SEASONAL VARIATIONS IN NUTRIENT COMPOSITION OF SELECTED FRUITS AND THEIR IMPLICATIONS FOR TYPE 2 DIABETIC MANAGEMENT.

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Abstract

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Fruits play a key role in type 2 diabetes management but seasonal changes can affect their nutrient profile and glycemic impact. This study examined the composition of selected tropical fruits across rainy and dry seasons in Ibadan, Nigeria, to assess implications for diabetes care. Fresh fruit samples were randomly purchased from Oje Market, Ibadan, during both rainy and dry seasons. Fruits were washed, peeled, homogenized, and analyzed in triplicates. Proximate composition was determined using standard AOAC methods. Reducing sugars were quantified by colorimetric methods. Vitamin C was measured by titration with 2,6-dichlorophenolindophenol, while B-vitamins and folate were determined spectrophotometrically. β-carotene, lycopene, flavonoids, phenolics, and total carotenoids were assessed using UV–visible spectrophotometry. Mineral elements (Ca, Mg, Na, K, Fe, Zn, P) were analyzed using atomic absorption spectrophotometry.

Moisture content was higher in the rainy season (up to 93.7% in watermelon), while dry season fruits had higher protein, reducing sugars, and B-vitamins. Vitamin C peaked in pawpaw (49.8 mg/100 g) and orange (45.7 mg/100 g) in the rainy season, while watermelon showed exceptionally high carotenoids (4986 µg/100 g). Dry season fruits recorded elevated reducing sugars, especially pawpaw (13.3%). Potassium was highest in pawpaw (5914 mg/kg), while banana contained the highest sodium (4032 mg/kg) Seasonal variation significantly alters nutrient and sugar composition of tropical fruits. Rainy season fruits, with lower sugar load and higher vitamin C, may support glycemic control, while dry season fruits, though nutrient-dense, could contribute to glycemic spikes.

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Introduction:-

Type 2 diabetes mellitus (T2DM) is a rapidly escalating global health challenge, contributing significantly to morbidity and mortality worldwide. Current estimates suggest that more than 537 million adults are living with diabetes, a figure projected to rise to 783 million by 2045 if urgent measures are not taken [1]. The burden is particularly acute in low- and middle-income countries, which now account for the majority of cases, largely due to rapid urbanization, lifestyle changes, and dietary transitions. T2DM is not only associated with elevated blood glucose levels but also with a range of long-term complications including cardiovascular disease, renal dysfunction, retinopathy, and neuropathy, all of which compromise quality of life and strain healthcare systems [2]. While pharmacological interventions remain important for glycemic regulation, lifestyle modification, especially dietary management, remains central to both prevention and effective control [3].

Diet plays a particularly critical role because it influences both the development of insulin resistance and the daily management of blood glucose fluctuations. Recommendations across international guidelines consistently highlight the consumption of foods rich in dietary fiber, vitamins, minerals, and bioactive compounds while limiting refined sugars and high-glycemic-load foods [4]. Within this framework, fruits are often positioned as essential dietary components because of their ability to deliver multiple nutrients in a natural form. They are sources of soluble and insoluble fiber, vitamin C, carotenoids, potassium, and a variety of polyphenols, all of which play protective roles against oxidative stress, inflammation, and metabolic dysregulation associated with T2DM [5]. Flavonoids in citrus fruits have been shown to improve endothelial function and reduce oxidative stress, while carotenoids in pawpaw and watermelon may contribute to antioxidant defense mechanisms [6].

Despite these benefits, fruit consumption among individuals with T2DM remains contested due to concerns about natural sugar content and the glycemic index of different fruit species. Fruits contain varying levels of glucose, fructose, and sucrose, and their impact on postprandial glycemia depends on the ratio of sugars, the presence of fiber, and the degree of ripeness [7]. For instance, ripe bananas tend to have higher free sugar concentrations compared to unripe ones, which significantly alters their glycemic potential. Consequently, dietary advice for people with T2DM often emphasizes moderation, portion control, and careful selection of fruit types. This complexity has led to general recommendations that encourage fruit intake but without specificity on which fruits, at what level of ripeness, or under what seasonal conditions are most suitable for glycemic control.

