

RESEARCH ARTICLE

ASSESSING THE EFFECT OF TOCOPHEROL-RICH MAIZE FLOUR ON THE HEALTH OF PREGNANT AND LACTATING WOMEN

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Abstract

Maternal nutrition during pregnancy and lactation is critical for maternal and neonatal health, particularly in low- and middle-income countries (LMICs) where food quality is poor and access to supplements is limited. Vitamin E (tocopherol) deficiency is prevalent in these regions and is associated with oxidative stress, compromised immunity, and adverse pregnancy outcomes. This study evaluated the nutritional, antioxidant, and biochemical effects of tocopherol-rich maize flour (TRMF) in pregnant and lactating women. A six-month comparative intervention study was conducted with 300 women: 200 in the intervention group consuming TRMF and 100 in the control group consuming conventional maize flour. Proximate composition, minerals, antioxidant parameters, and biochemical markers were assessed using standard laboratory methods. TRMF showed significantly higher protein (e.g., 12.5 ± 1.2 g/100g vs. 9.8 ± 0.9 g/100g, $p < 0.05$), crude fat, fibre, and ash content, along with elevated levels of calcium, iron, magnesium, and zinc. Antioxidant activity (DPPH, FRAP) and total phenolic content were markedly higher in the intervention group. Biochemical assessments revealed increased plasma tocopherol (e.g., 15.2 ± 2.1 $\mu\text{mol/L}$ vs. 10.4 ± 1.8 $\mu\text{mol/L}$, $p < 0.01$), improved lipid profiles (e.g., higher HDL, lower LDL and triglycerides), and better glycaemic control. These findings suggest that TRMF is a cost-effective, culturally acceptable, and sustainable dietary intervention to improve maternal nutritional status and reduce oxidative stress in resource-limited settings.

Keywords: Tocopherol-rich maize, Vitamin E, Pregnancy, Lactation, Antioxidant activity, Biofortification.

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1. Introduction

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The Good nutrition during pregnancy and lactation is crucial for fetal and maternal health, as well as long-term child outcomes. These stages impose greater physiological demands, requiring higher intakes of energy, macronutrients, and micronutrients. Insufficient intake can lead to complications such as intrauterine growth restriction, preterm birth, gestational metabolic disorders, and impaired immune development[1]. Micronutrient deficiencies, including iron, are common in LMICs like Pakistan, where cereal-based diets predominate and access to prenatal supplements is limited[2]. These deficiencies can contribute to cognitive impairments and increased susceptibility to infections. Vitamin E, a fat-soluble antioxidant, protects cellular membranes from oxidative damage [2]. It inhibits free radical release, regulates inflammation, and supports immune and neurological development. Pregnancy increases oxidative stress due to heightened placental and fetal metabolism, making adequate antioxidant intake essential[1]. However, dietary sources of vitamin E are often inadequate, and supplement-based interventions face challenges related to cost, accessibility, and adherence. Maize (*Zea mays* L.) is a staple food in South Asia, contributing significantly to daily energy intake. While conventional maize provides carbohydrates, fiber, and minerals, it is low in[3]. Advances in plant breeding have enabled the development of tocopherol-rich maize, offering a promising food-based alternative to synthetic supplements. Biofortified maize flour can be integrated into existing diets without altering cultural consumption patterns, enhancing acceptability and sustainability[3].

This study aimed to assess the effects of tocopherol-rich maize flour on nutrient composition, antioxidant potential, and selected biochemical indices in pregnant and lactating women. By examining food-level and physiological outcomes, it provides evidence for biofortified maize as a viable intervention to improve maternal nutrition in resource-constrained communities[1].

2. Materials and Methods

2.1 Study Design and Participants

A six-month, non-randomized comparative intervention study was conducted in rural areas of Multan, Pakistan. Participants were 300 pregnant (gestational age 12-28 weeks) and lactating women (postpartum <6 months), aged 18-35 years, with no known chronic diseases or allergies to maize. Exclusion criteria included severe anemia, multiple pregnancies, or use of vitamin E supplements. Participants were recruited via community health workers and provided written informed consent. The intervention group (n=200) received TRMF (300g/day, incorporated into daily meals like roti), while the control group (n=100) received equivalent conventional maize flour. Compliance was monitored via weekly self-reports and flour distribution logs. Baseline demographics were comparable (e.g., age: 25.4 ± 4.2 years intervention vs. 26.1 ± 3.9 years control). The study was approved by the Institutional Review Board of Bahauddin Zakariya University

2.2 Proximate Composition Analysis

Maize flour moisture, ash, crude fat, protein, and fibre were determined according to AOAC [4] Carbohydrate was determined by difference. All experiments were conducted in triplicate.

