www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2023; 12(9): 830-834

www.thepharmajournal.com
Received: 03-06-2023
Accepted: 09-07-2023

Adire Chandrakanth
P.G. Scholar, Department of Livestock Production Management, College of Veterinary Science, Rajendranagar, Hyderabad, Telangana, India

Ch Harikrishna
Professor (LPM), Livestock Farm Complex, College of Veterinary Science, Rajendranagar, Hyderabad, Telangana, India

DBV Ramana
Principal Scientist, Livestock Production Management, ICAR-CRIDA, Santoshnagar, Hyderabad, Telangana, India

A Sarat Chandra
Professor (LPM) and Associate Dean, College of Dairy Technology, Kamareddy, Telangana, India

M Venkateswarlu
Professor and University Head, Department of Animal Nutrition, College of Veterinary Science, Korutla, Jagtial, Telangana, India

Corresponding Author:
Adire Chandrakanth
P.G. Scholar, Department of Livestock Production Management, College of Veterinary Science, Rajendranagar, Hyderabad, Telangana, India

Study on effect of elevated atmospheric temperature and carbon dioxide levels on chemical and minerals (Cu, Fe, Zn and Mn) composition of groundnut haulms

Adire Chandrakanth, Ch Harikrishna, DBV Ramana, A Sarat Chandra and M Venkateswarlu

Abstract
A study was conducted to assess the impact of elevated carbon dioxide and temperature levels on the quality of groundnut haulms used as livestock feed. Groundnut crop was grown with recommended package of practices in Carbon dioxide and Temperature Gradient Chamber (CTGC) at four different environmental conditions, *viz*: Chamber with ambient temperature and carbon dioxide with 27 ± 0.5 ºC temp and 380 ± 25 ppm CO_2 (T_1; control), Chamber with elevated temperature of 5 ± 0.5 °C higher than control (T_2; eTemp), Chamber with elevated CO_2 concentration of 550 ± 50 ppm (T_3; eCO_2) and Chamber with elevated CO_2 concentration of 550 ± 50 ppm with elevated temperature of 5 ± 0.5 °C, over control (T_4; eCO_2+eTemp). At harvest stage, representative groundnut plants from each chamber were collected and haulms were separated and screened for further laboratory analysis. Higher (P<0.01) dry matter, NDF, ADF, ADL per cent were found in haulms of groundnut crop grown under elevated temperature (T_2) environmental conditions, while organic matter, crude protein (CP) and ether extract contents were found highest (P<0.01) at the ambient (T_1; control) climatic conditions. Growing groundnut crop under eCO_2+eTemp (T_4) environmental conditions increased (P<0.01) ash, crude fibre, hemicellulose and NFE contents in haulms of the crop. Significantly (P<0.01) higher cellulose content was found in haulms of groundnut crop grown under T_3 chamber, whereas a non-significant increase in ADL was observed under T_2 chamber conditions. Haulms of the groundnut crop grown in different CTGC chambers differed significantly (P<0.01) in copper (Cu), iron (Fe) and zinc (Zn) content (mg/kg), while manganese (Mn) content was comparable. The study concludes that, elevated temperature could impact the nutritive value of haulms compared to the elevated carbon dioxide. The nutritive value in terms of CP would decrease under elevated temperature and elevated carbon dioxide conditions resulting in lowered quality. Under elevated temperature conditions the ADL and other fibre fractions are also increased leading to high lignification, making it less palatable. The study also revealed that, the minerals (Cu, Fe and Zn) concentration were relatively higher at eTemp and eCO_2 conditions except manganese (Mn), which is comparable among treatments.

Keywords: Carbon dioxide, chemical composition, environment, fibre fractions, groundnut haulms, minerals, temperature