One of the less studied but crucial factors influencing the nutritional value and glycemic potential of fruits is seasonality. Fruits are living biological systems that respond dynamically to environmental conditions such as temperature, rainfall, sunlight, and soil composition. These environmental determinants significantly affect fruit growth, ripening, and biochemical composition. Vitamin C levels, for example, have been shown to vary depending on harvest time and seasonal climatic conditions [8]. Similarly, antioxidant activity, phenolic compounds, and organic acids in fruits can fluctuate between wet and dry seasons, sometimes increasing under stress conditions when plants accumulate protective metabolites [9]. In citrus fruits, cooler temperatures often enhance ascorbic acid and flavonoid concentrations, while warmer and wetter conditions may increase sugar accumulation but dilute other nutrients [6]. These compositional shifts are not trivial; they alter the balance between the health-promoting and glycemic effects of fruit consumption.

In tropical regions, where climate is characterized by distinct rainy and dry seasons, these variations may be particularly pronounced. Fruits such as banana (Musa spp.), pawpaw (Carica papaya), orange (Citrus sinensis), pineapple (Ananas comosus), and watermelon (Citrullus lanatus) are widely consumed staples in West Africa, especially in Nigeria. They serve as important sources of vitamins, minerals, hydration, and dietary fiber, forming an integral part of cultural diets and contributing significantly to food security [10]. However, their nutrient content is not constant across seasons. During the rainy season, accelerated growth and higher water content can dilute nutrient concentrations, whereas in the dry season, slower growth and mild stress often result in more concentrated sugars and bioactive compounds [11]. These variations potentially influence the role these fruits can play in T2DM management, particularly in terms of glycemic control and antioxidant defense.

In Nigeria and other parts of Sub-Saharan Africa, dietary management of T2DM faces unique challenges, including limited access to specialized foods, reliance on locally available fruits, and high out-of-pocket healthcare costs [10]. For many households, fruits are one of the most affordable sources of micronutrients, but their nutrient density and sugar content fluctuate seasonally in ways that are not fully understood. Without precise knowledge of how seasonal variations affect their composition, healthcare providers often rely on generalized dietary advice, which may not be optimal for glycemic control. For example, a fruit that is low in sugar and high in antioxidants during one season may become higher in sugar and lower in antioxidants in another, potentially undermining the health benefits for individuals with T2DM. This mismatch between nutritional recommendations and seasonal realities highlights a critical gap in both research and practice.

Furthermore, the importance of antioxidants and micronutrients in T2DM management cannot be overstated. Oxidative stress plays a pivotal role in the pathophysiology of diabetes and its complications, as hyperglycemia promotes the overproduction of reactive oxygen species [6]. Fruits with high levels of vitamin C, carotenoids, and polyphenols help counteract oxidative damage and improve insulin sensitivity [5]. Seasonal declines in these protective compounds could therefore reduce the therapeutic potential of fruits during certain periods, while seasonal increases could amplify their benefits. Understanding these fluctuations provides a foundation for designing more precise dietary interventions that align with the natural cycles of fruit availability.

This present study investigates the seasonal variation in nutrient composition of banana, pawpaw, orange, pineapple, and watermelon in Ibadan, Nigeria, and examines the implications for T2DM management. The findings aim to bridge existing knowledge gaps, inform clinical nutrition practice, and support individuals living with diabetes in making informed dietary choices that maximize health benefits across seasonal cycles.

Materials and Methods:-

Fresh samples of five tropical fruits, pawpaw (Carica papaya), banana (Musa sapientum), orange (Citrus sinensis), pineapple (Ananas comosus), and watermelon (Citrullus lanatus), were procured in their whole, raw form from Oje Market, Ibadan, Nigeria, during both the rainy and dry seasons to capture seasonal variation in nutrient composition. The fruits were washed with distilled water, peeled where necessary, and prepared for laboratory analysis under controlled conditions. All laboratory procedures followed standardized protocols established by the Association of Official Analytical Chemists (AOAC), and each analysis was conducted in duplicate to ensure accuracy and reproducibility.