2.3 Mineral Analysis

Calcium, iron, zinc, and magnesium were determined after wet digestion by titrimetric or colorimetric methods (EDTA complexometric-titration, absorbance at specific wavelengths)[5]

2.4 Antioxidant Activity

Antioxidant activity was tested using DPPH free radical scavenging assay, Ferric Reducing Antioxidant Power (FRAP) assay, and Total Phenolic Content (TPC) determined according to the Folin–Ciocalteu method[6]

2.5 Biochemical Assessment

Fasting plasma α -tocopherol concentration, serum lipid profiles (triglycerides, HDL-C, LDL-C), and blood glucose levels were determined by standard enzymatic and spectrophotometric methods[4].

2.6 Statistical Analysis

Data are presented as mean \pm SD. Normality was checked via the Shapiro-Wilk test. Differences between groups (TRMF vs. Control) were assessed using independent samples t-tests for two-group comparisons (e.g., in proximate composition, minerals, antioxidants, and biochemical markers). For multivariate analyses such as principal component analysis (PCA), ANOVA followed by Tukey's HSD was used to explore variability across parameters where multiple subgroups or time points were considered. Effect sizes (Cohen's d) were calculated for key outcomes. Data were analyzed using SPSS v.25. Statistical significance was set at $p < 0.05$.

