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EFFECT OF INDUCED AGEING ON NUTRIENTS CONTENT OF SOME SELECTED CASTOR SEEDS GENOTYPES

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ABSRACT
Castor is an important oilseed crop with great utilitarian value in industrial, pharmaceutical and agricultural sectors, the major constituents of the seeds are the lipids, carbohydrates, proteins and, of course, the nucleic acids. Seed deterioration is associated with various cellular, metabolic and chemical alterations to the seed constituents. The objective of this study was to determine the effects of induced ageing on the nutrient content of castor seeds. The study was carried out by subjecting castor seeds of various accessions to induced ageing by placing the seeds in an incubator at a temperature of 40^{O}C and 100% relative humidity for 0, 2, 4 and 6 days. A total of twelve (12) castor accessions were used for the study. Percentage total fats, total protein, total reducing sugar was determined in the aged seeds using standard biochemical procedures. The result showed a progressive decrease in fats, protein and reducing sugar content with increased ageing time which became significant at ($p < 0.05$) on day four in all parameters measured. The percentage decrease of fats ranged from 38.01% in NCRI-P-007 to 9.0% NCRICAS036, protein 57.98% in NCRI-P-40 to 54.10% NCRICAS019 and reducing sugar 39.93% in NCRI-P-39 to 14.55% in NCRICAS036. The result has led to the conclusion that castor seeds lose its nutrients content with storage time.

Key words: storage time, accessions, castor seeds, nutrients, reducing sugar

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INTRODUCTION
Castor is an important oilseed crop with great utilitarian value in industrial, pharmaceutical and agricultural sectors. The seeds contain between 40% and 60% oil. Its oil is unique among vegetable oils because the oil is the only commercial source of a hydroxylated fatty acid. The castor seed is inedible because the seed contains a toxic protein, ricin, and other toxic constituents such as ricinine and ricinoleic acids (Madeira *et al*., 2011). The presence of toxic components in castor seeds has remained a serious impediment in the consumption of castor seeds. Various detoxification methods have been used with varying degrees of success and limitations (Akande *et al*., 2016).

Raw castor seeds have been reported to contain 51% carbohydrate, 6.02% ash, 6.65% fat and 6.62% fibre (Adebato *et al*., 2019). Castor meal and husk for animal feed: Detoxified castor meal can be used as feed. Castor meal detoxified by boiling could be added up to 100gkg-1 in broiler finishing

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diets without deleterious effects (Ani and Okorie, 2009).

Seed deterioration is associated with various cellular, metabolic and chemical alterations including chromosome aberrations and damage to the DNA, impairment of RNA and protein synthesis, changes in the enzymes and food reserves and loss of membrane integrity (Kibinza *et al*., 2006). Major constituents of the seeds are the lipids, carbohydrates, proteins and, of course, the nucleic acids. However, the proportion of each component varies in seeds of various species. Some seeds are rich in lipids or proteins or both while the others are rich in carbohydrates. Any of these components may be damaged during the process of seed deterioration. However, the various reactions leading to this damage are not clearly understood. Several models have been proposed to explain the process of seed deterioration. However, there is no evidence for a single determinant of any one of the symptoms of deterioration (Kapoor *et al*., 2010).

The rate at which the seed aging process takes place depends on the ability of seed to resist degradation changes. Seeds of different plant species lose viability to a various degree even when kept under the same storage conditions. Accelerated aging of seed, i.e., seed exposure to high temperature and high relative humidity leads to loss of vigor and finally to a loss of viability which is an outstanding method for determination of changes in vigor during seed storage (Tian *et al*., 2008). The study was to determine the effects of induced ageing on the nutrient status of castor seeds. There are no reports on how ageing impacts on the nutrient composition of castor seeds. Therefore, this study was carried out to determine the effects of induced ageing on the nutrient status of castor seeds.

MATERIALS AND METHODS

Plant samples

The castor seeds were obtained from the National Cereal Research Institute (NCRI), Badeggi, Niger State, Nigeria.