1. Introduction
Climate change is one of the most critical threats facing the world today, with predicted increases in global mean temperature, length and severity of drought events, and atmospheric CO_2 concentration due to human activities. Greenhouse gases are the primary cause of rising temperatures in the atmosphere. The CO_2 level has risen at a pace of 1.9 ppm per year over the last twelve years and is expected to exceed 570 ppm by the middle of this century. As a result, the global surface temperature is expected to rise by 3-4.5˚C (IPCC, 2014) [11]. Many plants respond to elevated atmospheric carbon dioxide (eCO_2) concentrations by increased growth, biomass and productivity, with C_3 plants generally benefitting more than C_4 plants (Santos *et al*., 2014) [20]. There is growing evidence suggesting that many crops, notably C_3 crops, may respond positively to increased atmospheric CO_2 in the absence of other stressful conditions (Long *et al*., 2004) [13]. The dry matter production of C_3 and C_4 plants is likely to be increased by 30% and 10% respectively because of doubling effects of CO_2 (Newton, 1991) [16].
In C_3 plants like groundnut, the carbon from CO_2 is fixed into stable organic products in the mesophyll cells of leaves where, ribulose-1, 5-bisphosphate carboxylase/oxygenase (RuBisCo) enzyme is capable of catalysing two distinct reactions: one leading to the formation of two molecules of phosphoglycerate when CO_2 is the substrate; the other resulting in one molecule

each of phosphoglycerate and phosphoglycolate (2C molecule) when oxygen (O_2) is the substrate (Long *et al*., 2004) [13]. In general, C_3 plants are more responsive to elevated CO_2, which leads to greater main shoot length, elongation of branches, individual leaf area per plant, and dry mass. It is understood that the accumulation of sugars and starch in the leaves of elevated CO_2 grown plants reflects higher photosynthetic carbon assimilation (Cure and Acock, 1986) [4].

There is limited information available on the influence of rising CO_2 levels and temperatures on the quality of groundnut haulms. Hence, the present study was planned to determine the effects of elevated CO_2 and the temperature on the nutritional quality (proximate, fibre fractions and minerals composition) of groundnut haulms.

2. Materials and Methods

The study was conducted at Animal Science Laboratory, ICAR-CRIDA, Santoshnagar and Hayathnagar Research Farm, ICAR-CRIDA, Hayathnagar, Hyderabad. The groundnut (K6 variety) crop was grown with recommended package of practices in carbon dioxide and temperature gradient chambers (CTGC) at four differently set environmental conditions, *viz*: Chamber with ambient temperature and carbon dioxide with 27 ± 0.5 ºC temp and 380 ± 25 ppm CO_2 (T_1; control), Chamber with elevated temperature of 5 ± 0.5 °C higher than control (T_2; eTemp), Chamber with elevated CO_2 concentration of 550 ± 50 ppm (T_3; eCO_2) and Chamber with elevated CO_2 concentration of 550 ± 50 ppm with elevated temperature of 5 ± 0.5 °C, over control (T_4; eCO_2+eTemp).

At harvest stage, a bunch of plants from 4 corners and also from centre (5 samples (G1, G2, G3, G4 and G5) with 2 replicates each, totalling 10 samples) from each gradient chamber (T_1, T_2, T_3 and T_4) were collected and haulms were separated. Haulms were initially air dried and then oven dried at 60 ± 5 °C. Dried samples were ground to pass a 2 mm sieve in a Wiley mill. Further analysis of samples for organic matter (OM), crude protein (CP), ether extract (EE), fiber fractions and minerals were estimated in the animal nutrition laboratory at ICAR-CRIDA, Santoshnagar, Hyderabad.

2.1 Proximate Composition

The proximate analysis of groundnut haulms samples was performed as per the procedures described (AOAC, 1995) [3].

2.2 Fibre Fractions Analysis

Fiber fractions in groundnut haulms samples were performed as per the method described by Van Soest *et al*. (1995) [24].

2.3 Minerals Concentration

Minerals like Copper (Cu), Iron (Fe), Zinc (Zn) and Manganese (Mn) were estimated using di-acid digestion and Inductively Coupled Plasma-optical emission spectrometry (ICP-OES) method.

2.4 Statistical Analysis

Statistical analysis of the data was carried out using SPSS (Statistical Package for Social Sciences) Version 15. Least square analysis of variance was used to test the significance between various gradients according to the procedure described.

3. Results and Discussion

3.1 Proximate Composition

The results of the present study pertaining to proximate composition are presented in Table 1.

