SUMMARY AND CONCLUSION

The study entitled “Designing of complementary food mixes based on sorghum (Sorghum bicolor, L. Moench)” was planned with the objectives to design complementary food mixes based on sorghum using different processing methods and to evaluate the organoleptic properties, nutritional parameters, physico-chemical properties as well as shelf-life. The present study was conducted in three phases.

In the first phase, white sorghum variety CSV-23 was collected from Rajasthan College of Agriculture, MPUAT, Udaipur. For selection of the processing method which has maximum effect on reducing anti-nutrients and increasing in-vitro protein digestibility of the sorghum, the grains were subjected to different processing treatments viz. roasting, popping, germination & drying and malting & drying. The processed and raw untreated sorghum grains were ground to obtain flours. Nutritional analysis for proximate composition, anti-nutrients and in-vitro protein digestibility was carried out by using standard procedures on dry weight basis.

The findings revealed that moisture content of raw untreated and processed sorghum flours ranged from 9.81±0.37g/100g to 2.34±0.09g/100g. Highest protein content was found in malted & dried sorghum flour, i.e. 9.59±0.43g/100g. Low value of crude fat content was recorded in malted sample and highest was in raw, unprocessed sorghum flour. Crude ash was recorded maximum in popped sorghum flour. Highest crude fibre was found in malted & dried sample while the lowest was found in popped sorghum flour. Carbohydrate and energy were the highest in popped sample. Significant differences were observed between the proximate composition of raw untreated and processed sorghum flours.

Regarding anti-nutrients and in-vitro protein digestibility, maximum decrease up to 56.52% in tannin content was observed in malted & dried samples (0.61±0.05mg/100g) as compared to raw untreated (1.38±0.05mg/100g); 6.52 % in roasted (1.29±0.08mg/100g); 29.71% in popped (0.97±0.11mg/100g) and 44.20% in germinated & dried (0.77±0.05mg/100g) sorghum flours. The values for phytic acid content of the raw and processed sorghum flours showed that raw unprocessed
sorghum flour contained 362.65±0.60mg/100g. On processing, phytic acid content decreased significantly up to 13.62% in roasted; 19.55% in popped; 48.04% in germinated & dried and 59.29% in malted & dried sorghum flour. It is evident from the results that significantly higher *in-vitro* protein digestibility was recorded in malted & dried samples (96.18±0.63 per cent). Thus, malted & dried sorghum flour was selected for the formulation of complementary food mixes.

The second phase comprises of formulation of complementary food mixes. Regarding other ingredients used for the formulation of complementary food mixes, in the present study, whole green gram, chickpea (desi), rice flakes, barnyard millet, whole milk powder, sugar and pumpkin were procured from local market of Udaipur. Whole green gram and chickpea were also malted and rice flakes and barnyard millet were roasted and were pulverized. Total 20 combinations were tried out, out of which, four combinations of complementary food mixes were selected on the basis of organoleptic acceptability, for further evaluation.

The cost of the formulated mixes ranged from Rs. 6.88 to 8.65 per serving of complementary food mixes. The amount per serving of the formulated complementary food mixes was calculated such that each gram of the mix provides one kcal, which was 35g in the present study.

Phase three included the quality evaluation of the formulated complementary food mixes. The four combinations selected, were prepared in bulk, packed in HDPE pouches and labeled as R1 (MSF:MCF:RF:MP:S-30:20:10:30:10), R2 (MSF:MGF:RF:PF:MP:S-25:10:5:20:30:10), R3 (MSF:MGF:BMF:PF:MP:S-25:10:5:20:30:10) and R4 (MSF:MCF:BMF:PF:MP:S-25:10:5:20:30:10). They were stored at ambient temperature for a period of three months. The formulated mixes were subjected to nutrient analysis viz., proximate composition, mineral and vitamin estimation and anti-nutrients & *in-vitro* protein digestibility; physico-chemical and tests for storage stability in terms of organoleptic evaluation, peroxide value, free fatty acid and microbial examination.

Nutrient analysis was done at zero and ninety days and evaluation of storage stability was carried out at 0, 30, 60 and 90 days interval.
The moisture content of formulated complementary food mixes were recorded as 2.21±0.55g/100g (R1); 2.32±0.52g/100g (R2); 2.98±0.61g/100g (R3) and 3.16±0.23g/100g (R4). Protein content of the formulated mixes range from 11.95±1.82 to 14.0±0.01g/100g. The amount of crude fat was highest in R1, i.e. 3.74±0.15g, followed by R2 (2.82±0.41), R3 (2.85±0.33) and R4 (2.34±0.25). Total ash was found highest in R3 (3.25±0.11) while crude fibre content of R4 (0.47±0.01) was maximum. R3 had the highest value for carbohydrate 78.49±1.64g/100g, while in terms of energy; maximum value was recorded in R1, i.e. 401.03±0.06kcal/100g, on dry weight basis.