Preparation of castor seed samples

Twelve castor accessions were selected for accelerated ageing in a biochemical incubator at a temperature and relative humidity of 40^0C and 100% respectively for 2, 4 and 6 days of uninterrupted power source (5KVA solar). The aged seeds were then subjected to the various biochemical analyses. The aged castor seeds were decorticated and the nibs were then milled with electronic blender and used for nutrients analyses

Nutrient Analyses

Fats determination

For Soxhelt extraction, 2g of the milled sample was placed in a paper thimble and fed into a Soxhlet extractor which was fitted with a 500 mL round bottom flask and a condenser. The oil was extracted by using n-hexane (as an extracting solvent) on water bath for 6 hours. After extraction, the extra hexane was distilled off under vacuum in a rotary evaporator at 45°C Association of Official Analytical Chemists, AOAC (2013). The extracted oil was weighed and the yield was calculated.

Protein content determination

Protein in the castor seed was determined by Kjeldahl method as described by the Association of Official Analytical Chemists, AOAC (2013). The pulverised sample (0.25g) was digested in a digestion flask, with 6mL of concentrated H_2SO_4 and a speck of Kjeldahl catalyst (mixture of 1g Na_2SO_4 + 0.05g selenium) added. The flask was swirled in order to mix the contents thoroughly then digested on the digestion block till the mixtures became clear (colourless or greenish in colour). The digest was cooled and transferred to 100ml volumetric flask and

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volume was made up to mark by the addition of distilled water. Distillation of the digest was performed in Markham Distillation Apparatus. Ten milliliters of digest was introduced in the distillation tube then 10 ml of 40% NaOH was gradually added through the same way. Distillation was continued for at least 10 min and NH_3 produced was collected as NH_4OH in a conical flask containing 5ml of 4% boric acid solution with few drops of methyl red indicator. During distillation yellowish colour appears due to NH_4OH. The distillate was then titrated against standard 0.1 N HCl solutions till the appearance of pink colour. A blank was also run through all steps as above.

Percentage crude protein content of the sample was calculated by using the following formula:

$$\% N = \frac{(S-B) \times N \times 0.014 \times D \times 100}{\text{Weight of the sample} \times V}$$

% Crude Protein = 6.25* x %N (* Correction factor)

Where;
S = Sample titration reading
B = Blank titration reading

N = Normality of HCl
D = Dilution of sample after digestion
V = Volume taken for distillation

0.014 = Milli equivalent weight of Nitrogen

Determination of reducing sugar

The enzyme extraction was carried out as reported by De-Morias and Takaki (1998). In cold trismalate buffer (0.005M, pH 7), 2g of seed cotyledon was grinded into powder using mortar and pestle. The homogenate was centrifuged for 20min at 3000g and the supernatant used as crude extract.

To 0.1mL of the crude extract, 1ml of 0.1% starch solution was added and allowed to stand for 5 minutes. Then 1ml of DNS was added to the mixture and incubated in boiling water for 5mins, cooled and the absorbance read at 540nm. In a separate tube, standard glucose (1mg/mL) was also mixed with 1ml of DNS, incubated in boiling water for 5mins, cooled and the absorbance read at 540nm. The % reducing sugar was calculated as:

$$\% \text{ Reducing sugar} = \frac{\text{Conc. of std} \times \text{Abs of sample} \times 10}{\text{Abs of std} \times \text{weight of sample}}$$

Statistical Analysis of Data

Data are represented as Mean ± Standard error of mean and were subjected to analysis of variance (ANOVA) using the Statistical Package for Social Science (SPSS version 21.0). Means with significant differences were compared using Duncan Posthoc analysis test at a confidence level of 0.05.

RESULTS AND DISCUSSION

Effect of Induced Ageing on the Fats in Castor Seeds Accession

Table 1 revealed the effect of accelerated ageing on the fats content of castor seeds accessions. There was ageing time dependent decrease in fats in all the accessions. There were significant differences ($p < 0.05$) in the fats at the various ageing times among the accessions. The accession NCRICAS 006 had significantly higher oil yield than all other accessions throughout the ageing periods, while accession NCRICAS 039 had the lowest oil yield all through the accelerated ageing period especially on the sixth day (18.63±0.25 %). However, NCRI-P- 007 had the highest rate (38.01%) of oil yield reduction with ageing time (from day zero to six), while NCRICAS 036 showed the least (9.00 %).