3.1.1 Dry Matter (DM)

The dry matter per cent in haulms of groundnut crop grown in carbon dioxide and temperature gradient chambers (CTGC) differed significantly (p<0.01). Significantly (P<0.01) higher DM content was found (Table 1) in haulms of groundnut crop grown under elevated temperature (T_2; eTemp) and elevated carbon dioxide and temperature (T_4; eTemp+eCO_2) treatments, which could be due to an increase in photosynthesis, carbohydrate fixation, respiration and transpiration in the plants (Rosenzweig *et al*., 1996) [19]. Increased photosynthesis and carbohydrate fixation results in increased plant biomass, growth rate and dry matter according to Xie *et al.* (2004) [25]. Increased respiration and transpiration would also increase total leaf area, which would increase water evaporation, decreases water content and so relatively increases plant DM content. The results of the present study are in agreement with those of Denium and Dirven (1974) [5], who reported higher DM accumulation in plants when temperatures were elevated. Similarly, He *et al.* (2015) [9] also reported higher (p<0.05) dry matter in wheat straw grown in elevated CO_2 (eCO_2), elevated temperature (eTemp) and a combination of eCO_2+eTemp conditions.

Table 1: Proximate composition (% DMB) in haulms of groundnut crop grown in CTGC under different environmental conditions

Treatments	Mean chemical composition of groundnut haulms# (on % DMB)						
	DM	**ASH**	**OM**	**CF**	**CP**	**EE**	**NFE**
T_1 (control)	84.99^{ab}	10.34^{a}	89.66^{c}	21.44^{a}	7.67^{c}	1.85^{d}	58.69^{NS}
T_2 (eTemp)	85.30^{b}	11.45^{b}	88.55^{b}	23.12^{c}	7.10^{a}	1.45^{a}	56.86^{NS}
T_3 (eCO_2)	84.55^{a}	11.36^{b}	88.64^{b}	22.65^{b}	7.37^{b}	1.56^{b}	56.70^{NS}
T_4 (eCO_2+eTemp)	85.10^{ab}	12.21^{c}	87.79^{a}	23.79^{d}	7.14^{a}	1.69^{c}	61.24^{NS}
Overall Mean	84.99	11.34	88.66	22.75	7.32	1.64	58.37
N	40	40	40	40	40	40	40
CV	0.782	1.223	0.156	0.790	1.892	1.195	5.556
LSD	0.696	0.145	0.145	0.188	0.144	0.024	3.362

abcMeans in rows with different superscripts differ significantly (p<0.01)

#Each value is an average of duplicate analysis, N - Number of samples,

CV - Coefficient of variation, LSD - Least significance difference

3.1.2 Total Ash

The data presented in Table 1, showing that the ash content in haulms of groundnut crop varied significantly (p<0.01) across CTGC chambers. Significantly (p<0.01) higher ash content was found in haulms of groundnut crop grown under T_4 (eTemp+eCO_2) and T_2 (eTemp) treatment chambers. This may be caused by a fixation of higher carbon to nitrogen ratio, more carbon through increased photosynthetic activity and increased mineral deposition, like calcium and magnesium (Meena *et al*., 2017) [14]. Katyaayani *et al.* (2022) [12] also observed similar results of ash content in the stem portion of maize fodder grown in the CTGC chamber under different environmental conditions. Similar results were also observed in the maize genotypes of DHM117, Harsha and Varun by Shankar *et al.* (2015) [22]. On contrary, He *et al.* (2015) [9]

reported, significant decrease in wheat straw's ash content at higher temperatures. The variations across studies might be due to the fact that the ash content varies depending on the plant species (C_3 or C_4).

3.1.3 Organic Matter (OM)
The percentage of organic matter in haulms of groundnut crop grown in CTGC chambers differed significantly ($p<0.01$). The perusal of Table 1, showing that, significantly ($p<0.01$) higher OM content in haulms of groundnut crop grown under T_1 chamber under ambient climate conditions. Katyaayani *et al*. (2022) [12] also observed similar results in the stem portion of maize fodder grown in the CTGC chamber under different environmental conditions. On contrary, Abdalla *et al*. (2019) [1] reported, the whole forage, leaf, and stem of the grass (*Brachiaria decumbens*) was unaffected under higher levels of CO_2.

