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Millet: An Alternative Food Grain

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Abstract:

Millets belongs to a class of cereals other than wheat and rice were grown even during stone age and fascinatingly that was staple food of Indian and have ample references in Vedic scriptures. The uses of millets are in wide range- food grain, bird/cattle/live stock feed, fuel and building material. Millets are C4 plants having better photosynthesis efficiency, water use efficiency, better yield and more productive at building sugar molecules under hot dry conditions, temperate, tropical and subtropical conditions with less rainfall and drought prone conditions than C_3 species, such as wheat and rice. In this research comparative study between nine millets (Barnyard, Brown top, Foxtail, Kodo, Little, Finger, Great, Pearl and Proso millets) and two major food grains (rice and wheat) being carried out in respect of fifteen nutritional parameters. Based on the results millets being suggested as an alternative food grain to rice and wheat.

Key words: Millet, Nutritional Parameter, water use efficiency, C3-C4 Plant.

I INTRODUCTION

Millets are generally considered to be a group of highly variable small-seeded grasses, which are widely grown around the world as cereal crops or grains for human food and fodder [1]. It is observed by Cherfas [2] that these cereals may have been consumed by humans for about 7,000 years and potentially had a pivotal role in the rise of multi-crop agriculture and lead to settled farming societies. Fahad et al. [3] reiterated that millets are small-grained, annual, warm-weather cereals belonging to the grass family and suggested that millets are highly tolerant of drought and other extreme weather conditions and have a similar nutrient content to other major cereals [4].

Millet belongs to a class of cereals other than wheat, rice, maize and barley and has been documented that millets were grown during stone age by the inhabitants of Switzerland and since the Neolithic Era, millet was cultivated in the dry climates of Africa and northern China. Fascinatingly it was millets and not rice that was a staple food in Indian, Chinese Neolithic and Korean civilizations and millets spread all over the world. The leader of the Shang Dynasty in the 2nd Millennium BC was known as Hou Chi 'The ruler of Millet'. In vedic scriptures like Sathapatha Brahmana have ample references to millets. In Kalidasa's legendary literary masterpiece 'Shakuntala', sage Kanva pouring foxtail millet while bidding farewell to Shakuntala in Dushanta's court was aptly articulated. The interesting fact is that the millet is also pointed out in the Bible, and was used during those days to prepare bread [8]. Marco Polo wrote about food under the rule of Genghis Khan, that they have no shortage because they mostly use rice, foxtail or proso millet, and do not use bread, but simply boil these three sorts of grain [26].

II FEATURES OF MILLET PLANT

Millets are tall, vertical annual grasses similar to Maize. They vary in appearance and size, depending on variety and grow in height from 1 to 15 feet. These plants usually have coarse stems and grow in opaque bunches with grass-like leaves. They are abundant and slim, measuring about an inch broad and can grow over 6 feet long. The seeds are covered in coloured hulls, with colour depending on diversity, unusually hard to digest. Thus, hulling is necessary before the usage and it does not affect the nutrient value as the germ stays intact through this process. After hulling, millet grains appear as small spheres, colour depending on the variety [8,9]

III ENVIRONMENTAL CONDITIONS and USES

A. SOIL

- Variety of soils including- Well drained Loamy soils, Coarse, sandy soils or those with high acidity or alkalinity
- Can be grown on low fertile soils, saline soils, reclaim soils

B. CLIMATE:

- Dry areas of Temperate Tropical and sub-tropical conditions/regions
- Drought prone conditions
- Warm Temperatures
- Low and erratic rainfall

C. USES

- Food Grain, Staple food, Bird seed, Cattle Grain, livestock feed, building material, fuel, basic diet, traditional and novel food

Source: NABARD [8], Oelke, E.A et al., Fields Crops Manual[9], Shadang et al.[10], FAO[11]

IV C3-C4 PLANTS-MILLET

An important cellular process by which plants take in energy from the sun, water from the soil, and carbon dioxide (CO_2) from the air and convert them into sugar molecules (food) is known as Photosynthesis. This process also releases oxygen gas (O_2) as a by-product. The sugar molecules produced during photosynthesis are at the base of our food chain. The process by which plants take the carbon atoms found in CO_2 and use them to build sugar molecules is called carbon fixation. All plants perform photosynthesis, but not in the same way [13].

Photosynthesis: $6CO_2 + 6H_2O + \text{sunlight} \rightarrow C_6H_{12}O_6 + 6O_2$

Plants that use Calvin cycle (Calvin-Benson cycle or Photosynthetic Carbon Reduction (PCR) cycle) for fixing the CO_2 from the air are known as C3 plants. RuBisCO (or simply rubisco), is an enzyme involved with the Calvin Cycle that catalyzes an important step in carbon fixation (a process whereby molecules of atmospheric carbon dioxide are reduced to generate glucose). RuBisCO enzyme can survive on its own without the need of the plant and hence even if plant is dead it remains and helps decomposition. This is due to it not being affected by temperature or pH. RuBisCO catalyzes either the carboxylation (a chemical reaction in which a carboxylic acid group is produced by treating a substrate with carbon dioxide) or oxygenation (addition of oxygen) of RuBP (ribulose-1,5-bisphosphate). That is RuBP is the substrate that enzyme RuBisCO uses to fix CO_2 and ultimately produces a 3-carbon compound Phosphoglycerate (3-PGA). This process is referred to as the C3 (or C_3) cycle. Plants utilizing this pathway are often named as C3 species [12, 13, 14]

About 85% of plant species are C3 plants, which include the cereal grains viz. wheat, rice, barley, oats, Peanuts, cotton, sugar beets, tobacco, spinach, soybeans, most trees and most lawn grasses such as rye and fescue. C3 plants have the disadvantage that in hot dry conditions their photosynthetic efficiency suffers because of a process called photorespiration. When the CO_2 concentration in the chloroplasts drops below about 50 ppm, the catalyst rubisco that helps to fix carbon begins to fix oxygen instead. This is highly wasteful of the energy that has been collected from the light, and causes the rubisco to operate at perhaps a quarter of its maximal rate [14]