The observed decrease in this study was in agreement with findings of Vertucci (1992) who studied the changes in lipids during storage of groundnut and other oil seeds and

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suggested that the changes in lipid components of seeds were associated with seed deterioration and could be measured using differential scanning colorimetry. Braccini *et al.* (2000) observed reduction in protein, lipid and poly unsaturated fatty acids content and increased hexanal production in storage of soybean seeds. Simic *et al*. (2007) noticed a decrease in oil content of sun flower, soybean and maize seeds during storage. Similar results were observed by Balesevic *et al.* (2005) in sunflower during storage. The decrease in oil content with increased free fatty acid content may be due to the hydrolysis of storage lipids, coalescence of lipid bodies, and subsequent formation of free radical and led to lipid peroxidation (Paramasivam, 2005).

Effect of induced ageing on protein content

Table 2 shows the effect of induced ageing on the total protein content (%) of castor seed accessions. The accession NCRI-P-007 had the highest concentration of total protein all through the ageing times from 15.86±0.21 % on the zero day to 7.20±0.33% on the sixth day while NCRI-P-017 had the lowest total protein concentration from 10.54±0.11 % on the zero day to 4.79±0.20% on day six of ageing. There was a progressive decrease in total protein concentration with increase in ageing time in all the accessions. It was also observed that the total protein concentration of all the accessions were significantly ($P < 0.05$) decreased from day four. However, there was no significant ($P < 0.05$) difference in total protein among the accessions. The accession NCRI-P-40 had the highest % reduction in protein concentration (57.98 %), while accession NCRICAS 019 had the lowest (54.10 %).

The significant decrease in protein content of castor bean seed subjected to accelerated ageing in the accessions is in agreement with the report of Lakshmi *et al.* (2014) on the effect of accelerated ageing on seed viability and biochemical components of the edible bamboo (*Dendrocalamus brandisii* (Munro) Kurzsame). The authors reported a progressive reduction in the concentration of protein from day 0 to 8. The findings of Kapoor *et al.* (2011) and Kelpana and Madhava (1997) are in agreement with the result of the present study as there was decrease in the protein concentration of pigeon pea as well as rice seeds during accelerated ageing respectively. Several other authors have reported decrease in protein concentration in seeds (Basavarajappa *et al.,* 1991; Bernal-Lugo and Leopold, 1992; Ravikumar *et al.,* 2002). During seed ageing, the activities of free radicals increased as a result leading to oxidative stress. This may hence cause a decrease in the protein integrity, an elevated protein sensitivity to protease activity (protein denaturation) (Kibinza, 2011; Lakshmi *et al.,* 2014). The stress arising from accumulation of reactive oxygen species may also trigger cracks on the seed surface which may allow the leaking out of proteins.

Similarity in the % reduction in protein concentration of individual accessions of castor seeds (with mean value of 54.88 %) during ageing showed that all the individual accessions possess comparable viability and ability to handle stress.

Effect of induced ageing on reducing sugar concentration

The effect of induced ageing on the reducing sugar of castor seed accessions is as shown in Table 3. The accession NCRICAS 039 had the highest reducing sugar concentrations all through the ageing period with highest concentrations being 3.55±0.05 % on day zero and 2.38±0.13% day six while accession NCRICAS 006 had the lowest reducing sugar concentrations of 1.80±0.05 % on day zero and 1.20±0.05 % six respectively. The reducing sugar concentration of the accessions were observed to increase on day

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two with subsequent decrease on days four and six in most of the accessions. The concentration of reducing sugar in the aged castor seeds on days four and six were significantly ($p < 0.05$) decreased from that of days zero and two in all the accessions. The accession NCRI-P- 39 showed the highest percentage reduction (39.93 %) among the accessions while the least reduction (14.55 %) was noted in accession NCRICAS 036.