Proximate Analysis

Proximate composition was determined according to AOAC official methods.

Moisture Content: Moisture was determined by oven-drying approximately 2 g of each sample in pre-weighed crucibles at 100°C until constant weight, following AOAC Method 967.08. After drying, samples were cooled in a desiccator before reweighing, and moisture content was calculated from weight differences.

Ash Content: Ash content was measured using AOAC Method 942.05. About 2 g of each sample were incinerated in a muffle furnace at 550°C for 4 hours until white ash residue formed. Crucibles were cooled in a desiccator and weighed, with results expressed as a percentage of the initial weight.

Crude Protein: Protein was analyzed using the Kjeldahl method (AOAC 988.05), involving digestion with concentrated sulfuric acid and a catalyst, distillation of ammonia into boric acid, and titration with hydrochloric acid. Nitrogen content was calculated, and protein determined using the factor 6.25.

Crude Fat: Fat content was assessed by Soxhlet extraction (AOAC 2003.06). One gram of each dried sample was extracted with petroleum ether (boiling point 40–60°C) for six hours. The solvent was evaporated, and fat content calculated from weight differences of the extraction flask.

Crude Fibre: Fibre was estimated using AOAC Method 958.06. Samples were sequentially digested with dilute sulfuric acid and sodium hydroxide under reflux, filtered, dried, and weighed (W1). The residue was incinerated at 550°C, cooled, and weighed again (W2). Fibre content was determined from the weight difference (W1–W2).

Nitrogen-Free Extract (NFE): NFE was computed by difference as 100 – (% Moisture + % Crude Protein + % Crude Fat + % Crude Fibre + % Ash).

Mineral Analysis

Mineral composition was determined according to AOAC protocols.

Calcium, Potassium, and Sodium: The ash of each sample was dissolved in 2M HCl, filtered, and diluted to 100 ml. Concentrations of Ca, K, and Na were determined using a Jenway PFP7 Flame Photometer, with results calculated from calibration curves.

Phosphorus: Phosphorus was analyzed by the vanado-molybdate colorimetric method. The filtrate from the ash digest was reacted with vanadate yellow reagent, and absorbance measured at 470 nm. Phosphorus concentration was determined against standard curves.

Trace Elements: Selenium, magnesium, lead, cadmium, copper, manganese, iron, nickel, and zinc were determined using Atomic Absorption Spectrophotometry (AAS, Buck 200 model) at element-specific wavelengths, following AOAC Method 975.23.

Antioxidant Analysis

Lycopene: Lycopene was extracted with acetone and methanolic NaOH under reflux and quantified spectrophotometrically at 340 nm against standard curves.

Beta-Carotene: Extracted with a petroleum ether/acetone mixture (2:1), centrifuged, and measured at 450 nm using UV-Vis spectrophotometry, with concentrations determined against beta-carotene standards.

Total Flavonoids: Methanolic extracts were reacted with sodium nitrite, aluminum chloride, and NaOH, producing a yellow complex. Absorbance was measured at 415 nm, and flavonoid content expressed as quercetin equivalents.

Total Phenolics: Extracts were treated with Folin–Ciocalteu reagent and sodium carbonate, and absorbance measured at 760 nm. Phenolic content was expressed in gallic acid equivalents.

Total Carotenoids: Carotenoids were extracted in dimethylformamide (DMF), centrifuged, and quantified at 647 nm using calibration standards.

Vitamin Analysis

Vitamin B2 (Riboflavin): Extracted with hydrochloric acid and dichloroethene, measured fluorometrically at 460 nm, and calculated from riboflavin standards.