This problem of photorespiration is overcome in C4 plants by a two-stage strategy that keeps CO_2 high and oxygen low in the chloroplast where the Calvin cycle operates. In C3 photosynthesis, all the photosynthetic reactions take place in a single cell. Whereas, in C4 photosynthesis is commonly achieved with a modified cellular arrangement known as Kranz anatomy, which divides the reactions into two cell types (Mesophyll and Bundle Sheath cells). This two-cell arrangement allows a carbon concentrating mechanism to be employed, which greatly elevates the CO_2 concentration in Bundle Sheath cells (as much as 20 times higher than in Mesophyll cells). This effectively saturates the active site of Rubisco with CO_2, greatly reducing photorespiration, which has been estimated to decrease photosynthetic efficiency by 30%. These improvements in efficiency make C_4 species more productive at building sugar molecules under hot dry conditions than C_3 species. [15,16,17]

The C4 photosynthesis is an adaptation of the C3 pathway that overcomes the limitation of the photorespiration, improving photosynthetic efficiency and minimizing the water loss in hot, dry environments [18].

Most C4 plants are inborn to the temperate, tropical and sub-tropical conditions and under these conditions, they exhibit higher photosynthetic and growth rates due to gains in the water, carbon and nitrogen efficiency uses. Indeed, the highest known productivity in natural vegetation is for a C4 perennial grass in the central Amazon, which achieves a net production of 100 t (dry matter) ha-1 year-1. Some of the world´s most productive crops and pasture, such as maize (Zea mays), sugar cane (Saccharum officinarum), sorghum (Sorghum bicolor), amaranth, paspalums (Paspalum notatum and P. urvillei), bermudagrass (Cynodon dactylon), blue grama (Bouteloua gracilis) [19,20].

Increase of biomass production and CO_2 fixation in C4 is faster than that in C3, which reflects more efficient use of light and CO_2 in C4 plant. Also, in contrast to C3, C4 plants have less dense topology, higher robustness, better modularity, and higher CO_2 and radiation use efficiency. C4 plants such as maize, sorghum, and sugarcane, approximately have 50% higher photosynthesis efficiency than those of C3 plants such as rice, wheat, and potato. This is because the different mechanism of carbon fixation by the two types of photosynthesis [21, 22]

C4 plants such as millets are having better photosynthesis efficiency, water use efficiency, better yield and more productive at building sugar molecules under hot dry conditions, temperate, tropical and subtropical conditions with less rainfall and drought prone conditions than C_3 species, such as wheat and rice.

V TYPES OF MILLET

Millets are grouped as major millets- sorghum, pearl millet, finger millet; and minor millets- foxtail, little, kodo, proso and barnyard and these are one of the oldest foods known to humanity and belongs to Poaceae (or Gramineae) family, belonging to species under the five genera in the tribe Paniceae, namely Panicum, Setaria, Echinochloa, Pennisetum and Paspalum, and one genus, Eleusine, in the tribe Chlorideae [23,25]. According FAO millet species can be divided into two broad categories: pearl millet and small millets. The latter group, with the exception of proso millet, have smaller grains than pearl millet [24]. On the basis of area grown and its grain size the millets are classified as major millet and minor millets. The major millets include sorghum (jowar) and pearl millet (bajra). The finger millet (ragi/mandua), foxtail millet (kangni/Italian millet), little millet (kutki), kodo millet, barnyard millet (sawan/jhangora), proso millet (cheena/common millet), and brown top millet (korale) are categorized under minor millets. In certain countries of Africa, other millets such as fonio and tef are grown [26]

VI COMPARATIVE ANALYSIS OF MILLET CEREALS &FOOD GRAINS

To undertake comparative analysis of millets and food grains following procedure adopted.

Stage1: Selection of Millet cereals & food grains: A total of nine millets (including minor and major millets) and two most commonly used food grains rice and wheat are considered and selected for study (Table 1).
Stage2: Nutritional Parameters: Based on the available literature fifteen nutritional parameters are identified for comparative analysis from different sources.

Stage3: Data Compilation: Comprehensive data tabulation which includes vernacular names of millets, nutritional properties of millet cereals and food grains, and their coding.

Stage4: Comparative Analysis:
A.Nutritional parameters of millets (M1 to M9)versus nutritional parameters of rice (FG2)
B.Nutritional parameters of millets (M1 to M9)versus nutritional parameters of wheat (FG1)

Stage5: Results and discussions

Stage 1 & 2- The details of millets and food grains under consideration& nutritional parameters and their codes for comparative analysis are tabulated in table 1.

Stage 3- The vernacular names of millets are compiled for better understanding and familiarity and arranged in table 2. The collected data for all millets and food grains under consideration for all nutritional parameters from different sources (S1 to S9) organized in table 3.

Table 1. Details of Millets cereals, Food grains, nutritional parameters

MILLET/FOOD GRAIN	CODE	NUTRITIONAL PARAMETER	CODE
Barnyard Millet	M1	Niacin	NP1
Brown Top Millet	M2	Riboflavin	NP2
Foxtail Millet	M3	Thiamine	NP3
Kodo Millet	M4	Carotene	NP4
Little Millet	M5	Iron	NP5
Finger Millet	M6	Fibre	NP6
Great Millet	M7	Sugar	NP7
Pearl Millet	M8	Calcium	NP8
Proso Millet	M9	Phosphorous	NP9
Wheat	FG1	Protein	NP10
Rice	FG2	Minerals	NP11
		Zn	NP12
		Ash	NP13
		Fat	NP14
		Energy	NP15