The significant reduction in reducing sugar concentration of castor seeds from the fourth day of ageing is in agreement with the findings of Kapoor *et al.* (2011) who estimated some physiological and biochemical changes during deterioration in aged rice seeds. The authors recorded significant differences in the reducing sugar content. Lehle (2016) reported a positive correlation between the leakage of reducing sugar and the duration of accelerated ageing during cotton (*Gossypium hirsutum*) seed imbibition. Although, the decrease in the authors report was progressive from the zero hour through the 216th hour while the present study decreased from day four to day six. The observed variation from the present study may be due to the conditions for accelerated ageing employed or the nature or genetic make-up of the seed. Verma *et al.* (2005) in their study of viability and vigour loss of aged Indian mustard seeds reported a decrease in reducing sugar content with increasing ageing time. A definite relationship has been obtained between leaching out of reducing sugars and the loss of viability of soybean seed during storage. The increased leaching of substances from the seeds was perhaps due to damage to the semi permeable cell membrane. Upon imbibition, more substances leak out from aged seeds than from fresh ones. Excess leakage of sugar may represent loss of respirable substrate from seeds (Bewley and Black, 1994). Cracks as well as bruises in seeds under high temperature may also result in exposing carbohydrates to leakages (Shelar, 2008). Another probable reason for the declining concentration of reducing sugar could be as a result of inter conversion of simple sugar into complex sugars and Maillard reaction (reactions between amino acids and simple sugars) (Murthy *et al.,* 2003).

CONCLUSION AND RECOMMENDATION

The study showed that there was significant decline in fats, reducing sugar and protein level of castor seed accessions from the 4th day of accelerated ageing. Thus**,** there was nutrient loss with storage time of castor seeds. It is clear from the study that with increase in storage period there was decreased in nutrients level of castor seeds. From the above study, castor seeds should not be stored beyond four years after harvesting in order to preserve its nutrients

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REFERENCES

Adebayo, O. C., Ogidi, C. O. & Akinyele, B. J. (2019). Nutritional value and safety of castor bean (*Ricinus communis*) seeds detoxified in solid-state fermentation by *Pleurotus ostreatus*. *Biofarmasi Journal of Natural Products Biochemistry*, 17(2), 51-56.

Akande, T. O., Odunsi, A. A. & Akinfala, E. O. (2016). A review of nutritional and toxicological implications of castor bean (*Ricinus communis* L.) meal in animal feeding systems. *Journal of Animal Physiology and Animal Nutrition*, *100,* 201–210.

Ani, A.O., & Okorie, A.U. (2009). Response of broiler finishers to diets containing graded levels of processed castor oil bean (*Ricinus communis* L.) meal. *Journal of Animal Physiology and Animal Nutrition, 93*, 157-164.

Association of Official Analytical Chemists (AOAC). (2013). Official Methods of Analysis of AOAC International. 19th edition. AOAC 53 International, Gaithersburg, Maryland, USA.

Balesevic-Tubic, S., Malenèiæ, D., Tatiæ, M., & Miladinovic, J. (2005). Influence of aging process on biochemical changes in sunflower seed. *HELIA*, *28*(42), 107-114.

Basavarajappa, B. S., Shekar Shetty, H., & Prakash, H. S. (1991). Membrane deterioration and other biochemical-changes, associated with accelerated aging of maize seeds. *Seed Science and Technology*, *19*(2), 279-286.

Bernal-Lugo, I., & Leopold, A. C. (1992). Changes in soluble carbohydrates during seed storage. *Plant Physiology*, 98(3), 1207-1210.Bewley, J. D., & Black, M. (2012). *Physiology and Biochemistry of Seeds in Relation to Germination: Viability, Dormancy and Environmental Control*. Springer Science and Business Media.

Bewley, J. D., & Black, M. (2012). *Physiology and Biochemistry of Seeds in Relation to Germination: Viability, Dormancy and Environmental Control*. Springer Science and Business Media.

Braccini, A.D.L.E., Reis, M. S., Moreria, M. A., Sediyama, C. S. & Scapim C. A. (2000). Biochemical changes associated to soybean seeds osmoconditioning during storage. *Pesquisa Agropecuária Brasileira, 35*(2), 433-447.

De-Morias G.A. & Takaki, M. (1998). Determination of amylase activities in cotyledons of *Phaseolus vulgaris* L. *Brazilian Achivwa of Bioogy and Technology* 41, 17-25

Kalpana, R., & Madhava, R. K. V. (1997). Protein metabolism of seeds of pigeonpea (*Cajanus cajan* (L.) Millsp.) cultivars during accelerated ageing. *Seed Science and Technology*, *25*(2), 271-279.

