructans significantly decreased the VLDL levels in mice (fed with inulin for 12 weeks) whereas the HDL and LDL levels were not significantly altered. The contradictory results were presented in the study performed by Mistry et al (2018). It demonstrated that neither short chain inulin nor long chain inulin have any adverse effect on the metabolism of cholesterol in the experimental mice, even after raise in the generation of short chain fatty acids.

It is evident that the consumption of the modified *Rab* improves systolic blood pressure. Though it does not reduce the diastolic BP but indeed it prevents the rise in the diastolic blood pressure. Similar results were discussed by Castro-Sanchez et al (2017) and Becerril-Alarcón et al (2019) recommending that inulin supplementation significantly lower the systolic BP. It also reduced the diastolic BP but not significantly, thus it prevents increase in the diastolic Blood Pressure.

Cai et al (2018); Heil et al (2020) and Hess et al (2019), reported the positive effect of inulin on both the systolic and diastolic blood pressure. The review performed by Faghihimani et al (2021) suggested that the inulin supplementation only effectively reduces the systolic blood

pressure in females but does not have any favorable effect on the male subjects.

Our data suggest that developed inulin fortified *Rab* has beneficial effects which protect against cardio vascular diseases by improving lipid profile and blood pressure levels. Adding inulin to traditional beverage would increase the adaptation and reach of the product. It might be an effective tool to prevent and manage dyslipidemia in rural and urban Rajasthan and connected regions.

V. CONCLUSION

Results of the current study have proven that the consumption of 200 ml inulin incorporated maize Rab (5% inulin), daily for 28 days may decrease the LDL, cholesterol, and triglyceride values in human. It also significantly increased in the level of high-density lipoprotein. Even though prior studies have reported that prebiotics could have beneficial effect on the lipid parameters, researches have also mentioned clashing results. Results from our study has supported that prebiotics have hypolipidemia effect on humans. Additionally, our study suggested that traditional beverage like Rab could be fortified with inulin (prebiotic) and used as a hypolipidemic beverage. This established that inulin incorporated maize Rab has the potential to be safely used as a nondrug option in the management of hyper lipidaemia, especially in Rajasthan and connected states of India. Thus, it is evident that consuming developed maize *Rab* resulted in the betterment of the health of hyperlipidemic individuals.

Table 1: Distribution of participants according to lipid profile

Lipid parameters	Pre-intervention	Post-intervention	(%) difference
LDL cholesterol			
<100 Optimal	Nil	Nil	Nil
100-129 Near optimal/above optimal	66.66%	66.66%	Nil
130-159 Borderline high	33.33%	33.33%	Nil
160-189 High	Nil	Nil	Nil
≥190 Very high	Nil	Nil	Nil
Total cholesterol			
<200 Desirable	Nil	Nil	Nil
200-239 Borderline high	86.66%	86.66%	Nil
≥240 High	13.33%	13.33%	Nil
HDL cholesterol			
<40 Low	76.66%	76.66%	Nil
>40 <60 normal	23.33%	23.33%	Nil
≥60 High	Nil	Nil	Nil

Table 2: Per-centage distribution of participants based on blood pressure

Blood pressure (mmHg)	Per-centage (%)		(%) Difference
	Pre-intervention BP_1	Post-intervention BP_2	
Normal (120/80)	26.66	33.33	25
Prehypertensive (120-139/80-89)	43.33	36.66	15.39
Hypertensive (> 140/90)	30	30	Nil

Table 3: Mean ± SD of lipid profile and blood pressure of participants

Blood parameters	Pre-intervention values	Post-intervention values	't' values	(%) Difference
LDL mg/dL	123.58±14.14	122.75±14.67	4.45**	0.67
HDL mg/dL	35.21±8.26	35.78±8.42	-3.26**	1.61
TG mg/dL	137.30±15.08	136.62±15.24	3.56**	0.80
Cholesterol total mg/dL	223.05±14.71	222.48±14.68	2.09*	0.25
VLDL mg/dL	27.78±4.95	27.71±4.9	0.43^{NS}	0.25
Non-HDL Cholesterol mg/dL	152.31±17.88	151.86±17.74	1.21^{NS}	0.29
Systolic Blood pressure (mmHg)	131.72±10.94	130.68±10.53	3.19***	0.78
Diastolic Blood pressure (mmHg)	88.43±5.73	87.9±5.5	1.76^{NS}	0.59

* = 5per-cent level of significance

** = 1per-cent level of significance

*** = 0.1per-cent level of significance

^{NS} = non-significant

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CONFLICT OF INTEREST

The authors declared that there is no conflict of interest regarding the publication of this article.

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