Table 2. Vernacular names of millets

English	Other	Scientific	Hindi	Telugu	Kannada	Tamil	Malyalam	Marathi	Gujrati	Bangla	Oriya	Kasmiri
Barnyard Millet	Japanese Millet / Sawank	Echinochloa Frumantacea	Jhangora / Shama	Odalu / Bonta Chamula	Samai	Kuthiravaali		Shamul	Sama	Shamula		
Brown Top Millet	Dixie signalgrass	Brachiaria ramosa (L.) Stapf; Panicum ramosum L										
Foxtail Millet	Moha Millet / Italian Millet	Setarai Italica	Kangni	Korra / Korralu	Navane / Priyangu Thene	Tenai		Rala	Ral Kang	Syama Dhan		Shol
Kodo Millet	Pakodi / Manakodra	Paspalum Scrobiculatum	Kodra	Arikelu	Harka	Varagu		Harik	Kodra	Kodoadhan	Kodus	
Little Millet	Goudli / Gondola	Panicum Miliare	Kutki	Sama	Same	Samai		Sava	Gadro	Kangani	Suan	Ganuhaar

Finger Millet	Rajika	Eleusine Coracana	Mandua /Madua	Ragulu	Ragi	Kelvargu / Kezhvaragu	Moothari	Nachni	Bhav / Nagali / Bavto	Mandua /Madua	Mandia	
Sorghum	Great Millet / Milo / Chari	Sorghum Vulgare	Jowar	Jonnalu	Jola	Cholam	Cholum	Jwari	Jowar	Jowar	Janha	
Pearl Millet	Spiked Millet / Bullrush	Pennisetum Typhoideum	Bajra	Gantilu / Sazzalu	Sajje	Kambu	Kambu	Bajri	Bajri	Bajra	Bajra	Bajru
Proso Millet	French Millet / Common Millet	Panicum Miliaceum	Barri	Varigalu/ Varagulu	Baragu	Panivaragu		Vari	Vari		Chinna	Pingu

Source: NABARD[8], USDA[27], ICAR-IIMR[26], Ahmed[28]

Table 3NP1 to NP15 data of M1 to M9 and FG1 and FG2 from different sources (S1 to S9)

M/FG	Niacin(mg) NP1									Riboflavin(mg) NP2									Thiamine(mg) NP3								
	S1	S2	S3	S4	S5	S6	S7	S8	S9	S1	S2	S3	S4	S5	S6	S7	S8	S9	S1	S2	S3	S4	S5	S6	S7	S8	S9
M1	1.5	4.2	NR	NR	NR	4.2	4.2	NR	NR	0.08	0.10	NR	NR	NR	0.1	0.1	NR	NR	0.31	0.33	NR	NR	NR	0.33	0.33	NR	0.33
M2	18.5	NR	NR	NR	NR	NR	NR	NR	NR	0.027	Na	NR	NR	NR	NR	NR	NR	NR	3.2	Na	NR	NR	NR	NR	NR	NR	NR
M3	1.5	3.2	NR	NR	NR	3.2	3.2	NR	NR	0.31	0.11	NR	NR	NR	0.11	0.11	NR	NR	0.59	0.59	NR	NR	NR	0.59	0.59	NR	0.6
M4	2.0	2.0	NR	NR	NR	2	2	NR	NR	0.09	0.09	NR	NR	NR	0.09	0.09	NR	NR	0.33	0.15	NR	NR	NR	0.15	0.15	NR	0.15
M5	1.5	3.2	NR	NR	NR	3.2	3.2	NR	NR	0.07	0.09	NR	NR	NR	0.09	0.09	NR	NR	0.30	0.30	NR	NR	NR	0.3	0.3	NR	NR
M6	1.1	1.1	NR	NR	NR	1.1	1.1	NR	NR	0.19	0.19	NR	NR	NR	0.19	0.19	NR	NR	0.42	0.42	NR	NR	NR	0.42	0.42	NR	0.4
M7	1.8	4.3	NR	NR	NR	4.3	4.3	NR	5.19	0.13	0.15	NR	NR	NR	0.15	0.15	NR	0.05	0.37	0.38	NR	NR	NR	0.38	0.38	NR	0.28
M8	2.3	2.8	NR	NR	NR	2.8	2.8	NR	1.11	0.25	0.21	NR	NR	NR	0.21	0.21	NR	NR	0.33	0.38	NR	NR	NR	0.38	0.38	NR	0.3
M9	2.3	4.5	NR	NR	NR	4.5	4.5	NR	NR	0.18	0.28	NR	NR	NR	0.28	0.28	NR	NR	0.20	0.41	NR	NR	NR	0.41	0.41	NR	0.41
FG1	5.0	5.1	NR	NR	NR	5.1	5.1	NR	4.31	0.17	0.10	NR	NR	NR	0.1	0.1	NR	0.1	0.35	0.41	NR	NR	NR	0.41	0.41	NR	0.44
FG2	1.2	4.3	NR	NR	NR	4.3	4.3	NR	5.56	0.06	0.04	NR	NR	NR	0.04	0.04	NR	0.06	0.06	0.41	NR	NR	NR	0.41	0.41	NR	0.5

M/FG	Carotene (mg) NP4									Iron (mg) NP5									Fibre (g) NP6								
	S1	S2	S3	S4	S5	S6	S7	S8	S9	S1	S2	S3	S4	S5	S6	S7	S8	S9	S1	S2	S3	S4	S5	S6	S7	S8	S9
M1	0	NR	NR	NR	NR	NR	NR	NR	NR	2.9	18.6	15.2	NR	15.2	5	18.6	NR	NR	9.8	13.6	14.7	NR	10.1	9.8	NR	9.8	NR