Kapoor, N., Arya, A., Siddiqui, M. A., Kumar, H., & Amir A (2011). Physiology and biochemical changes during seed deterioration in aged seeds of rice (*Oryza sativa* L.)", America *Journal of Plant Physiology*, 6(1), 28-35.

Kapoor, R., Arya, A., Siddiqui, M.A., Amir, A., & Kumar, H. (2010). Seed Deterioration in Chickpea (*Cicer arietinum* L.) under Accelerated Ageing. *Asian Journal of Plant Science,* 9(3), 158-162.

Kibinza, S., Bazin, J., Bailly, C., Farrant, J. M., Corbineau, F., & El-Maarouf-Bouteau, H. (2011). Catalase is a key enzyme in seed recovery from ageing during priming. *Plant Science*, 181(3), 309-315.

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Kibinza, S., Vinel D., Côme, D., Bailly, C., & Corbineau, F. (2006). Sunflower seed deterioration as related to moisture content during ageing, energy metabolism and active oxygen species scavenging. *Physiologia Plantarum*, *128*(3), 496-506.

Lakshmi, C. J., Seethalakshmi, K. K., Chandrasekhara Pillai, P. K., & Raveendran, V. P. (2014). Effect of accelerated ageing on seed viability and biochemical components of the edible bamboo *Dendrocalamus brandisii* (munro) kurz. *Research Journal of Recent Science*, *3*, 15-18.

Lehle, F. R. (2016). Leakage of Reducing Sugards and Amino Acids During Cotton (*Gossypium hirsutum*) Seed Imbibation. College of Agriculture, University of Arizona (Tucson, AZ) Cotton: A College of Agriculture Report. Accessed 6-Jan-2017 from http://hdl.handle.net/10150/204521.

Madeira Jr., J. V., Macedo, J. A. & Macedo, G. A. (2011). Detoxification of castor bean residues and the simultaneous production of tannase and phytase by solid-state fermentation using *Paecilomyces variotii*. *Bioresources Technology*, *102* (15), 7343- 7348.

Murthy, U. N., Kumar, P. P., & Sun, W. Q. (2003). Mechanisms of seed ageing under different storage conditions for *Vigna radiata* (L.) Wilczek: lipid peroxidation, sugar hydrolysis, Maillard reactions and their relationship to glass state transition. *Journal of Experimental Botany*, *54*(384), 1057-1067.

Paramasivam, V. (2005). Seed and nutrient management in groundnut (*Arachis hypogea* L.) M.Sc. (Ag.) Thesis, TamilNadu Agricultural University, Coimbatore. Tamil Nadu.

Ravikumar, R., Ananthakrishnan, G., Girija, S., & Ganapathi, A. (2002). Seed viability and biochemical changes associated with accelerated ageing in *Dendrocalamus strictus* seeds. *Biologia plantarum*, *45*(1), 153-156.

Shelar, V. R. (2008). Role of mechanical damage in deterioration of soybean seed quality during storage- A review. *Agricultural Review*, 29(3), 177-184.

Simic, B., Popoviæ, R., Sudaric, A., Rozman, V., Kalinovic, I., & Cosic, J. (2007). Influence of Storage Condition on Seed Oil Content of Maize, Soybean and Sunflower. *Agriculturae Conspectus Scientificus*, 72(3),211-213.

Tian, X., Song, S., & Lei, Y. (2008). Cell death and reactive oxygen species metabolism during accelerated ageing of soybean axes. *Russian Journal Plant Physiology*, 55(1), 33-40.

Verma, S. S., Tomer, R. P. S., & Verma, U. (2005). Loss of viability and vigour in Indian mustard seeds stored under ambient conditions. *Seed Research New Delhi*, *31*(1), 90-93.

Vertucci, C.W. (1992). Theoretical basis of protocols for seed storage III. Optimum moisture contents for pea seeds stored at different temperatures. *Annals of Botany*, *74,* 531-540.