3.1.4 Crude fibre (CF)
The data presented in Table 1, showing that the crude fibre content in haulms of groundnut crop varied significantly ($P<0.01$) across CTGC chambers. Significantly ($p<0.01$) higher crude fibre content was found in haulms of groundnut crop grown under T_4 (eTemp+eCO_2) and T_2 (eTemp) treatments, which could be due to increased structural carbohydrates as well as increased lignification. Katyaayani *et al*. (2022) [12] observed similar results in the leaf portion of maize fodder grown in the CTGC chamber under different environmental conditions. This study contrasts the results of Hogy *et al*. (2013), who claimed that warming had no effect on the concentration and yield of a C_3 crop (barley).

3.1.5 Crude Protein (CP)
The crude protein (%) in haulms of groundnut crop grown in different CTGC chambers differed significantly ($P<0.01$). Significantly ($P<0.01$) lesser crude protein content was found in haulms of groundnut crop grown under T_2 and T_4 climatic conditions (Table 1). Katyaayani *et al*. (2022) [12] observed similar results in the leaf portion of maize fodder grown in the CTGC chamber under different environmental conditions. The significant decrease in protein content under eTemp and eCO_2+eTemp conditions has been attributed to a dilution effect caused by an increase in total non-structural carbohydrates, rather than an absolute decrease in protein content in stems and leaves (Dumont *et al*., 2014) [6]. The decrease in CP under elevated CO_2 and eTemp treatments, both individually and in combination, is consistent with previous research (Fernando *et al*., 2012; Goufo *et al*., 2014; He *et al*., 2015 and Santosh *et al*., 2018) [7, 8, 9, 21].

3.1.6 Ether Extract (EE)
The data presented in Table 1, showing that the ether extract content in haulms of groundnut crop varied significantly ($p<0.01$) across CTGC chambers. Significantly ($p<0.01$) lower EE content was found in haulms of groundnut crop grown under T_2 (eTemp) chamber conditions. Katyaayani *et al*. (2022) [12] observed similar results in the leaf portion of maize fodder grown in the CTGC chamber under different environmental conditions. Little is known about the impact of high temperatures on the content and distribution of EE in plants. It could be due to an increase in photosynthesis, according to Tao *et al*. (2006) [23]. The findings of the present study are in contrary to the reports of He *et al*. (2015) [9], who found that the EE content of wheat straw was significantly higher under eTemp and eCO_2+eTemp climatic conditions.

3.1.7 Nitrogen Free Extract (NFE)
The percentage of nitrogen free extract (Table 1) was relatively higher in haulms of groundnut crop grown under T_4 (eCO_2+eTemp) chamber, however the differences were non-significant. Lower NFE content was found in haulms of the groundnut crop grown under eCO_2 treatment (T_3). Katyaayani *et al*. (2022) [12] observed contrary results in the stem portion of maize fodder grown in the CTGC chamber under different environmental conditions, where higher NFE content was found in eCO_2 and lower NFE content in eCO_2+eTemp treatments. The percentage of nitrogen free extract depends on the percentage of ash, CP, CF, and EE contents, the greater these contents, the lower is the NFE.

3.2 Fibre Fractions
The results of the present study pertaining to fibre fraction analysis are presented in Table 2.

3.2.1 Neutral Detergent Fibre (NDF)
The data presented in Table 2, revealed that the neutral detergent fibre content in groundnut crop haulms varied significantly ($p<0.01$) across CTGC chambers. Significantly ($p<0.01$) higher NDF content was found in groundnut crop haulms grown under eTemp (T_2) and eCO_2+eTemp (T_4) chamber conditions. It could be due to increase in structural carbohydrate as well as increased lignification and temperature enhances plant growth, decreases leaf-to-stem ratios and increases NDF, ADF and lignin content. Furthermore, early leaf maturation at high temperature, as well as interference with nutrient and water relations and assimilate partitioning, may also affect NDF content. The results of the present study corroborating the findings of Katyaayani *et al.* (2022) [12], who also observed higher NDF ($P<0.05$) content in leaf and stem portion of maize fodder grown under eTemp and eCO_2+eTemp chamber conditions. Newman *et al.* (2005) [15] found similar results in rhizome peanut herbage grown under combination of two treatments (eCO_2+eTemp) and He *et al.* (2015) [9] observed increased NDF in wheat straw grown under elevated temperature (eTemp), elevated carbon dioxide (eCO_2) and a combination of two treatments (eCO_2+eTemp).