Vitamin B1 (Thiamine): Extracted with dilute sulfuric acid and enzymatically hydrolyzed with taka-diastase. Absorbance of the complex was measured at 285 nm and compared with thiamine standards.

Vitamin B9 (Folic Acid): Extracted in distilled water and treated with sodium dithionite for decolorization. Absorbance was recorded at 445 nm, and concentrations determined from folic acid standards.

Vitamin B6 (Pyridoxine): Extracted using ammonium chloride, chloroform, and ethanol, followed by separation. The absorbance of the chloroform layer was measured at 415 nm and compared against pyridoxine standards.

Vitamin C (Ascorbic Acid): Ascorbic acid was extracted with metaphosphoric acid–EDTA solution and quantified by titration with dichlorophenol-indophenol (DCPIP) dye until a faint pink endpoint was observed.

Statistical Analysis

Data obtained from all analyses were expressed as mean values of duplicate determinations. Statistical analyses were performed using appropriate descriptive and inferential statistical tools to compare seasonal variations. Significance was accepted at $p < 0.05$.

Results:-

The proximate composition of fruits during the rainy season (Table 1) showed banana with the highest protein (1.53 ± 0.06%) and carbohydrate content (18.28 ± 0.01%), while watermelon had the lowest dry matter (6.30 ± 0.02%) and carbohydrate (3.72 ± 0.04%). Pineapple and pawpaw recorded relatively low macronutrient densities, consistent with their high moisture levels.

Table 1 Proximate Composition of Fruits during Rainy Season (Mean ± SD)

SAMPLE	%CP	%CFAT	%CFIBRE	%ASH	%M	%DM	%CHO
BANANA	1.53 ± 0.06	0.12 ± 0.01	0.87 ± 0.01	2.34 ± 0.03	76.88 ± 0.02	23.13 ± 0.02	18.28 ± 0.01
PINEAPPLE	0.43 ± 0.08	0.15 ± 0.01	0.85 ± 0.02	1.81 ± 0.03	86.90 ± 0.02	13.11 ± 0.02	9.88 ± 0.02
PAWPAW	0.43 ± 0.06	0.10 ±0.01	0.36 ± 0.02	1.92 ± 0.01	90.67 ± 0.02	9.34 ± 0.02	6.53 ± 0.01
WATER MELON	0.54 ± 0.08	0.13 ± 0.01	0.38 ± 0.01	1.53 ± 0.01	93.71 ± 0.02	6.30 ± 0.02	3.72 ± 0.04
ORANGE	0.63 ± 0.08	0.38 ± 0.02	0.61 ± 0.02	1.47 ± 0.02	87.93 ± 0.02	12.08 ± 0.02	9.01 ± 0.04

%CP-percentage protein content, %CFAT-percentage fat content, %CFIBRE- percentage fibre content, %ASH-percentage ash content, %M-percentage moisture content, %DM-percentage dry matter, %CHO-percentage carbohydrate content

Table 2 Reducing Sugar Content of Fruit Samples during Rainy Season (Mean ± SD)

FRUIT SAMPLES	%FRUCTOSE	%GLUCOSE
BANANA	6.29 ± 0.03	6.82 ± 0.01
PINEAPPLE	1.80 ± 0.03	1.33 ± 0.01
PAWPAW	1.85 ± 0.01	1.44 ± 0.01
WATERMELON	2.22 ± 0.01	1.93 ± 0.01
ORANGE	2.07 ± 0.01	1.88 ± 0.01

Reducing sugar analysis (Table 2) indicated that banana contained the highest fructose (6.29 ± 0.03%) and glucose (6.82 ± 0.01%), while pineapple and pawpaw had the lowest concentrations. Watermelon and orange showed intermediate levels.