Regarding the presence of anti-nutrients, values for both tannin and phytate were recorded least in R1, i.e. 0.36±0.03mg/100g and 56.0±0.02 mg/100g, respectively. Complementary food mix R4 had the highest in-vitro protein digestibility (78.49±0.05%) followed by R3 (71.01±0.05%); R1 (67.97±0.08%) and R2 (65.94±0.09%).

Minerals viz. iron, calcium, magnesium and zinc were also analyzed. Values for iron ranged between 1.49±0.01mg/100g to 2.97±0.02 mg/100g. Calcium was found to be the highest in R3, i.e. 39.54±0.02mg/100g and magnesium was highest in R4 (13.18±0.02mg/100g). Zinc content of the formulated mixes was 1.50±0.01 mg/100g in R1; 1.73±0.01 mg/100g in R2; 1.18±0.01 mg/100g in R3 and 1.91±0.01 mg/100g in R4, on dry weight basis. Regarding vitamins, it was found that beta-carotene was below traceable limits in R1 while ascorbic acid was lowest in R2 complementary food mix. Highest amount of beta carotene was recorded in R2 and ascorbic acid was found maximum in R3.

All four complementary food mixes were well accepted in terms of organoleptic attributes. The overall acceptability scores were in the range of 8.23±0.04 to 8.71±0.05, i.e. they were “liked very much” by the panel members.

Regarding physico-chemical properties, lowest bulk density (0.64±0.04g/ml); water absorption capacity (166.26±0.77%); swelling index (1.38±0.01); viscosity (9.82±0.25 cps) and wettability (14.73±0.15 sec.), were recorded in formulated mix R1. On the other hand, lowest water solubility index was found in R3 (44.91±0.42).
Shelf-life of the formulated complementary food mixes, stored at ambient temperature for three months, was analyzed in the third phase of the present study. Nutritional assessment of the formulated mixes carried out at zero and ninety days of the storage duration, revealed that there was a significant increase in the moisture content of the complementary food mixes while energy of the mixes significantly decreased. Crude protein, crude fat, total ash, crude fibre and carbohydrate showed a non-significant decrease over storage period. There was a significant decrease in mineral content (Iron, Magnesium and Zinc) of the formulated complementary food mixes except Calcium, which showed a significant increase in the values over 90 days storage period.

Values of beta-carotene and ascorbic acid significantly decreased during 90 days storage. Regarding anti-nutrients in formulated mixes, tannin showed a non-significant variation over the storage period while phytic acid decreased significantly. The in-vitro protein digestibility of the mixes also showed a decreasing trend during storage interval.

The storage stability was assessed by evaluating organoleptic attributes, peroxide value and free fatty acid and microbial status in the complementary food mixes at monthly intervals up to 90 days. The overall acceptability of the complementary food mixes decreased over the storage period. The scores remained in the range of being “liked very much” only for R1, while scores decreased to “liked moderately” category after ninety days interval for R2, R3 and R4. Initially, up to 60 days peroxide value was not detected while at 90 days it was recorded in the range of 0.54±0.02 to 0.87±0.02 meq/kg. The free fatty acids followed an increasing trend across the entire storage period of 90 days. The results of microbiological examination revealed that bacterial count was lower than the limit of $10^5$ for flours in the formulated mixes over the entire storage period. Regarding yeast and mold count, <10 cfu/g was recorded for all the samples during the storage period.

Thus, on the basis of above results, it can be concluded that the complementary food mixes formulated in the present study, using malted sorghum flour were cost-effective and nutritionally sound for consumption by infant of weaning age to fulfill his/her nutritional requirements. All the four formulated
complementary food mixes have superior nutritional values and were well accepted organoleptically over three months storage period. Although peroxide value, free fatty acids and bacterial count were detected in the formulated mixes at 90 days interval, but the values were far below the limits making them safe for consumption. So it is apparent that the mixes could be stored up to three months at ambient temperature and are safe for feeding a child of weaning age.

The amount of complementary food mix recommended for one feed is calculated to be 35g based on the energy density. All the four complementary food mixes are recommended as complementary food for weaning children from 6-24 months age, increasing the frequency of feed depending on the age.

**Recommendations**-

- Complementary food mixes from fermented sorghum and pulse blend may be developed and analyzed for storage stability.
- Since sorghum is a gluten-free grain, the complementary food mixes formulated in the study can be recommended to children suffering from celiac disease.
- Also studies on development of complementary foods based on sorghum for malnourished children and elderly can also be carried out.
- The complementary food mixes formulated in this study, can be recommended to ICDS services, to be distributed to the mothers of weaning children, to assure proper development of the child.
- From commercial point of view, effect of different types of packaging and storage conditions can also be studied.
- The processing techniques (roasting, popping, germination and malting) are cost-effective and can be easily performed at the homestead level.
- Popularization and commercialization of the formulated complementary food mixes can be done in collaboration with self-help groups at village level.