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A novel ultrasonic technique for the study of refrigeration and fermentation effect of coconut water

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ABSTRACT

A continuous study is performed to analyse the fermented as well as refrigerated effect of coconut water using ultrasonic parameters namely adiabatic compressibility (β_s) and specific acoustic impedance (Z_A) by employing its thermal variations. This technique – Thermo - Acoustic Analysis (TAA) has been done to refrigerated, air fermented and yeast fermented samples of coconut water to study its physical properties using ultrasonic parameters. The study reveals that physical properties are unaltered in refrigerated samples whereas a relative shift in the parameters occurs in fermented samples which are greater for yeast fermented samples.

Key words: adiabatic compressibility, specific acoustic impedance, coconut water, fermented samples

1. Introduction

Coconut water is an ancient tropical beverage which comes from immature coconuts. Though this coconut water extracted directly from the nut is easy to handle, its storage for a long period is difficult because this liquid is very sensitive to biological and chemical changes [1]. Preservation of tender coconut water is the greatest challenge we face in the present scenario because the processing methods may cause loss in nutritional and therapeutic value of coconut water [2-9]. There are several conventional thermal techniques used to preserve coconut water [10].Freezing and cooling are the two processes currently used in the industry besides conventional thermal techniques. Studies on physico – chemical changes of coconut water for a period of two weeks storage at refrigerated temperature (10^0C) and at ambient temperature (28^0C) showed that there is not much change in the physico– chemical parameters at cold temperature but changes occur at ambient temperature [11]. Again, study on coconut water in opaque and transparent bottles and in commercially packed bottles during 4 –day storage under refrigeration (4^0C) done by Gobin and co – workers [12] showed that there are no significant changes in the sensory parameters of coconut water during refrigeration.

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In the present paper, a systematic study of coconut water using a new technique Thermo – Acoustic Analysis (TAA) was done successfully to study its physical properties in refrigerated and fermented samples. To promote this hygienic drink as a substitute for commercially available beverages, it has to be bottled and stored. During this process, physical and chemical changes can occur in coconut water. Hence an attempt has been made to study the physical characteristics of fresh, refrigerated and fermented samples of coconut water continuously for a period of 5 days using ultrasonic parameters viz; adiabatic compressibility and specific acoustic impedance.

2. Experimental details

Freshly obtained tender coconut water is taken as the sample for study. A portion of it is refrigerated. Another portion is kept in a bottle covered with netted cloth for normal fermentation which is considered as the air – fermented sample. 10 mg of yeast was added to 100 ml of coconut water in order to study its fermentation effect. This was considered as the yeast – fermented sample. The three sets of samples namely fresh, air – fermented and yeast – fermented samples were analysed continuously for 5 consecutive days. The ultrasonic velocities of these samples were measured at six different temperatures ranging from 298 K to 323K at an interval of 5 K using a single – crystal ultrasonic interferometer [Mittal Enterprises – Model No. F81] within an accuracy of $\pm$ 0.1m/s. The density measurements were performed using a 12 cm^3 double – stem pyknometer and the masses of the liquid samples were determined using a single pan electronic balance [Dhona 200B] having an accuracy of $\pm$ 0.1 mg. The temperatures of the samples were kept constant using a thermostatically controlled water circulating arrangement with an accuracy of $\pm$ 0.1K.

3. Theory

Thermal analysis refers to measurement of physical and chemical properties of matter as a function of temperature. Generally it covers properties like heat capacity, enthalpy etc [13]. In the present paper, thermal analysis has been extended to cover physical parameters like adiabatic compressibility (β_s) and specific acoustic impedance (Z_A), both derived from ultrasonic velocity.

Adiabatic compressibility [14] is given by the relation

$$\beta_s = \frac{1}{U^2 \rho} \qquad (1)$$

and Specific acoustic impedance [15] is given by

$$Z_A = U\rho \qquad (2)$$

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where U is the ultrasonic velocity and ρ is the density of a substance.

4. Results and Discussion

The variations of U, ρ, β_s and Z_A with temperature for fresh, refrigerated, air – fermented and yeast – fermented samples are tabulated in Table 1.