3. Results

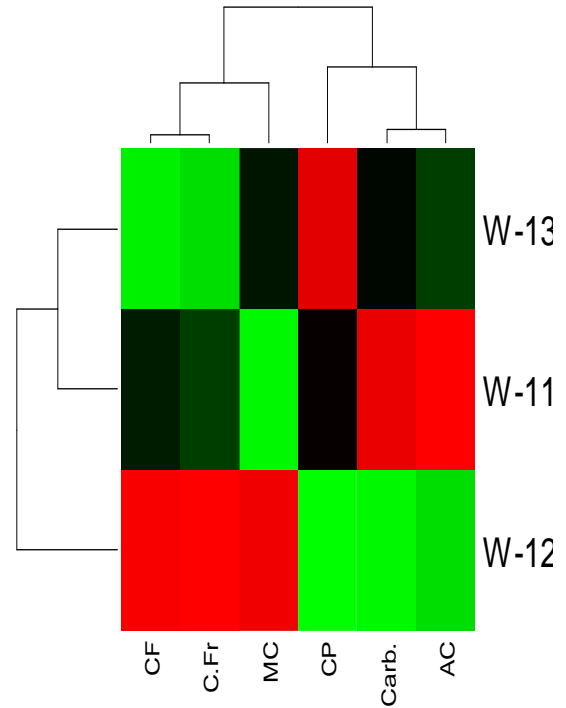
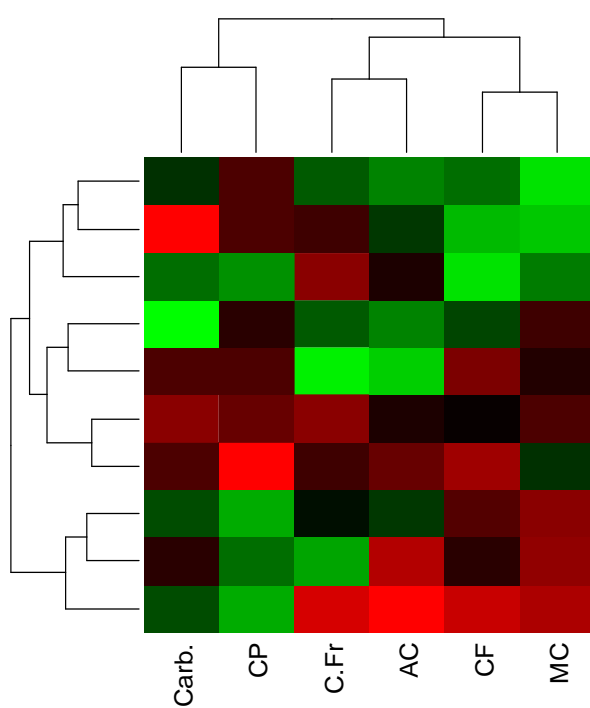
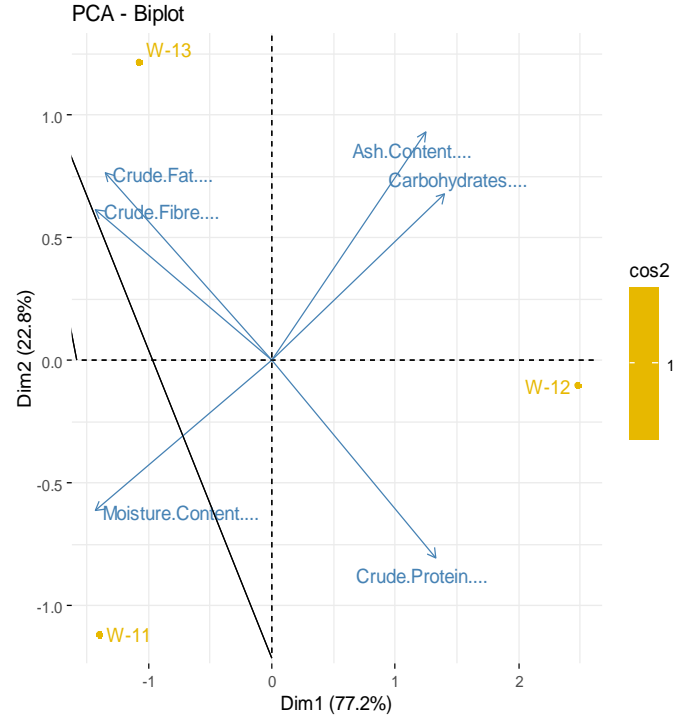
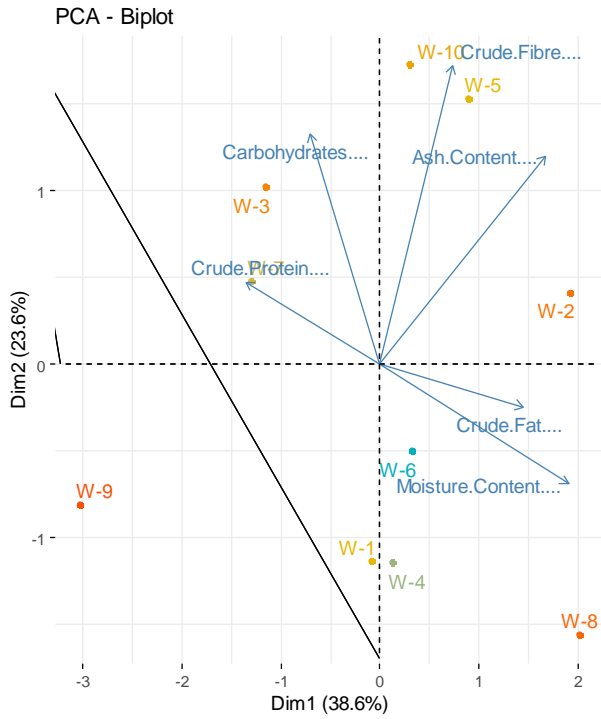
TRMF had higher protein, crude fat, and fibre content than conventional maize flour. Mineral analysis revealed higher calcium, iron, magnesium, and zinc content in the intervention group. Antioxidant tests demonstrated that the DPPH-free radical scavenging capacity, FRAP value, and total phenolic content of TRMF were significantly higher. Biochemical variables showed higher levels of plasma tocopherols, enhanced serum lipid profile, and reduced blood glucose concentration in women consuming TRMF compared to controls.

3.1 Proximate Composition

PCA revealed clear separation between groups along PC1 (explaining 38.6% variance), driven by higher protein, fat, fibre, and ash in TRMF. Heat map confirmed clustering with warmer intensities for these parameters in TRMF.