M2	0	NR	NR	NR	NR	NR	NR	NR	NR	0.6	NR	NR	NR	NR	NR	NR	NR	NR	12.5	NR	NR	NR	NR	NR	NR	NR	NR
M3	32	NR	NR	NR	NR	NR	NR	NR	NR	6.3	2.8	2.8	2.8	2.8	2.8	2.8	NR	NR	8.0	6.7	8.0	8.0	8.0	8	NR	1	NR
M4	0	NR	NR	NR	NR	NR	NR	NR	NR	2.9	1.7	0.5	NR	0.5	0.5	107	NR	NR	9.0	5.2	9.0	NR	9.0	9	NR	10.2	NR
M5	0	NR	NR	NR	NR	NR	NR	NR	NR	2.8	9.3	9.3	NR	9.3	9.3	9.3	NR	NR	9.8	7.6	8.6	NR	7.6	7.6	NR	0.1	NR
M6	42	NR	NR	NR	NR	NR	NR	NR	NR	5.4	3.9	3.9	3.9	3.9	3.9	3.9	NR	NR	3.6	3.6	3.6	3.6	3.6	3.6	NR	3	NR
M7	47	NR	NR	NR	NR	NR	NR	NR	NR	4.1	5.4	NR	NR	NR	4.1	5.4	NR	NR	1.3	2.0	NR	NR	NR	1.6	NR	NR	NR
M8	132	NR	NR	NR	NR	NR	NR	NR	NR	8.0	11.0	16.9	16.9	16.9	8.0	11	NR	NR	1.2	2.3	1.2	1.3	1.3	1.2	NR	NR	NR
M9	0	NR	NR	NR	NR	NR	NR	NR	NR	5.9	2.9	NR	2.2	0.8	0.8	2.9	NR	NR	2.2	5.2	NR	2.2	2.2	2.2	NR	0.3	NR
FG1	64	NR	NR	NR	NR	NR	NR	NR	NR	5.3	3.5	NR	NR	5.3	5.3	3.5	NR	NR	1.2	2.0	NR	NR	1.2	1.2	NR	NR	NR
FG2	0	NR	NR	NR	NR	NR	NR	NR	NR	1.0	1.8	NR	NR	0.7	0.7	1.8	NR	NR	0.2	1.0	NR	NR	0.2	0.2	NR	NR	NR

M/FG	Sugar (g) NP7									Calcium (mg) NP8									Phosporous (mg) NP9								
	S1	S2	S3	S4	S5	S6	S7	S8	S9	S1	S2	S3	S4	S5	S6	S7	S8	S9	S1	S2	S3	S4	S5	S6	S7	S8	S9
M1	65.5	55	74.3	NR	NR	65.5	55	65.5	NR	20	22	14	NR	11	20	22	NR	NR	280	NR	121	NR	NR	280	280	NR	NR
M2	69.7	NR	NR	NR	NR	NR	NR	NR	NR	10	NR	NR	NR	NR	NR	NR	NR	NR	470	NR	NR	NR	NR	NR	NR	NR	NR
M3	60.6	63.2	60.9	NR	NR	60.9	63.2	72.4	NR	30	31	31	31	31	31	31	40	NR	290	NR	290	NR	NR	290	290	300	NR
M4	65.6	66.6	65.9	NR	NR	65.9	66.6	59.2	NR	40	35	27	NR	27	27	35	40	NR	240	NR	188	NR	NR	188	188	300	NR
M5	65.5	60.9	75.7	NR	NR	67	60.9	72.3	NR	20	17	17	NR	17	17	17	20	NR	280	NR	220	NR	NR	220	220	300	NR
M6	72.7	72.6	72	NR	NR	72	72.6	72	NR	33	350	25	344	344	344	350	300	NR	270	NR	283	NR	NR	283	283	300	NR
M7	72.4	70.7	NR	NR	NR	72.6	70.7	NR	NR	30	25	NR	NR	NR	25	25	NR	NR	280	NR	NR	NR	NR	222	222	NR	NR
M8	67.	67	67.	NR	NR	67.	67	NR	NR	50	42	42	38	38	42	42	NR	NR	350	NR	29	NR	NR	29	26	NR	NR

	1		5			5															6			6	9		
M9	68.9	63.8	NR	NR	NR	70.4	63.8	72.26	NR	10	8	NR	14	14	14	8	10	NR	330	NR	NR	NR	NR	206	206	200	NR
FG1	76.2	71	NR	NR	NR	71.2	71	NR	NR	50	30	NR	NR	41	41	30	NR	NR	320	NR	NR	NR	NR	306	306	NR	NR
FG2	79.0	76	NR	NR	NR	78.2	76	76.7	NR	10	33	NR	NR	10	10	33	10	NR	110	NR	NR	NR	NR	160	160	170	NR

M/FG	Protein (g) NP10									Minerals (g) NP11									Zn NP12								
	S1	S2	S3	S4	S5	S6	S7	S8	S9	S1	S2	S3	S4	S5	S6	S7	S8	S9	S1	S2	S3	S4	S5	S6	S7	S8	S9
M1	6.2	11	11.6	NR	11.2	6.2	11	6.2	NR	4.4	NR	4.4	NR	4.4	4.4	NR	4.4	NR	NR	NR	NR	NR	NR	3	3	NR	57.45
M2	11.5	NR	NR	NR	NR	NR	NR	NR	NR	4.2	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
M3	12.3	11.2	12.3	12.3	12.3	12.3	11.2	9.7	NR	3.3	NR	3.3	3.3	3.3	3.3	NR	1.5	NR	NR	NR	NR	NR	NR	2.4	2.4	NR	60.6
M4	6.2	9.8	8.3	NR	8.3	8.3	9.8	10.6	NR	2.6	NR	2.6	NR	2.6	2.6	NR	4.4	NR	NR	NR	NR	NR	NR	0.7	0.7	NR	32.7
M5	7.7	9.7	8.7	NR	7.7	7.7	9.7	13.4	NR	1.5	NR	1.5	NR	1.5	1.5	NR	1.1	NR	NR	NR	NR	NR	NR	3.7	3.7	NR	NR
M6	7.1	7.7	7.3	7.3	7.3	7.3	7.7	8	NR	2.7	NR	2.7	2.7	2.7	2.7	NR	2.7	NR	NR	NR	NR	NR	NR	2.3	2.3	NR	36.6
M7	10.4	10.4	NR	NR	NR	10.4	10.4	NR	NR	1.6	NR	NR	NR	NR	1.6	NR	NR	NR	NR	NR	NR	NR	NR	1.6	1.6	NR	3.01
M8	11.6	11.8	11.6	10.6	10.6	11.6	11.8	NR	NR	2.3	NR	2.3	2.3	2.3	2.3	NR	NR	NR	NR	NR	NR	NR	NR	3.1	3.1	NR	NR
M9	12.5	12.5	NR	12.5	12.5	12.5	12.5	13.71	NR	1.9	NR	NR	1.9	1.9	1.9	NR	1.07	NR	NR	NR	NR	NR	NR	1.4	1.4	NR	NR
FG1	11.8	11.6	NR	NR	11.8	11.8	11.6	NR	NR	1.5	NR	NR	NR	1.5	1.5	NR	NR	NR	NR	NR	NR	NR	NR	2.7	NR	NR	2.9
FG2	6.9	7.9	NR	NR	6.8	6.8	7.9	7.5	NR	0.6	NR	NR	NR	0.6	0.6	NR	1.6	NR	NR	NR	NR	NR	NR	1.4	NR	NR	0.5