Table 3 Vitamins and Antioxidants Contents of Fruit Samples (Mean ± SD)

SAMPLE	BANANA	PINEAPPLE	PAWPAW	WATER-MELON	ORANGE

Vitamin C	9.07 ± 0.01	32.80 ± 0.02	49.84 ± 0.01	8.13 ± 0.02	45.68 ± 0.01
Vitamin B1	0.047 ± 0.001	0.088 ± 0.001	0.028 ± 0.001	0.019 ± 0.001	0.076 ± 0.001
Vitamin B2	0.054 ± 0.001	0.036 ± 0.002	0.033 ± 0.001	0.022 ± 0.001	0.028 ± 0.002
Vitamin B6	0.683 ± 0.001	0.183 ± 0.002	0.350 ± 0.014	0.245 ± 0.007	0.175 ± 0.007
Folate	18.75 ± 0.02	10.87 ± 0.02	1.04 ± 0.01	2.68 ± 0.02	36.66 ± 0.01
Beta-carotene	83.28 ± 0.01	91.16 ± 0.01	84.75 ± 0.02	2157.63 ± 0.01	123.50 ± 0.03
Flavonoids	3.88 ± 0.02	6.77 ± 0.02	4.66 ± 0.02	6.05 ± 0.01	2.66 ± 0.02
Total Carotenoids	127.67 ± 0.02	146.78 ± 0.02	237.86 ± 0.01	4986.41 ± 0.01	625.88 ± 0.01
Lycopene	0.03 ± 0.01	0.06 ±0.01	1.91 ± 0.02	4.77 ± 0.01	0.68 ± 0.01
Total Phenolics	2.20 ± 0.03	4.81 ± 0.02	6.77 ± 0.02	8.28 ± 0.01	3.30 ± 0.02

Vitamin and antioxidant content (Table 3) revealed pawpaw and orange as the richest in Vitamin C (49.84 ± 0.01 mg/100g and 45.68 ± 0.01 mg/100g, respectively), whereas watermelon was distinguished by exceptionally high β-carotene (2157.63 ± 0.01 µg/100g), total carotenoids (4986.41 ± 0.01 µg/100g), and lycopene (4.77 ± 0.01 mg/100g). Banana contained the highest Vitamin B6 (0.683 ± 0.001 mg/100g).

Proximate Composition of Fruits during Dry Season Table 4

SAMPLE	**%CP**	**%CFAT**	**%CFIBRE**	**%ASH**	**%M**	**%DM**
BANANA	1.87 ± 0.04	0.36 ± 0.02	0.57 ± 0.03	1.07 ± 0.05	92.34 ± 0.12	7.66 ± 0.08
PAWPAW	1.18 ± 0.03	0.24 ± 0.01	0.18 ± 0.02	0.85 ± 0.03	86.29 ± 0.10	13.71 ± 0.09
WATER MELON	1.39 ± 0.05	0.17 ± 0.01	0.23 ± 0.01	0.68 ± 0.02	88.46 ± 0.13	11.54 ± 0.08

ORANGE	1.27 ± 0.04	0.21 ± 0.02	0.33 ± 0.03	0.91 ± 0.04	84.09 ± 0.11	15.91 ± 0.10
PINEAPPLE	1.07 ± 0.03	1.07 ± 0.05	0.19 ± 0.01	0.82 ± 0.03	89.35 ± 0.14	10.65 0.09

During the dry season (Table 4.7), banana again recorded the highest protein content (1.87 ± 0.04%), while orange had the highest dry matter (15.91 ± 0.10%). Pineapple exhibited a notable increase in fat (1.07 ± 0.05%) compared to the rainy season.

Table 5 Reducing Sugar Content of Selected Fruits during Dry Season

SAMPLE	Reducing Sugar
BANANA	9.78 ± 0.12
PAWPAW	13.26 ± 0.15
WATER MELON	8.67 ± 0.10
ORANGE	11.47 ± 0.13
PINEAPPLE	10.48 ± 0.11

Reducing sugar concentrations (Table 5) were highest in pawpaw (13.26 ± 0.15%), followed by orange (11.47 ± 0.13%) and pineapple (10.48 ± 0.11%) during dry season. Watermelon consistently showed the lowest reducing sugar levels.