Table 2: Fibre fractions (% DMB) in groundnut crop haulms grown in CTGC under different environmental conditions

Treatments	Mean fibre fractions of groundnut haulms# (on % DMB)				
	NDF	**ADF**	**Hemi-cellulose**	**Cellulose**	**ADL**
T_1 (control)	57.37^a	34.79^a	22.57^a	20.36^a	3.48^a
T_2 (eTemp)	62.25^d	37.30^d	24.95^c	23.65^b	3.75^b
T_3 (eCO_2)	60.24^b	36.66^c	23.57^b	24.72^d	3.66^b
T_4 (eCO_2+eTemp)	61.81^c	35.64^b	26.17^d	24.35^c	3.66^b
Overall Mean	60.42	36.10	24.32	23.27	3.64
N	40	40	40	40	40
CV	0.283	0.533	1.048	0.648	4.741
LSD	0.179	0.201	0.266	0.157	0.180

^{abc}Means in rows with different superscripts differ significantly ($P<0.01$)

#Each value is an average of duplicate analysis, N - Number of samples,

CV - Coefficient of variation, LSD - Least significance difference

3.2.2 Acid Detergent Fibre (ADF)
The acid detergent fibre content (Table 2) in haulms of groundnut crop varied significantly ($p<0.01$) across CTGC chambers. Significantly ($p<0.01$) higher ADF content was found in groundnut crop haulms grown under T_2 (eTemp) and T_3 (eCO_2) chamber conditions, which could be due to an increase in structural carbohydrate as well as increased lignification. Temperature also enhances plant growth, decreases leaf-to-stem ratios and increases NDF, ADF and lignin content. Furthermore, early leaf maturation at high temperature, as well as interference with nutrient and water relations and assimilate partitioning, may affect ADF content. Similarly, Katyaayani *et al.* (2022) [12] observed higher ADF ($P<0.05$) content in leaf and stem portion of maize fodder grown under eTemp and eCO_2+eTemp chamber conditions. Newman *et al*. (2005) [15] also found similar results in rhizome peanut herbage grown under combination of two treatments (eCO_2+eTemp) and He *et al.* (2015) [9] also observed increased ADF in wheat straw grown under eTemp, eCO_2 and a combination of two treatments (eCO_2+eTemp).

3.2.3 Hemicellulose
The hemicellulose content of groundnut haulms varied significantly ($P<0.01$) between CTGC chambers (Table 2). Significantly ($P<0.01$) higher hemicellulose content was found in haulms of groundnut crop grown under eCO_2+eTemp chamber conditions, which could be due to an increase in structural carbohydrate as well as increased lignification. Temperature also enhances plant growth, decreases leaf-to-stem ratios, and increases NDF, ADF and lignin content. Similar to the present study, Katyaayani *et al.* (2022) [12] also observed higher hemicellulose ($p<0.05$) content in leaf and stem portion of maize fodder grown under eCO_2+eTemp climate conditions.

3.2.4 Cellulose
The data presented in Table 2, showing that the percentage of cellulose in haulms of groundnut crop grown in CTGC chambers differed significantly ($P<0.01$). Significantly ($P<0.01$) higher cellulose content was found in haulms of groundnut crop grown under T_3 and T_4 chamber conditions. In general, a rise in temperature increases concentration of structural carbohydrates. The results of the present study contradict the findings reported by Porteaus *et al*. (2009) [18], who reported that the cellulose content was unaffected under elevated CO_2 conditions.

3.2.5 Acid Detergent Lignin (ADL)
The acid detergent lignin content (Table 2) in haulms of groundnut crop varied significantly ($P<0.01$) across CTGC chambers. Significantly ($P<0.01$) higher ADL content was found in haulms of groundnut crop grown under T_2 and T_4 chamber conditions, which could be due to an increase in structural carbohydrate as well as increased lignification. Similarly, Katyaayani *et al.* (2022) [12] also observed higher ADL ($P<0.05$) content in leaf and stem portion of maize fodder grown under eTemp and eCO_2+eTemp chamber conditions. Newman *et al*. (2005) [15] found similar results in rhizome peanut herbage grown under combination of two treatments (eCO_2+eTemp) and He *et al.* (2015) [9] observed increased ADL in wheat straw grown under elevated temperature and carbon dioxide conditions. Temperature enhances plant growth, decreases leaf-to-stem ratios, and increases NDF, ADF and lignin content. Furthermore, early leaf maturation at high temperature as well as interference with nutrient and water relations and assimilate partitioning may affect ADL content.