M/FG	Ash(g) NP13									Fat(g) NP14									Energy(kcal) NP15								
	S1	S2	S3	S4	S5	S6	S7	S8	S9	S1	S2	S3	S4	S5	S6	S7	S8	S9	S1	S2	S3	S4	S5	S6	S7	S8	S9
M1	NR	4.5	NR	NR	NR	2.2	NR	NR	NR	NR	3.9	5.8	NR	NR	NR	3.9	2.2	NR	NR	300	300	NR	NR	307	300	NR	NR
M2	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR

M3	NR	3.3	NR	NR	NR	4.3	NR	NR	NR	NR	4.0	4.3	NR	NR	NR	4	3.5	NR	NR	351	331	NR	NR	331	351	353	NR
M4	NR	3.3	NR	NR	NR	1.4	NR	NR	NR	NR	3.6	1.4	NR	NR	NR	3.6	4.2	NR	NR	353	309	NR	NR	309	353	346	NR
M5	NR	5.4	NR	NR	NR	4.7	NR	NR	NR	NR	5.2	5.3	NR	NR	NR	5.2	1.8	NR	NR	329	341	NR	NR	341	329	360	NR
M6	NR	1.5	NR	NR	NR	1.3	NR	NR	NR	NR	2.6	1.3	NR	NR	NR	1.5	1.3	NR	NR	336	328	NR	NR	328	336	332	NR
M7	NR	1.6	NR	NR	NR	1.9	NR	NR	NR	NR	3.1	NR	NR	NR	NR	3.1	NR	NR	NR	329	NR	NR	NR	349	329	NR	NR
M8	NR	2.2	NR	NR	NR	5	NR	NR	NR	NR	4.8	5.0	NR	NR	NR	4.8	NR	NR	NR	363	361	NR	NR	361	363	NR	NR
M9	NR	3.1	NR	NR	NR	1.1	NR	NR	NR	NR	3.5	NR	NR	NR	NR	3.5	1.76	NR	NR	364	NR	NR	NR	341	364	341	NR
FG 1	NR	1.6	NR	NR	NR	1.5	NR	NR	NR	NR	2.0	NR	NR	NR	NR	2	NR	NR	NR	348	NR	NR	NR	346	348	NR	NR
FG 2	NR	1.3	NR	NR	NR	0.5	NR	NR	NR	NR	2.7	NR	NR	NR	NR	2.7	1	NR	NR	362	NR	NR	NR	345	362	348	NR

Source: S1[29], S2[28],S3[10],S4[30],S5[31],S6[23],S7[8],S8[25],S9[32] NR-Not Reported

Stage 4: To perform the comparative analysis, average value of each nutritional parameter (composed from all nine sources, a total of fifteen nutritional parameters)for all 9 millet cereals (M1 to M9) and food grains- wheat & rice (FG1 and FG2) are computed by using the data from table 3, and presented in table 4.

Table 4 Mean values of NP1 to NP15 data of M1 to M10 and FG1 and FG2 from different sources

NP→ FG↓	NP1(mg)	NP2(mg)	NP3(mg)	NP4 (mg)	NP5 (mg)	NP6 (g)	NP7(g)	NP8(mg)	NP9(mg)	NP10 (g)	NP11(g)	NP12	NP13(g)	NP14(g)	NP15(kcal)
M1	3.52	0.095	0.326	0	12.58	11.3	63.40	18.17	240.25	8.48	4.4	21.15	3.35	3.95	301.75
M2	18.5	0.027	3.20	0	0.60	12.5	69.70	10.00	470.00	11.50	4.2	NR	NR	NR	NR
M3	2.77	0.160	0.592	32	3.30	6.81	63.53	32.00	292.00	11.70	3.0	21.8	3.8	3.95	343.4
M4	2.00	0.090	0.186	0	2.80	8.56	64.90	33	220.80	8.75	2.96	11.37	2.2	3.20	334
M5	2.77	0.085	0.30	0	8.22	6.88	67.05	17.85	248.00	9.22	1.42	3.7	5.05	4.37	340
M6	1.10	0.190	0.416	42	4.11	3.51	72.32	261.25	283.80	7.46	2.7	13.73	1.4	1.67	332
M7	3.98	0.126	0.358	47	3.75	1.63	71.6	26.25	241.33	10.40	1.6	2.07	1.75	3.1	335.67
M8	2.36	0.220	0.354	132	12.67	1.42	67.22	42.0	302.70	11.28	2.3	3.1	3.6	4.86	362
M9	3.95	0.255	0.368	0	2.58	2.38	67.83	11.14	235.5	12.67	1.73	1.4	2.1	2.92	352.5
FG1	4.92	0.114	0.404	64	4.58	1.40	72.35	38.4	310.67	11.72	1.50	2.8	1.55	2.0	348
FG2	3.93	0.048	0.358	0	1.20	0.40	77.18	17.67	150.00	7.30	0.85	0.95	0.9	2.13	354.25

For better understanding of the comparative analysis pictographic representations are organized from Figures 1 to 15.