Table 6 Vitamins and Antioxidants Contents of Fruit Samples during Dry Season

SAMPLE	BANANA	PINEAPPLE	PAWPAW	WATER-MELON	ORANGE
Vitamin C	13.65 ± 0.01	19.34 ± 0.01	18.47 ± 0.01	23.47 ± 0.01	29.65 ± 0.01
Vitamin B1	1.36 ± 0.01	1.15 ± 0.01	2.24 ± 0.01	1.59 ± 0.01	1.08 ± 0.01
Vitamin B2	0.048 ± 0.001	0.053 ± 0.001	0.059 ± 0.001	0.073 ± 0.001	0.034 ± 0.001
Vitamin B6	2.24 ± 0.01	3.36 ± 0.01	3.27 ± 0.01	2.79 ± 0.01	2.57 ± 0.01
β-carotene	116.21 ± 0.01	271.80 ± 0.01	267.82 ± 0.01	314.18 ± 0.01	121.65 ± 0.01
Total Carotenoids	342.18 ± 0.01	641.05 ± 0.01	628.37 ± 0.01	715.28 ± 0.01	391.26 ± 0.01
Calcium (mg/kg)	25.99 ± 0.01	167.85 ± 0.01	46.35 ± 0.01	29.45 ± 0.01	34.27 ± 0.01
Magnesium (mg/kg)	136.44 ± 0.01	123.00 ± 0.01	120.72 ± 0.01	90.60 ± 0.01	102.96 ± 0.01
Sodium (mg/kg)	4032.00 ± 1.00	1824.00 ± 1.00	2592.00 ± 1.00	984.00 ± 1.00	2400.00 ± 1.00

Potassium (mg/kg)	1056.00 ± 1.00	475.00 ± 1.00	5913.60 ± 1.00	580.80 ± 1.00	580.80 ± 1.00
Iron (mg/kg)	6.48 ± 0.01	3.90 ± 0.01	6.48 ± 0.01	7.14 ± 0.01	5.04 ± 0.01
Zinc (mg/kg)	2.73 ± 0.01	0.61 ± 0.01	2.14 ± 0.01	1.13 ± 0.01	1.01 ± 0.01
Total Phosphorus (mg/kg)	24.79 ± 0.01	20.66 ± 0.01	13.08 ± 0.01	8.26 ± 0.01	9.64 ± 0.01
Total Phenolics	0.143 ± 0.001	0.231 ± 0.001	0.227 ± 0.001	0.236 ± 0.001	0.167 ± 0.001
Flavonoids	0.000 ± 0.001	0.006 ± 0.001	0.005 ± 0.001	0.007 ± 0.001	0.004 ± 0.001
Lycopene (mg/kg)	0.87 ± 0.01	127.18 ± 0.01	125.69 ± 0.01	137.09 ± 0.01	11.26 ± 0.01

During dry season, data shows that orange provided the highest Vitamin C (29.65 ± 0.01 mg/100g), whereas watermelon had the greatest lycopene content (137.09 ± 0.01 mg/kg) and remained the richest source of carotenoids (Table 4.9). Pawpaw was outstanding in potassium (5913.60 ± 1.00 mg/kg), while banana contained the highest sodium (4032.00 ± 1.00 mg/kg) and magnesium (136.44 ± 0.01 mg/kg).

Discussion:-

The present study investigated seasonal variations in the nutrient composition of five commonly consumed tropical fruits in Ibadan, Nigeria, with implications for the dietary management of type 2 diabetes mellitus (T2DM). The results demonstrated that both proximate composition and bioactive compounds were significantly influenced by seasonal changes, with notable implications for glycemic regulation, antioxidant defense, and micronutrient adequacy in individuals living with diabetes.

In terms of proximate composition, banana consistently exhibited the highest protein and carbohydrate content across both seasons, whereas watermelon was distinguished by its high moisture content and comparatively low carbohydrate density. These findings agree with earlier reports that noted banana’s relatively higher macronutrient profile compared to other tropical fruits [12]. The carbohydrate richness of banana, although nutritionally valuable, implies a higher glycemic potential, thus warranting moderation in diabetic diets. In contrast, watermelon, despite its low macronutrient content, offered a hydration advantage and contributed significantly to antioxidant intake [10].