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APPENDICES

Table 1: Effect of ageing on crude fats (%) of castor seed accessions

	Days of induced ageing				
Accessions	0	2	4	6	% reduction
NCRICAS 006	55.40^{f}±0.49	53.21±0.23^{f}	51.47±0.38^{e}	48.51±0.40^{d}	12.44
NCRICAS 036	51.99±0.18^{e}	50.91±0.44^{e}	49.06±0.29^{d}	47.31±0.47^{c}	9.00
NCRICAS 019	35.31±0.21^{c}	33.23±0.22^{c}	31.24±0.42^{c}	29.50±0.34^{b}	16.45
NCRICAS 012	36.51±0.32^{d}	34.76±0.53^{d}	31.83±0.11^{c}	28.99±0.58^{b}	20.60
NCRICAS 039	25.70±0.20^{a}	23.26±0.36^{a}	21.08±0.33^{a}	18.63±0.25^{a}	27.51
NCRICAS 044	28.05±0.07^{b}	27.31±0.38^{b}	23.00±0.61^{b}	19.63±0.30^{a}	30.02
.NCRI-P-38	51.09±0.13^{e}	50.78±0.16^{e}	48.72±0.28^{c}	45.58±0.10^{e}	10.78
NCRI-P-40	51.65±0.35^{e}	50.68±0.26^{e}	49.05±0.36^{c}	45.72±0.55^{e}	11.48
NCRI-P-45	48.43±0.41^{d}	45.98±0.68^{d}	44.11±0.58^{b}	36.57±3.45^{d}	24.49
NCRI-P-007	37.46±0.60^{c}	35.05±0.56^{c}	33.48±0.60^{b}	30.02±0.18^{c}	38.01
NCRI-P-055	29.26±0.16^{a}	28.40±0.36^{a}	25.25±0.45^{a}	21.89±0.65^{ab}	25.19
NCRI-P-017	31.31±0.74^{b}	29.59±0.34^{b}	25.65±0.78^{a}	22.14±0.77^{b}	29.29

Values are mean ± standard error of mean of three determinations. Values with different superscript along the column are significantly ($p < 0.05$) different.

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Table 2: Effect of Induced Ageing on Total Protein Contents (%) of Castor Seed Accessions

Accessions	Days of induced ageing				
	0	2	4	6	% Reduction
NCRICAS 006	11.39±0.37^{b}	10.35±0.59^{b}	7.25±0.28^{a}	5.18±0.33^{a}	54.52
NCRICAS 036	12.12±0.41^{cd}	11.02±0.50^{c}	7.71±0.18^{b}	5.51±0.22^{a}	54.54
NCRICAS 019	16.64±0.36^{c}	15.13±0.30^{c}	10.59±0.42^{b}	7.57±0.25^{a}	54.51
NCRICAS 012	16.46±0.55^{c}	14.96±0.38^{b}	10.47±0.48^{ab}	7.48±0.24^{a}	54.57
NCRICAS 039	17.37±0.34^{d}	15.79±0.20^{c}	11.05±0.41^{b}	7.90±0.31^{a}	54.52
NCRICAS 044	11.77±0.66^{d}	10.70±0.45^{b}	7.49±0.31^{ab}	5.35±0.19^{a}	54.55
NCRI-P-38	11.47±0.15^{c}	10.35±0.38^{bc}	7.36±0.22^{b}	4.98±0.18^{a}	56.58
NCRI-P-40	11.85±0.22^{c}	10.77±0.28^{bc}	7.54±0.32^{b}	4.98±0.14^{a}	57.98
NCRI-P-45	14.91±0.40^{c}	13.55±0.32^{c}	9.49±0.16^{b}	6.78±0.37^{a}	54.53
NCRI-P-007	15.86±0.21^{c}	14.42±0.52^{c}	10.09±0.15^{b}	7.20±0.33^{a}	54.60
NCRI-P-055	15.11±0.33^{d}	13.74±0.40^{cd}	9.62±0.61^{b}	6.87±0.25^{a}	54.53
NCRI-P-017	10.54±0.11^{b}	9.58±0.08^{b}	6.71±0.82^{a}	4.79±0.20^{a}	54.55

Values are mean ± standard error of mean of three determinations. Values with different superscript along a row are significantly ($p < 0.05$) different.