Table 1: Proximate Composition

PARAMETER	TRMF (MEAN ± SD)	CONTROL (MEAN ± SD)	P-VALUE
PROTEIN (G/100G)	12.5 ± 1.2	9.8 ± 0.9	<0.05
CRUDE FAT (G/100G)	4.8 ± 0.5	3.2 ± 0.4	<0.01
FIBER (G/100G)	3.1 ± 0.3	2.0 ± 0.2	<0.05
ASH (G/100G)	1.5 ± 0.2	1.2 ± 0.1	<0.05
CARBOHYDRATES (%)	75.2 ± 2.1	80.1 ± 1.8	<0.05

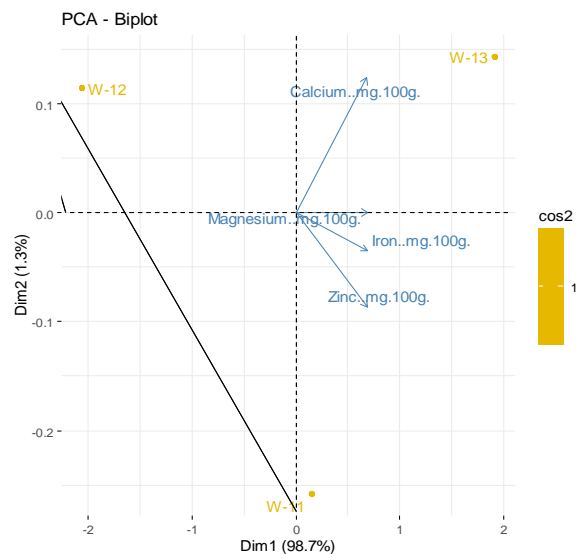
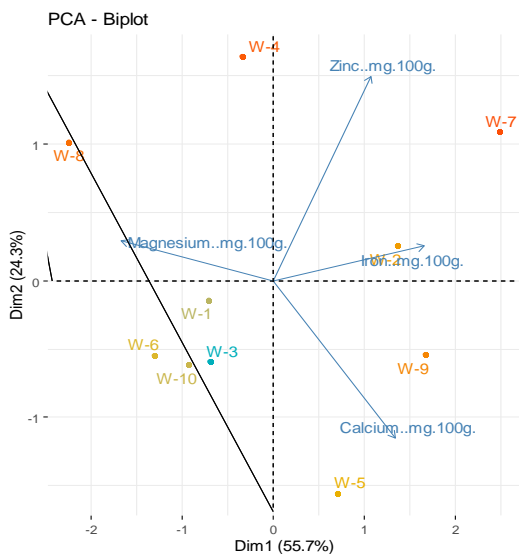