The reducing sugar content varied markedly with season, with banana showing the highest concentrations in the rainy season, while pawpaw and orange recorded significant elevations in the dry season. Such variations may be attributed to physiological changes during fruit ripening and climatic influences on carbohydrate metabolism [13]. From a dietary standpoint, these fluctuations are particularly relevant for glycemic management in T2DM, where fruits with lower sugar loads, such as watermelon and pineapple during the rainy season, may be more favorable. Conversely, pawpaw and orange, despite their higher sugar contents in the dry season, remain valuable sources of antioxidants and micronutrients, suggesting that portion control rather than exclusion should guide diabetic dietary planning.

Vitamin C was notably higher in pawpaw and orange during the rainy season and remained dominant in orange during the dry season. This supports research that emphasized citrus fruits as potent sources of ascorbic acid in West African diets [14]. Vitamin C plays a crucial role in reducing oxidative stress, a key mechanism underlying diabetic complications [6]. Thus, the seasonal elevation of vitamin C, particularly in citrus fruits, underscores their functional relevance for antioxidant protection in diabetic management.

Carotenoid and lycopene content were markedly higher in watermelon across both seasons, with β-carotene concentrations peaking in the rainy season. These findings corroborate the pfevious research where watermelon was highlighted as an important dietary source of lycopene with potential hypoglycemic and cardioprotective benefits [15]. Given that oxidative stress and inflammation exacerbate insulin resistance, the abundant carotenoids in watermelon suggest a protective role, making it a strategic dietary fruit for diabetic individuals irrespective of season.

Mineral analysis revealed pawpaw as a rich source of potassium, while banana contained the highest sodium and magnesium levels. This aligns with earlier reports which emphasized pawpaw's potassium content as beneficial for blood pressure regulation, an important comorbidity in diabetic patients [16]. Magnesium, abundant in banana, has been shown to enhance insulin sensitivity and glucose utilization [17]. However, the relatively high sodium concentration in banana warrants careful monitoring, especially among diabetic patients with hypertension or renal impairment.

Conclusion:-

The study revealed marked seasonal variations in the nutritional profiles of the selected fruits. Banana consistently showed the highest protein and carbohydrate contents, while pawpaw and orange were rich in vitamin C. Watermelon was the dominant source of carotenoids and lycopene, and pawpaw contributed the highest potassium levels. Notably, sugar contents were elevated in the dry season, particularly in pawpaw and orange. These findings indicate that while all fruits studied offer valuable nutrients and antioxidants, their seasonal nutrient shifts should be considered when recommending fruit consumption for individuals with type 2 diabetes to balance glycemic control with nutritional benefits.