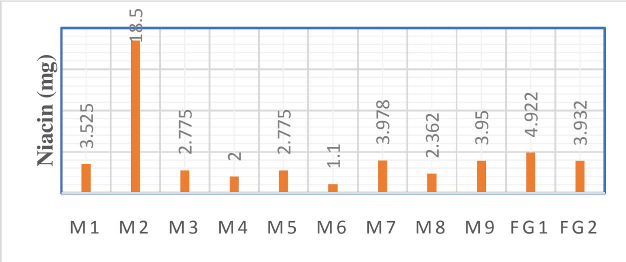

Fig. 1 Average NP1 value of all millets and food grains

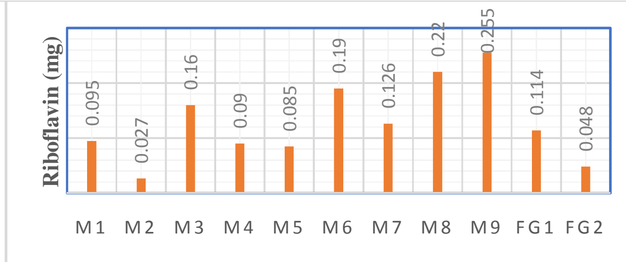

Fig. 2 Average NP2 value of all millets and food grains

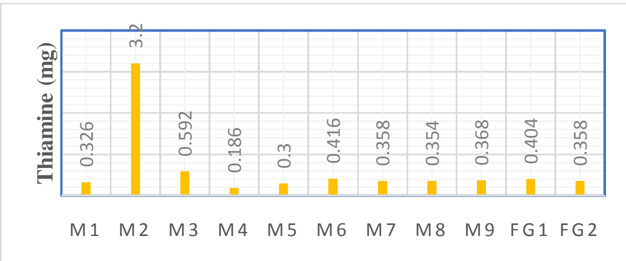

Fig. 3 Average NP3 value of all millets and food grains

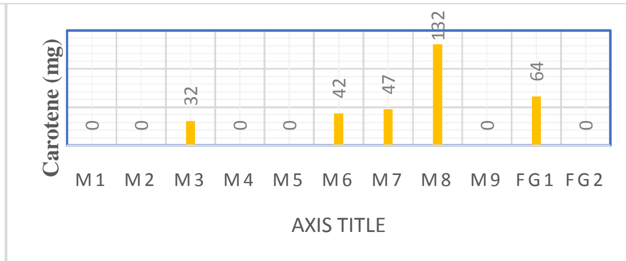

Fig. 4 Average NP4 value of all millets and food grains

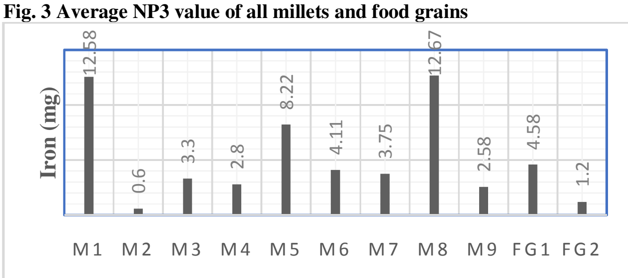

Fig. 5 Average NP5 value of all millets and food grains

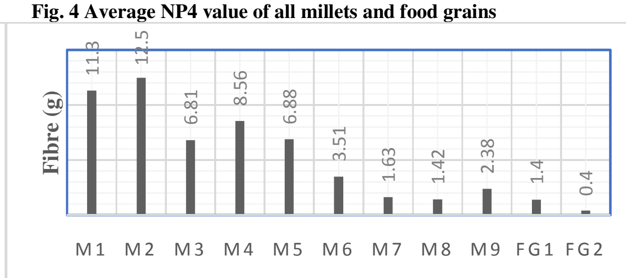

Fig. 6 Average NP6 value of all millets and food grains

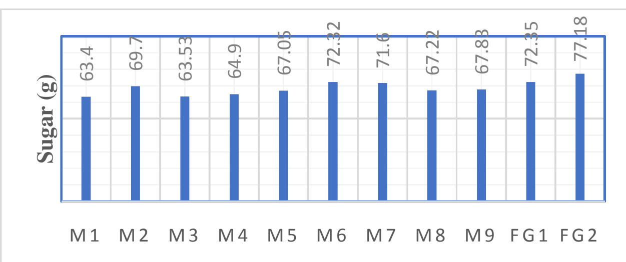

Fig. 7 Average NP7 value of all millets and food grains

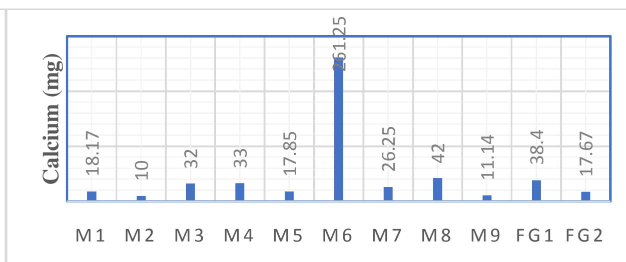

Fig. 8 Average NP8 value of all millets and food grains

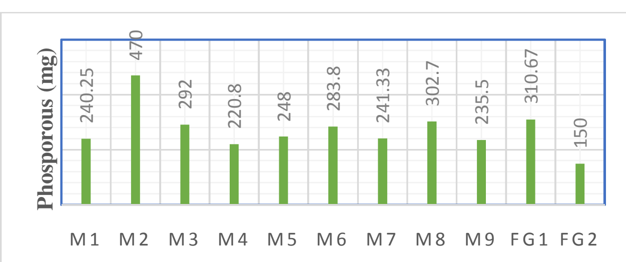

Fig. 9 Average NP9 value of all millets and food grains

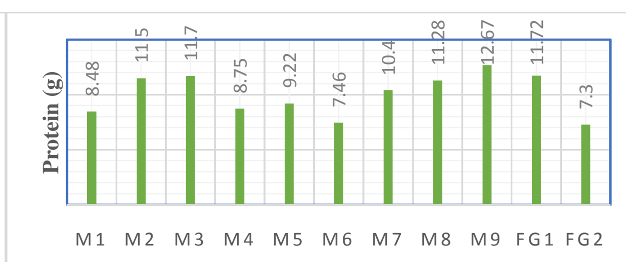

Fig. 10 Average NP10 value of all millets and food grains

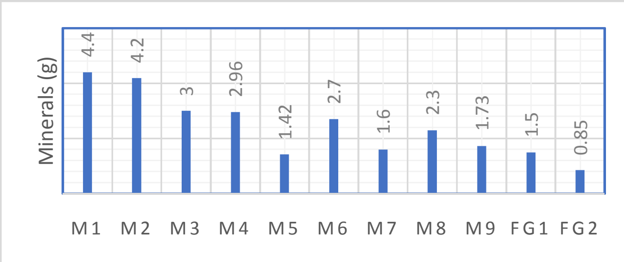

Fig. 11 Average NP11 value of all millets and food grains

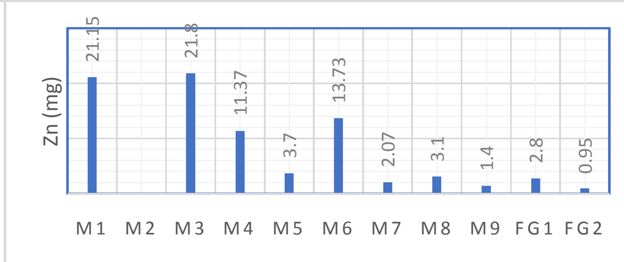

Fig. 12 Average NP12 value of all millets and food grains

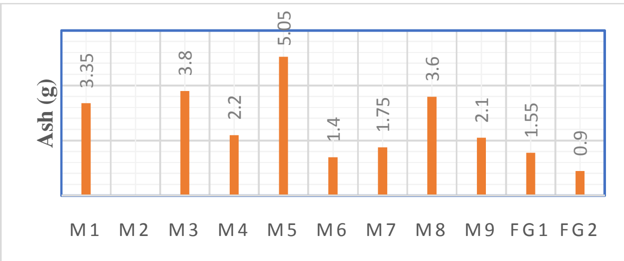

Fig. 13 Average NP13 value of all millets and food grains

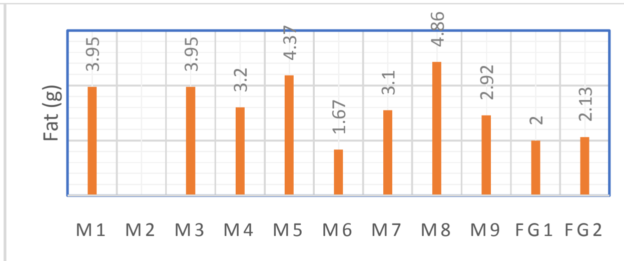

Fig. 14 Average NP14 value of all millets and food grains

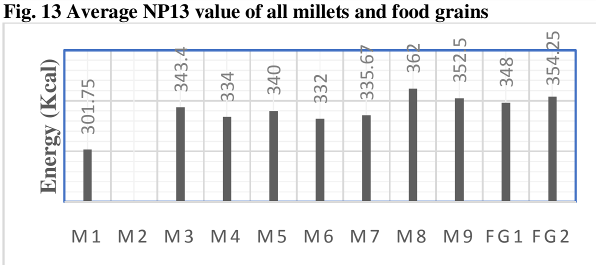