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Table 3: Effect of Induced Ageing on Reducing Sugar Concentrations (g/50g) of Castor Seed Accessions

Days of induced ageing					
Accessions	0	2	4	6	% Reduction
NCRICAS 006	1.80±0.05^{b}	1.86±0.08^{b}	1.44±0.03^{ab}	1.20±0.05^{a}	33.33
NCRICAS 036	1.86±0.07^{b}	1.93±0.04^{b}	1.72±0.10^{a}	1.58±0.07^{a}	14.55
NCRICAS 019	1.80±0.10^{b}	1.92±0.13^{b}	1.65±0.08^{a}	1.54±0.09^{a}	14.68
NCRICAS 012	2.85±0.05^{b}	2.61±0.10^{b}	2.19±0.08^{a}	1.99±0.16^{a}	30.18
NCRICAS 039	3.55±0.05^{b}	3.65±0.12^{b}	2.68±0.11^{a}	2.38±0.13^{a}	33.00
NCRICAS 044	2.31±0.10^{b}	2.44±0.08^{b}	1.82±0.11^{a}	1.52±0.07^{a}	34.06
NCRI-P-38	2.86±0.14^{b}	2.46±0.21^{ab}	1.94±0.17^{a}	1.72±0.11^{a}	39.93
NCRI-P-40	2.89±0.0^{b}	2.45±0.18^{b}	1.87±0.06^{a}	1.85±0.16^{a}	22.95
NCRI-P-45	2.43±0.13^{b}	2.31±0.22^{b}	1.69±0.14^{a}	1.54±0.17^{a}	36.63
NCRI-P-007	2.68±0.15^{b}	2.46±0.13^{b}	1.91±0.20^{a}	1.73±0.12^{a}	35.33
NCRI-P-055	2.30±0.17^{b}	2.34±0.1.4^{b}	1.84±0.13^{a}	1.52±0.11^{a}	34.06
NCRI-P-017	2.94±0.21^{b}	2.85±0.18^{a}	2.47±0.16^{a}	2.29±0.13^{a}	23.85

Values are mean ± standard error of mean of three determinations. Values with different superscript along the row are significantly ($p < 0.05$) different

Table 1: Effect of Ageing on Crude Fats (%) of Castor Seed Accessions

	Days of induced ageing				
Accessions	0	2	4	6	% reduction
NCRICAS 006	55.40^{f}±0.49	53.21^{f} ±0.23	51.47^{e}±0.38	48.51^{d}±0.40	12.44
NCRICAS 036	51.99^{e} ±0.18	50.91^{e}±0.44	49.06^{d}±0.29	47.31^{c}±0.47	9.00
NCRICAS 019	35.31^{c}±0.21	33.23^{c}±0.22	31.24^{c}±0.42	29.50^{b}±0.34	16.45
NCRICAS 012	36.51^{d}±0.32	34.76^{d}±0.53	31.83^{c}±0.11	28.99^{b}±0.58	20.60
NCRICAS 039	25.70^{a}±0.20	23.26^{a}±0.36^{a}	21.08^{a}±0.33	18.63^{a}±0.25	27.51
NCRICAS 044	28.05^{b}±0.07	27.31^{b}±0.38	23.00^{b}±0.61	19.63^{a}±0.30	30.02
NCRI-P-38	51.09^{e}±0.13	50.78^{e}±0.16	48.72^{c}±0.28	45.58^{e} ±0.10	10.78
NCRI-P-40	51.65^{e}±0.35	50.68^{e}±0.26	49.05^{c}±0.36	45.72^{e} ±0.55	11.48
NCRI-P-45	48.43^{d}±0.41	45.98^{d}±0.68	44.11^{b}±0.58	36.57^{d} ±3.45	24.49
NCRI-P-007	37.46^{c}±0.60	35.05^{c}±0.56	33.48^{b}±0.60	30.02^{c} ±0.18	38.01
NCRI-P-055	29.26^{a}±0.16	28.40^{a}±0.36	25.25^{a}±0.45	21.89^{ab}±0.65	25.19
NCRI-P-017	31.31^{b}±0.74	29.59^{b}±0.34	25.65^{a}±0.78	22.14^{b}±0.77	29.29

Values are mean ± standard error of mean of three determinations. Values with different superscript along the column are significantly ($p < 0.05$) different.