3.3 Minerals concentration
The data pertaining to minerals composition are presented in Table 3. Statistical analysis revealed that, the minerals content (copper (Cu), iron (Fe) and zinc (Zn)) in haulms of groundnut crop varied significantly ($P<0.01$) between CTGC chambers, however manganese (Mn) content in haulms was comparable among different environmental chambers.

Table 3: Minerals composition (mg/kg) in groundnut crop haulms grown in CTGC under different environmental conditions

Treatments	Mean minerals concentration of groundnut haulms# (mg/kg)			
	Cu	**Fe**	**Zn**	**Mn**
T_1 (control)	6.30^{ab}	598.40^{a}	19.00^{a}	28.90^{NS}
T_2 (eTemp)	7.90^{c}	817.30^{c}	31.20^{c}	28.90^{NS}
T_3 (eCO_2)	6.50^{b}	736.40^{b}	24.20^{b}	30.40^{NS}
T_4 (eCO_2+eTemp)	5.90^{a}	697.30^{b}	20.30^{a}	28.80^{NS}
Overall Mean	6.70	712.40	23.60	29.30
N	40	40	40	40
CV	7.643	7.847	7.232	6.521
LSD	0.533	58.504	1.789	1.996

abcMeans in rows with different superscripts differ significantly ($P<0.01$)
#Each value is an average of duplicate analysis, N - Number of samples,
CV - Coefficient of variation, LSD - Least significance difference

The study shown that, most of the minerals concentration were relatively higher at eTemp and eCO_2 conditions. The present findings are in contradiction with Abdalla *et al*. (2019) [1], who reported, elevated CO_2 had no effect on minerals concentrations except calcium. Our results are also not in line with the reports of Overdieck (1993) [17], McGrath (2010) [2] and Fernando *et al*. (2012) [7], who reported a lower iron and zinc concentration under elevated CO_2 conditions than ambient conditions.

5. Conclusions
The chemical composition of haulms of groundnut crop grown in CTGC chambers indicated that elevated temperature could impact the nutritive value of haulms compared to the elevated carbon dioxide. The nutritive value of haulms of groundnut crop in terms of CP would decrease under elevated temperature and elevated carbon dioxide conditions resulting in lowered quality. Under elevated temperature conditions the ADL and other fibre fractions percentage is also increased leading to high lignification, making it less palatable. The study also revealed that, the minerals (Cu, Fe and Zn) concentration were relatively higher at eTemp and eCO_2 conditions except manganese (Mn), which is comparable among treatments.

6. References

1. Abdalla Filho AL, Junior GTC, Lima PM, Soltangheisi A, Abdalla AL, Ghini R, *et al*. Fiber fractions, multielemental and isotopic composition of a tropical C_4 grass grown under elevated atmospheric carbon dioxide. Peer Journal. 2019l;7:e5932.