Table 1 -Variation of U (m/s), $\boldsymbol{\rho}$ (kg/m^3), $\boldsymbol{\beta_s}$ (m^2 N^{-1}) and $\boldsymbol{Z_A}$ (kg m^{-2}s^{-1}) at different temperatures for fresh, refrigerated, air – fermented and yeast – fermented samples.

Parameters	298 K	303 K	308 K	313 K	318 K	323 K
Fresh Sample						
U	1527.5	1536.4	1546.6	1553.3	1559.8	1563.4
ρ	1026.83	1024.92	1022.25	1021.12	1018.37	1017.90
$\beta_s \times 10^{10}$	4.174	4.133	4.090	4.059	4.036	4.019
$Z_A \times 10^{-6}$	1.568	1.575	1.581	1.586	1.588	1.591
Refrigerated 1 day						
U	1529.8	1539.0	1547.9	1555.8	1561.9	1568.1
ρ	1025.90	1024.29	1022.28	1020.26	1017.60	1015.50
$\beta_s \times 10^{10}$	4.165	4.122	4.083	4.049	4.028	4.005
$Z_A \times 10^{-6}$	1.569	1.576	1.582	1.587	1.589	1.592
Refrigerated 2 days						
U	1529.8	1539.7	1548.5	1555.9	1562.9	1567.7
ρ	1026.40	1024.54	1022.54	1020.46	1017.60	1016.45
$\beta_s \times 10^{10}$	4.163	4.117	4.078	4.048	4.023	4.003
$Z_A \times 10^{-6}$	1.570	1.577	1.583	1.588	1.590	1.593
Refrigerated 3 days						
U	1530.1	1539.6	1548.3	1557.2	1562.3	1567.1
ρ	1026.46	1024.68	1022.80	1020.06	1018.60	1017.22
$\beta_s \times 10^{10}$	4.161	4.117	4.078	4.043	4.022	4.003
$Z_A \times 10^{-6}$	1.571	1.578	1.584	1.588	1.591	1.594
Refrigerated 4 days						
U	1529.9	1539.1	1547.8	1555.6	1561.7	1567.3
ρ	1026.40	1024.46	1022.86	1020.36	1018.37	1016.68
$\beta_s \times 10^{10}$	4.163	4.121	4.081	4.050	4.026	4.004
$Z_A \times 10^{-6}$	1.570	1.577	1.583	1.587	1.590	1.593
Refrigerated 5 days						

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U	1529.4	1539.3	1548.5	1556.3	1561.3	1566.8
ρ	1025.60	1024.52	1022.19	1019.32	1018.01	1015.94
$\beta_s \times 10^{10}$	4.169	4.119	4.080	4.050	4.030	4.010
$Z_A \times 10^{-6}$	1.569	1.577	1.583	1.586	1.589	1.592
Air fermented 1 day						
U	1529.0	1538.4	1547.8	1554.5	1561.3	1567.4
ρ	1023.32	1021.54	1019.17	1017.18	1015.30	1012.10
$\beta_s \times 10^{10}$	4.180	4.136	4.096	4.068	4.040	4.022
$Z_A \times 10^{-6}$	1.565	1.572	1.577	1.581	1.585	1.586
Air fermented 2 days						
U	1528.6	1537.6	1546.8	1553.9	1560.4	1565.3
ρ	1022.43	1020.50	1018.50	1016.26	1014.74	1013.11
$\beta_s \times 10^{10}$	4.186	4.145	4.104	4.075	4.047	4.029
$Z_A \times 10^{-6}$	1.563	1.569	1.575	1.579	1.583	1.585
Air fermented 3 days						
U	1527.6	1536.5	1546.8	1554.0	1559.9	1565.3
ρ	1020.32	1018.44	1016.99	1014.85	1013.03	1011.46
$\beta_s \times 10^{10}$	4.200	4.159	4.110	4.080	4.057	4.035
$Z_A \times 10^{-6}$	1.559	1.565	1.573	1.577	1.580	1.583
Air fermented 4 days						
U	1529.4	1537.8	1548.4	1553.4	1560.6	1564.8
ρ	1017.41	1015.25	1013.62	1012.62	1010.17	1008.26
$\beta_s \times 10^{10}$	4.202	4.165	4.115	4.092	4.065	4.050
$Z_A \times 10^{-6}$	1.556	1.561	1.569	1.573	1.576	1.578
Air fermented 5 days						
U	1526.5	1535.6	1543.8	1551.6	1558.0	1562.7
ρ	1014.78	1012.77	1011.28	1008.57	1007.20	1004.81
$\beta_s \times 10^{10}$	4.229	4.187	4.149	4.118	4.090	4.075
$Z_A \times 10^{-6}$	1.549	1.555	1.561	1.565	1.569	1.570
Yeast fermented 1 day						
U	1526.4	1536.4	1545.4	1554.1	1560.2	1565.2
ρ	1021.81	1019.31	1018.01	1015.38	1013.07	1010.21
$\beta_s \times 10^{10}$	4.200	4.156	4.113	4.078	4.055	4.041
$Z_A \times 10^{-6}$	1.560	1.566	1.573	1.578	1.580	1.581
Yeast fermented 2 days						