References:-

1. Magliano, D.J., Boyko, E.J. & IDF Diabetes Atlas 10th edition scientific committee (2021) **IDF Diabetes Atlas**. 10th ed. Brussels: International Diabetes Federation. Chapter 3, Global picture. Available at: https://www.ncbi.nlm.nih.gov/books/NBK581940/ [Accessed 20 Aug. 2025].
2. Yapislar, H. &Gurler, E.B. (2024) 'Management of microcomplications of diabetes mellitus: challenges, current trends, and future perspectives in treatment', **Biomedicines**, 12(9), p.1958. doi:10.3390/biomedicines12091958.
3. Yeh, Y.K., Yen, F.S. &Hwu, C.M. (2023) 'Diet and exercise are a fundamental part of comprehensive care for type 2 diabetes', **Journal of Diabetes Investigation**, 14(8), pp.936–939. doi:10.1111/jdi.14043.
4. Evert, A.B. et al. (2019) 'Nutrition therapy for adults with diabetes or prediabetes: a consensus report', **Diabetes Care**, 42(5), p.731. doi:10.2337/dci19-0014.
5. Krawczyk, M., Burzynska-Pedziwiatr, I., Wozniak, L.A. &Bukowiecka-Matusiak, M. (2023) 'Impact of polyphenols on inflammatory and oxidative stress factors in diabetes mellitus: nutritional antioxidants and their application in improving antidiabetic therapy', **Biomolecules**, 13(9), p.1402. doi:10.3390/biom13091402.
6. Mahmoud, A.M., Hernández Bautista, R.J., Sandhu, M.A. & Hussein, O.E. (2019) 'Beneficial effects of citrus flavonoids on cardiovascular and metabolic health', **Oxidative Medicine and Cellular Longevity**, 2019, p.5484138. doi:10.1155/2019/5484138.
7. Singh, M.K. et al. (2025) 'Fruit carbohydrates and their impact on the glycemic index: a study of key determinants', **Foods (Basel)**, 14(4), p.646. doi:10.3390/foods14040646.
8. Carr, A.C. & Rowe, S. (2020) 'Factors affecting vitamin C status and prevalence of deficiency: a global health perspective', **Nutrients**, 12(7), p.1963. doi:10.3390/nu12071963.

9. Maury, G.L. et al. (2020) ‘Antioxidants in plants: a valorization potential emphasizing the need for the conservation of plant biodiversity in Cuba’, **Antioxidants (Basel)**, 9(11), p.1048. doi:10.3390/antiox9111048.
10. Oyeyinka, B.O. &Afolayan, A.J. (2020) ‘Potentials of Musa species fruits against oxidative stress-induced and diet-linked chronic diseases: in vitro and in vivo implications of micronutritional factors and dietary secondary metabolite compounds’, **Molecules (Basel)**, 25(21), p.5036. doi:10.3390/molecules25215036.
11. Sonko, E., Tsado, D., Yaffa, S., Okhimamhe, A. &Eichie, J. (2016) ‘Wet and dry season effects on select soil nutrient contents of upland farms in North Bank Region of the Gambia’, **Open Journal of Soil Science**, 6, pp.45–51. doi:10.4236/ojss.2016.63005.
12. Anjum, S. & Sundaram, S. (2022) ‘Comparative study on nutrient composition and functional characteristics of tropical fruits with emphasis on banana fruit peel’, **International Journal of Pharmacy and Pharmaceutical Sciences**, pp.25–35. doi:10.22159/ijpps.2022v14i5.44144.
13. Chung, S.W., Jang, Y.J., Kim, S. & Kim, S.C. (2023) ‘Spatial and compositional variations in fruit characteristics of papaya (Carica papaya cv. Tainung No. 2) during ripening’, **Plants (Basel)**, 12(7), p.1465. doi:10.3390/plants12071465.
14. Sir Elkhatim, K.A., Elagib, R.A.A. & Hassan, A.B. (2018) ‘Content of phenolic compounds and vitamin C and antioxidant activity in wasted parts of Sudanese citrus fruits’, **Food Science & Nutrition**, 6(5), pp.1214–1219. doi:10.1002/fsn3.660.
15. Naz, A., Butt, M.S., Sultan, M.T., Qayyum, M.M. & Niaz, R.S. (2014) ‘Watermelon lycopene and allied health claims’, **EXCLI Journal**, 13, pp.650–660.
16. Baqar, S., Michalopoulos, A., Jerums, G. &Ekinci, E.I. (2020) ‘Dietary sodium and potassium intake in people with diabetes: are guidelines being met?’, **Nutrition & Diabetes**, 10(1), p.23. doi:10.1038/s41387-020-0126-5.
17. Liu, H., Li, N., Jin, M., Miao, X., Zhang, X. & Zhong, W. (2020) ‘Magnesium supplementation enhances insulin sensitivity and decreases insulin resistance in diabetic rats’, **Iranian Journal of Basic Medical Sciences**, 23(8), pp.990–998. doi:10.22038/ijbms.2020.40859.9650.