Fig. 15 Average NP15 value of all millets and food grains

In the stage 4 to analyse and compare i) the nutritional parameters of millets (M1 to M9)and wheat (FG1) & ii) the nutritional parameters of millets (M1 to M9)and rice, data tables 5 & 6 are organized based on table 4.

Table 5 Comparison of NP1 to NP15 data of M1 to M10 and FG2

NP→ FG↓	NP1 (mg)	NP2 (mg)	NP3 (mg)	NP4 (mg)	NP5 (mg)	NP6 (g)	NP7 (g)	NP8 (mg)	NP9 (mg)	NP10 (g)	NP11 (g)	NP12	NP13(g)	NP14 (g)	NP15 (kcal)
M1	~~3.52~~	0.095	~~0.326~~	0	12.58	11.3	~~63.40~~	18.17	240.25	8.48	4.4	21.15	3.35	3.95	~~301.75~~
M2	18.5	~~0.027~~	3.20	0	~~0.60~~	12.5	~~69.70~~	~~10.00~~	470.00	11.50	4.2	NR	NR	NR	NR
M3	~~2.77~~	0.16	0.592	32	3.3	6.81	~~63.53~~	32.00	292.00	11.70	3.0	21.8	3.8	3.95	~~343.4~~
M4	~~2.00~~	0.09	0.186	0	2.8	8.56	~~64.90~~	33	220.80	8.75	2.96	11.37	2.2	3.20	~~334~~
M5	~~2.77~~	0.085	~~0.30~~	0	8.22	6.88	~~67.05~~	17.85	248.00	9.22	1.42	3.7	5.05	4.37	~~340~~
M6	~~1.10~~	0.19	0.416	42	4.11	3.51	~~72.32~~	261.25	283.80	7.46	2.7	13.73	1.4	1.67	~~332~~
M7	3.98	0.126	0.358	47	3.75	1.63	~~71.6~~	26.25	241.33	10.40	1.6	2.07	1.75	3.1	~~335.67~~
M8	~~2.36~~	0.22	0.354	132	12.67	1.42	~~67.22~~	42.0	302.70	11.28	2.3	3.1	3.6	4.86	~~362~~
M9	3.95	0.255	0.368	0	2.58	2.38	~~67.83~~	~~11.14~~	235.5	12.67	1.73	1.4	2.1	2.92	~~352.5~~
FG2	**3.93**	**0.048**	**0.358**	**0**	**1.2**	**0.40**	**77.18**	**17.67**	**150.00**	**7.30**	**0.85**	**0.95**	**0.9**	**2.13**	**354.25**