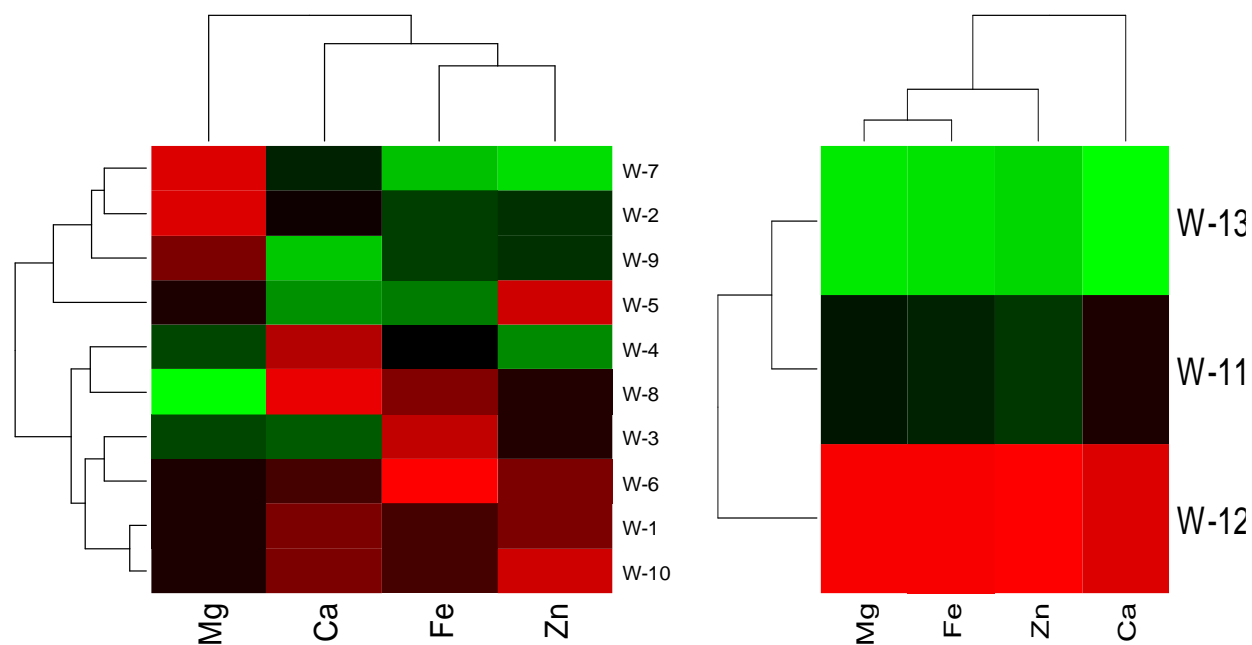
3.2 Mineral Analysis

PCA of mineral proportions indicated a clear distinction between the intervention and control groups along PC1, with calcium, iron, magnesium, and zinc contributing the most. Heat map exhibited distinct disparities in elemental contents.

Table 2: Mineral Content

PARAMETER	TRMF (MEAN ± SD)	CONTROL (MEAN ± SD)	P-VALUE
CALCIUM (MG/100G)	45 ± 5	25 ± 3	<0.05
IRON (MG/100G)	4.5 ± 0.5	2.0 ± 0.3	<0.05
MAGNESIUM (MG/100G)	150 ± 10	110 ± 8	<0.05
ZINC (MG/100G)	4.0 ± 0.4	2.0 ± 0.3	<0.05