Table 2: Effect of Induced Ageing on Total Protein Contents (%) of Castor Seed Accessions

Accessions	Days of induced ageing				
	0	2	4	6	% Reduction
NCRICAS 006	11.39^{b}±0.37	10.35^{b}±0.59	7.25^{b}±0.28	5.18^{a}±0.33	54.52
NCRICAS 036	12.12^{cd}±0.41	11.02^{c}±0.50	7.71^{b}±0.18	5.51^{a}±0.22	54.54
NCRICAS 019	16.64^{c}±0.36	15.13^{c}±0.30	10.59^{b} ±0.42	7.57^{a}±0.25	54.51
NCRICAS 012	16.46^{c}±0.55	14.96^{b}±0.38	10.47^{ab}±0.48	7.48^{a}±0.24	54.57
NCRICAS 039	17.37^{d}±0.34	15.79^{c}±0.20	11.05^{b} ±0.41	7.90^{a}±0.31	54.52
NCRICAS 044	11.77^{d}±0.66	10.70^{b} ±0.45	7.49^{ab}±0.31	5.35^{a}±0.19	54.55
NCRI-P-38	11.47^{c}±0.15	10.35^{bc}±0.38	7.36^{b}±0.22	4.98^{a}±0.18	56.58
NCRI-P-40	11.85^{c}±0.22	10.77^{bc}±0.28	7.54^{b}±0.32	4.98^{a}±0.14	57.98
NCRI-P-45	14.91^{c}±0.40	13.55^{c}±0.32	9.49^{b}±0.16	6.78^{a}±0.37	54.53
NCRI-P-007	15.86^{c}±0.21	14.42^{c}±0.52	10.09^{b}±0.15	7.20^{a}±0.33	54.60
NCRI-P-055	15.11^{d}±0.33	13.74^{cd}±0.40	9.62^{b}±0.61	6.87^{a}±0.25	54.53
NCRI-P-017	10.54^{b} ±0.11	9.58^{b}±0.08	6.71^{a}±0.82	4.79^{a}±0.20	54.55

Values are mean ± standard error of mean of three determinations. Values with different superscript along a row are significantly ($P < 0.05$) different.

Table 3: Effect of Induced Ageing on Reducing Sugar Concentrations (g/50g) of Castor Seed Accessions

Days of induced ageing					
Accessions	0	2	4	6	% Reduction
NCRICAS 006	1.80^{b}±0.05	1.86^{b}±0.08	1.44^{ab}±0.03	1.20^{a}±0.05	33.33
NCRICAS 036	1.86^{b}±0.07	1.93^{b}±0.04	1.72^{a}±0.10	1.58^{a}±0.07	14.55
NCRICAS 019	1.80^{b}±0.10	1.92^{b}±0.13	1.65^{a}±0.08	1.54^{a}±0.09	14.68
NCRICAS 012	2.85^{b}±0.05	2.61^{b}±0.10	2.19^{a}±0.08	1.99^{a}±0.16	30.18
NCRICAS 039	3.55^{b}±0.05	3.65^{b}±0.12	2.68^{a}±0.11	2.38^{a}±0.13	33.00
NCRICAS 044	2.31^{b}±0.10	2.44^{b}±0.08	1.82^{a}±0.11	1.52^{a}±0.07	34.06
NCRI-P-38	2.86^{b}±0.14	2.46^{b}±0.21	1.94^{a}±0.17	1.72^{a}±0.11	39.93
NCRI-P-40	2.89^{b}±0.0	2.45^{b}±0.18	1.87^{a}±0.06	1.85^{a}±0.16	22.95
NCRI-P-45	2.43^{b}±0.13	2.31^{b}±0.22	1.69^{a}±0.14	1.54^{a}±0.17	36.63
NCRI-P-007	2.68^{b}±0.15	2.46^{b}±0.13	1.90^{a}±0.20	1.73^{a}±0.12	35.33
NCRI-P-055	2.30^{b}±0.17	2.34^{b}±0.14	1.84^{a}±0.13	1.52^{a}±0.11	34.06
NCRI-P-017	2.94^{b-}±0.21	2.85^{a}±0.18	2.40^{a}±0.16	2.29^{a}±0.13	23.85

Values are mean ± standard error of mean of three determinations. Values with different superscript along the row are significantly ($P < 0.05$) different