NB: ~~red colour strike through~~NP value is less than the corresponding NP value of base grain FG2

Table 6 Comparison of NP1 to NP15 data of M1 to M10 and FG1

NP→ FG↓	NP1 (mg)	NP2 (mg)	NP3 (mg)	NP4 (mg)	NP5 (mg)	NP6 (g)	NP7 (g)	NP8 (mg)	NP9 (mg)	NP10 (g)	NP11 (g)	NP12	NP13 (g)	NP14 (g)	NP15 (kcal)
M1	~~3.52~~	~~0.095~~	~~0.326~~	~~0~~	12.58	11.3	~~63.40~~	18.17	~~240.25~~	~~8.48~~	4.4	21.15	3.35	3.95	~~301.75~~

M2	18.5	~~0.027~~	3.20	~~0~~	~~0.60~~	12.5	~~69.70~~	10.00	470.00	~~11.50~~	4.2	NR	NR	NR	NR
M3	~~2.77~~	0.160	0.592	~~32~~	~~3.30~~	6.81	~~63.53~~	32.00	~~292.00~~	~~11.70~~	3.0	21.8	3.8	3.95	~~343.4~~
M4	~~2.00~~	~~0.090~~	~~0.186~~	~~0~~	~~2.80~~	8.56	~~64.90~~	33	~~220.80~~	~~8.75~~	2.96	11.37	2.2	3.20	~~334~~
M5	~~2.77~~	~~0.085~~	~~0.30~~	~~0~~	8.22	6.88	~~67.05~~	17.85	~~248.00~~	~~9.22~~	~~1.42~~	3.7	5.05	4.37	~~340~~
M6	~~1.10~~	0.190	0.416	~~42~~	~~4.11~~	3.51	~~72.32~~	261.25	~~283.80~~	~~7.46~~	2.7	13.73	1.4	1.67	~~332~~
M7	~~3.98~~	0.126	0.358	~~47~~	~~3.75~~	1.63	~~71.6~~	26.25	~~241.33~~	~~10.40~~	1.6	2.07	1.75	3.1	~~335.67~~
M8	~~2.36~~	0.220	~~0.354~~	132	12.67	1.42	~~67.22~~	42.0	~~302.70~~	~~11.28~~	2.3	3.1	3.6	4.86	362
M9	~~3.95~~	0.255	~~0.368~~	~~0~~	~~2.58~~	2.38	~~67.83~~	11.14	~~235.5~~	12.67	1.73	1.4	2.1	2.92	352.5
FG1	**4.92**	**0.114**	**0.404**	**64**	**4.58**	**1.40**	**72.35**	**38.4**	**310.67**	**11.72**	**1.50**	**2.8**	**1.55**	**2.0**	**348**

NB: ~~red colour strike through~~NP value is less than the corresponding NP value of base grain FG1

VI RESULTS AND DISCUSSIONS

From the compiled data and analysis,it can be assessed thatNP1 value of M1, M3, M4, M5, M6 and M8 is less than that of FG2 and whereas NP1 value of M2, M7 and M9 are more than that of FG2. NP2 value of M2 is less than that of FG2 whereas all remaining millets have higher NP2 value than that of FG2. It is also observed that NP3 value of M1 and M5 are less than that of FG2 and for all remaining millets this value is greater than that of FG2. The values of NP4, NP6, NP9, NP10, NP11, NP12, NP13 and NP14 for all millets are higherthan that of FG2. In case of NP5 value of M2 is lower than that of FG2 and for remaining millets this value is more than that of FG2. It is also observed that the values of NP7 and NP15 (i.e.,sugar and energy respectively) of FG2 are greater than that of all millets. NP8 values of M2 and M9 are less than that of FG2 and whereas for all remaining eight millets this value is more than that of FG2.

While comparing the NP values of millets and FG1, it can be confirmed from the compiled data that the values of NP6, NP8, NP12, and NP14 of all millets are more than the corresponding values of FG1. NP1 value of M2 is more than that of FG1 and for remaining all millets this value is lesser than that of FG1. The NP2 value of M1, M2, M4 and M5 is less than that of FG2 and for all remaining millets this value is greater than the corresponding value of FG1. It is also clear from the data that the NP3 values of M2, M3, M6 and M7 are more than the corresponding value of FG1 and for remaining millets this value is less than that of FG1. NP4 values of M8 is more than that of FG1 and whereas in case of all remaining millets this NP4 value is lower than the corresponding value of FG1. The values of NP5 of M5 and M9 are more than that of FG1 and for the remaining millets this value is less than that of FG1. The value of NP7 (i.e., sugar) of all millets is less than the corresponding value of FG1. NP9 value of M2 is more than corresponding value of FG1 and for all remaining millets this value is less than that of FG1. It is also established that NP10 value of FG1 is greater than that of all millets except M9. Similarly, NP11value of FG1 is greater than that of all millets except M5. It can also be concluded that NP15 value of FG1 is lower than that of M8 and M9 and this value for all remaining millets is more than that of FG1.

VII CONCLUSIONS:

About 85% of plant species are C3 plants, which include the cereal grains viz. wheat, rice, in hot dry conditions their photosynthetic efficiency suffers which is highly wasteful of the energy that has been collected from the light. C4 plants such as millet approximately have 50% higher photosynthesis efficiency than those of C3 plants. From the literature it can also be observed that millets are having better photosynthesis efficiency, water use efficiency, better yield and more productivity under hot dry conditions, temperate, tropical and subtropical conditions with less rainfall and drought prone conditions than C_3 species. Millets are highly tolerant of drought and other extreme weather conditions and have a better nutrient content to other major cereals.Combination of variety of millets can be used as food grain, staple food, bird seed, cattle grain, livestock feed, building material, fuel, basic diet, traditional and novel food. Disseminating the use of millet as an alternative grain is the need of the hour for sustainable development.

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