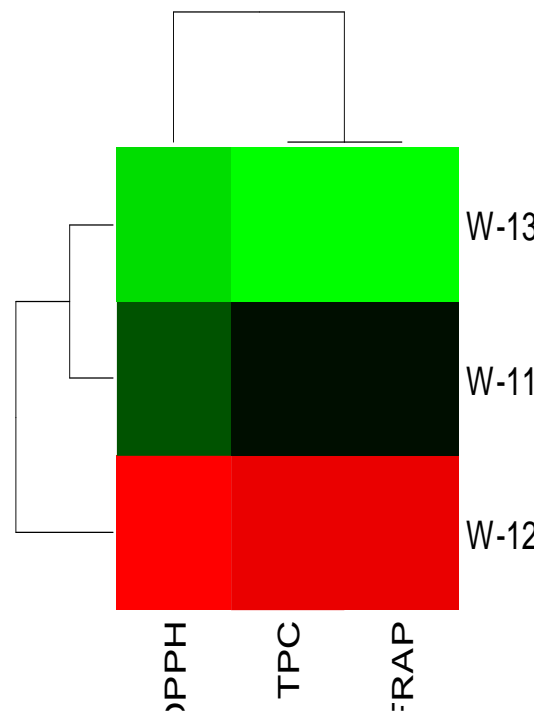
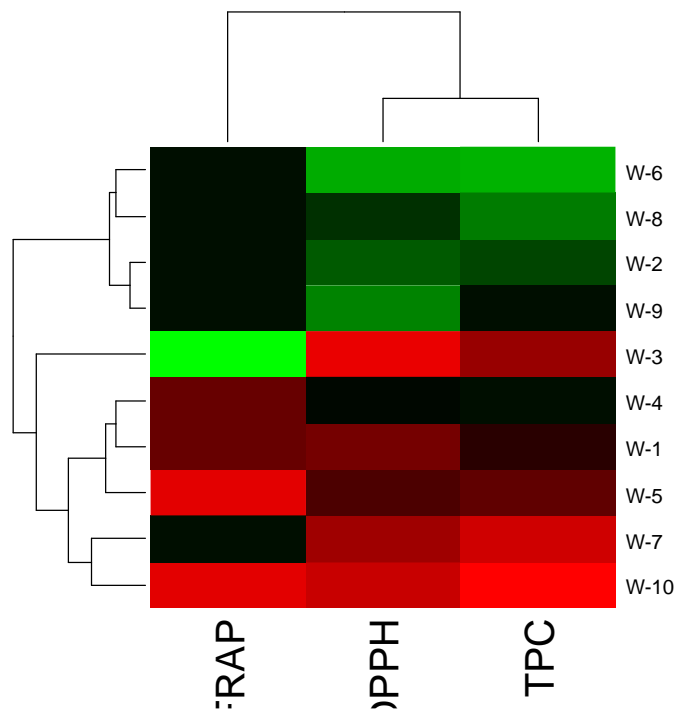
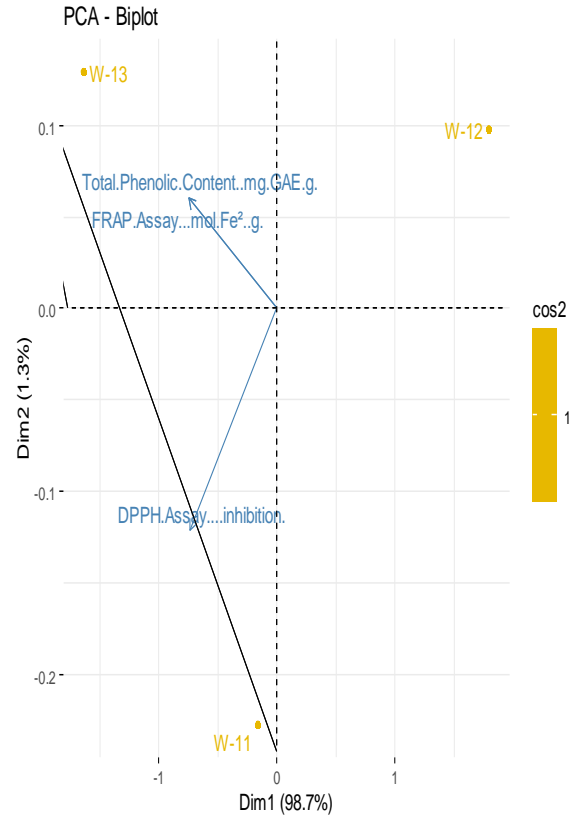
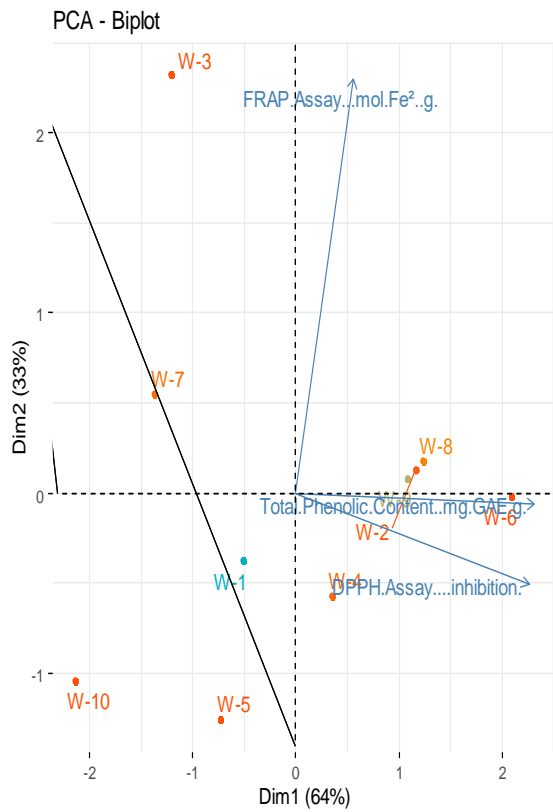


3.3 Antioxidant Potential

PCA of antioxidant processes disclosed that PC1 explained most of the variability and was positively related with all anti-oxidative indexes. Heat map showed significantly increased antioxidant activity in TRMF.

Table 3: Antioxidant Parameters

Parameter	TRMF (Mean \pm SD)	Control (Mean \pm SD)	p-value
DPPH (% inhibition)	80 \pm 5	50 \pm 4	<0.01
FRAP ($\mu\text{mol Fe}^{2+}/\text{g}$)	25 \pm 3	15 \pm 2	<0.01
TPC (mg GAE/g)	12 \pm 1	6 \pm 0.5	<0.01