2. Ainsworth EA, McGrath JM. Direct effects of rising atmospheric carbon dioxide and ozone on crop yields. In Climate Change and Food Security. Springer Dordrecht; c2010. p. 109-130.
3. AOAC. Official Methods of Analysis. 16th edn. Association of official analytical chemists, Washington DC, USA; c1995.
4. Cure JD, Acock B. Crop response to Carbon Dioxide Doubling: A Literature Survey. Agricultural and Forest Meteorology. 1986;38:127-145.
5. Deinum B, Dirven JGP. Climate, nitrogen and grass. Comparison of yield and chemical composition of some temperate and tropical grass species grown at different temperatures. Netherlands Journal of Agricultural Science. 1974;23:69-82.
6. Dumont B, Urra DA, Niderkorn V, Lüscher A, Porqueddu C, Picon-Cochard C. Effects of climate change on forage quality of grasslands and their use by grazing animals. Hal Archives- 01611403; c2014.
7. Fernando N, Panozzo J, Tausz M, Norton R, Fitzgerald G, Seneweera S. Rising atmospheric CO_2 concentration affects mineral nutrient and protein concentration of wheat grain. Food Chemistry. 2012;133(4):1307-1311.
8. Goufo P, Ferreira LM, Carranca C, Rosa EA, Trindade H. Effect of elevated carbon dioxide concentration on rice quality: Proximate composition, dietary fibers, and free sugars. Cereal Chemistry. 2014;91(3):293-299.
9. He X, Wu Y, Cai M, Mu C, Luo W, Cheng Y, *et al*. The effect of increased atmospheric temperature and CO_2 concentration during crop growth on the chemical composition and *in vitro* rumen fermentation characteristics of wheat straw. Journal of Animal Science and Biotechnology. 2015;6(1):1-8.
10. Hogy P, Poll C, Marhan S, Kandeler E, Fangmeier A. Impacts of temperature increase and change in precipitation pattern on crop yield and yield quality of barley. Food chemistry. 2013;136(3-4):1470-1477.
11. IPCC. Climate Change: Synthesis Report. Contribution of working groups I. II and III to the Fifth Assessment Report. In Proceedings of the Intergovernmental Panel on Climate Change, Copenhagen, Denmark; c2014 Nov 1. p. 1-167.
12. Katyaayani S, Chandra AS, Ramana DBV, Prasad RMV, Sreenivas D. A study to predict impact of atmospheric temperature and carbon dioxide increase on proximate, fibre fractions and mineral (Cu, Fe, Zn, Mn) composition of maize fodder. The Pharma Innovation Journal. 2022;11(8):977-981.
13. Long SP, Ainsworth EA, Rogers A, Ort DR. Rising atmospheric carbon dioxide: Plants FACE the future. Annual Review of Plant Biology. 2004;55:591-628.
14. Meena K, Verma SC, Bhardwaj SK. Impact of elevated CO_2 and temperature on quality and biochemical parameters of pea (*Pisum sativum*). Indian Journal of Agricultural Sciences. 2017;87(8):1035-1040.
15. Newman YC, Sollenberger LE, Boote KJ, Allen Jr LH, Vu JCV, Hall MB. Temperature and carbon dioxide effects on nutritive value of rhizoma peanut herbage. Crop science. 2005;45(1):316-321.
16. Newton PCD. Direct effects of increasing carbon dioxide on pasture plants and communities. New Zealand Journal of Agricultural Research. 1991;34(1):1-24.
17. Overdieck D. Elevated CO_2 and the mineral content of herbaceous and woody plants. Vegetatio. 1993;104(1):403-411.
18. Porteaus F, Hill J, Ball AS, Pinter PJ, Kimball BA, Wall GW, *et al*. Effect of Free Air Carbon dioxide Enrichment (FACE) on the chemical composition and nutritive value of wheat grain and straw. Animal Feed Science and Technology. 2009;149(3-4):322-332.
19. Rosenzweig C, Tubiello FN. Effects of changes in minimum and maximum temperature on wheat yields in the central US A simulation study. Agricultural and Forest Meteorology. 1996;80(2-4):215-230.
20. Santos RM, Voltolini TV, Angelotti F, Aidar SDT, Chaves ARDM. Productive and morphogenetic responses of buffel grass at different air temperatures and CO_2 concentrations. Brazilian Journal of Animal Science. 2014;43:404-409.
21. Santosh J, Shanwad UK, Umesh MR, Mallikarjun K, Halepyati AS, Shankergoud I. Impact of climate change on nutritional quality of maize and groundnut genotypes. Journal of Farm Sciences. 2018;31(3):271-274.
22. Shankar SK, Vanaja M, Lakshmi JN. Impact of elevated atmospheric CO_2 concentration on nutrient quality of different maize genotypes. Journal of Agrometeorology. 2015;17(1):124-126.
23. Tao F, Yokozawa M, Xu Y, Hayashi Y, Zhang Z. Climate changes and trends in phenology and yields of field crops in China. Agricultural and Forest Meteorology. 2006;138(1-4):82-92.
24. Van Soest PV, Robertson JB, Lewis BA. Methods for dietary fiber, neutral detergent fiber, and non starch polysaccharides in relation to animal nutrition. Journal of Dairy Science. 1995;74(10):3583-3597.
25. Xie Z, Zhu J, Pan H, Ma H, Liu G, Georg C, *et al*. Stimulated rice growth and decreased straw quality under free air CO_2 enrichment (FACE). The Proceedings of the China Association for Science and Technology. NewYork: Science Press Beijing; c2004. p. 640-645.