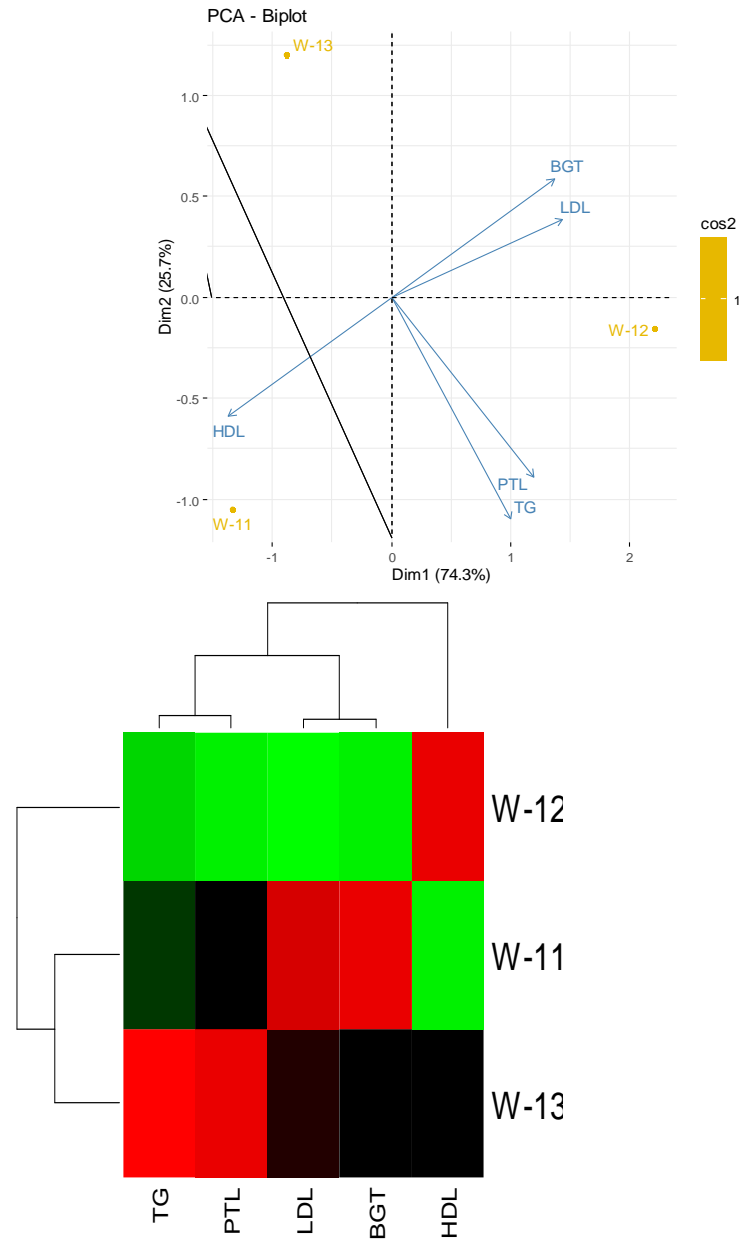
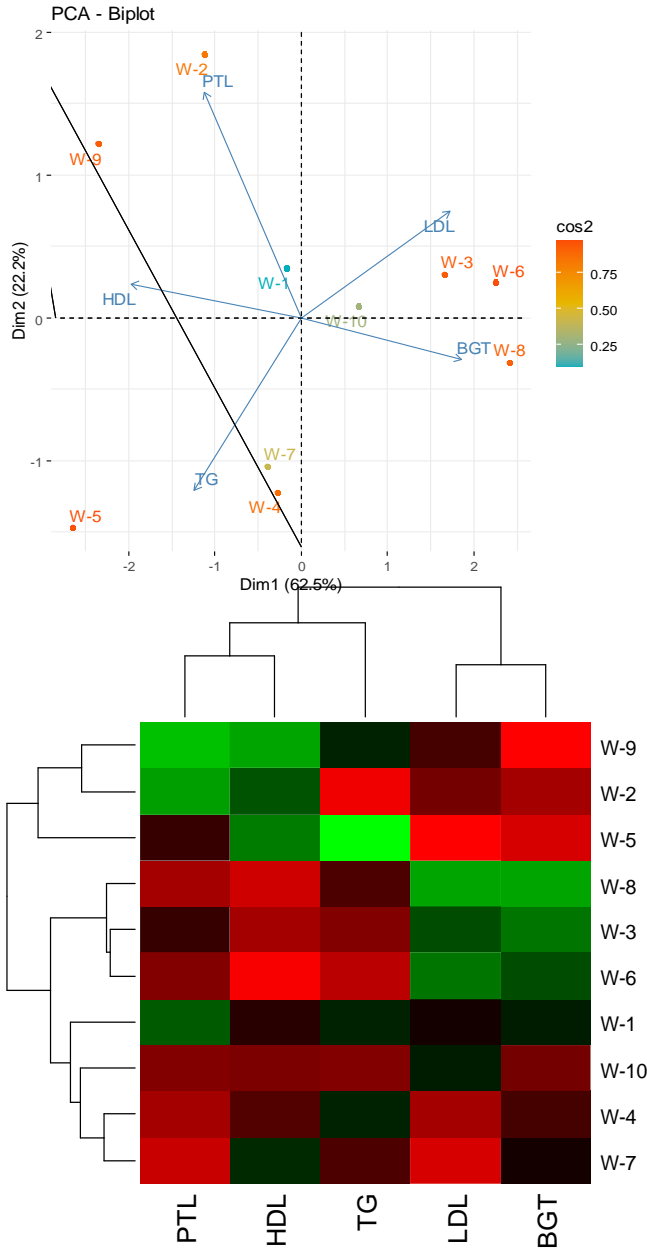


3.4 Biochemical Analysis

PCA of biochemical data revealed clear separation between groups. Heat map demonstrated greater intensity for plasma tocopherol and HDL in the intervention group.

Table 4: Biochemical Markers

PARAMETER	TRMF (MEAN \pm SD)	CONTROL (MEAN \pm SD)	P-VALUE
PLASMA TOCOPHEROL (μ MOL/L)	15.2 \pm 2.1	10.4 \pm 1.8	<0.01
TRIGLYCERIDES (MG/DL)	120 \pm 10	150 \pm 12	<0.05
HDL (MG/DL)	55 \pm 5	45 \pm 4	<0.05
LDL (MG/DL)	90 \pm 8	110 \pm 9	<0.05
BLOOD GLUCOSE (MG/DL)	85 \pm 5	95 \pm 6	<0.05



4. Discussion

This research demonstrates that TRMF may improve the nutritional, antioxidant, and biochemical status of pregnant and lactating women in resource-scarce areas. The enriched nutritional content, including higher protein, crude fat, fiber, and ash, highlights the potential of biofortification to increase macronutrient concentration[7]. Higher contents of calcium, iron, magnesium, and zinc in TRMF enhance mineral availability, essential for maternal health[8].

The antioxidant activity of TRMF was significantly greater, indicating that tocopherol-enriched maize boosts antioxidant capacity. Vitamin E ameliorates oxidative stress in pregnancy, as shown by its beneficial effects on oxidative status[9]. The combination of tocopherols and phenolics confers antioxidant defense[10].

Improved plasma tocopherol, HDL cholesterol, and glucose levels support the value of TRMF in maternal health. These results suggest that dietary vitamin E modifies lipid profiles and glucometabolic responses, potentially reducing complications like gestational diabetes[11]. Compared to other biofortified crops, TRMF shows significant enhancement of antioxidants, particularly beneficial for pregnant women[12]. Its integration into diets without changing cultural habits promotes sustainability[4].

Limitations include the non-randomized design, which may introduce selection bias and confounding factors, such as differences in baseline socioeconomic status or dietary habits between groups. Randomization was not feasible due to community-based logistics in rural Multan, where participants were recruited from clustered villages to facilitate flour distribution and monitoring, ensuring cultural acceptability and compliance. This approach, while practical, limits causal inference. Additional limitations include potential self-report bias in compliance monitoring and the short-term (six-month) follow-up, which does not capture long-term neonatal outcomes. Future studies should employ randomized controlled trials with larger samples and extended follow-up to assess infant health metrics, such as birth weight and cognitive development.

5. Conclusion

This study evaluated the influence of tocopherol-rich maize flour (TRMF) on maternal nutrition, antioxidant activity, and biochemical health in pregnant and lactating women. TRMF significantly improved proximate composition, mineral content, antioxidant assays, and biochemical markers. TRMF offers a practical intervention to combat micronutrient deficiencies and oxidative stress in pregnant and lactating women in LMICs.

6. Ethical Considerations

Informed written consent was obtained from all participants prior to participation. The study was approved by the Institutional Review Board of Bahauddin Zakariya University (Approval No. 4413E).

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