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U	1527.6	1538.4	1545.8	1552.9	1559.7	1564.1
ρ	1015.16	1013.23	1011.83	1009.12	1007.52	1006.28
$\beta_s \times 10^{10}$	4.221	4.170	4.136	4.109	4.080	4.062
$Z_A \times 10^{-6}$	1.551	1.559	1.564	1.567	1.571	1.574
Yeast fermented 3 days						
U	1525.9	1536.1	1544.0	1551.4	1558.6	1561.8
ρ	1010.58	1008.87	1007.71	1004.89	1003.65	1003.25
$\beta_s \times 10^{10}$	4.250	4.201	4.163	4.135	4.102	4.086
$Z_A \times 10^{-6}$	1.542	1.550	1.556	1.559	1.564	1.567
Yeast fermented 4 days						
U	1523.8	1532.4	1540.9	1548.1	1554.0	1558.9
ρ	1011.53	1009.71	1008.40	1005.40	1003.95	1002.63
$\beta_s \times 10^{10}$	4.258	4.218	4.177	4.150	4.125	4.104
$Z_A \times 10^{-6}$	1.541	1.547	1.554	1.556	1.560	1.563
Yeast fermented 5 days						
U	1522.6	1532.1	1540.4	1547.5	1553.6	1558.5
ρ	1013.17	1010.99	1009.79	1007.00	1005.42	1004.04
$\beta_s \times 10^{10}$	4.257	4.214	4.174	4.147	4.121	4.100
$Z_A \times 10^{-6}$	1.543	1.549	1.555	1.558	1.562	1.565

The variations of β_s with temperature and Z_A with temperature for fresh, refrigerated, air – fermented and yeast – fermented samples are plotted in Figs. 1(a), 1(b) and 1(c) and 2 (a), 2 (b) and 2 (c).

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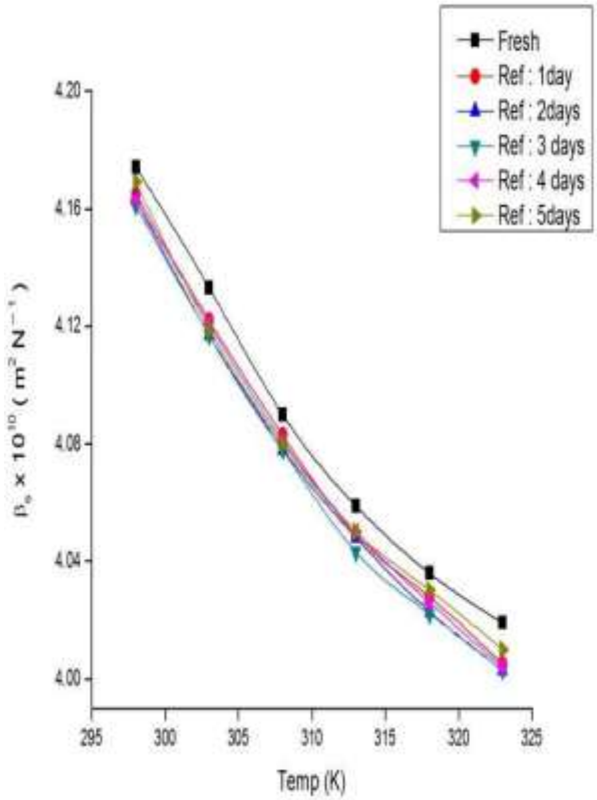

Fig. 1(a)

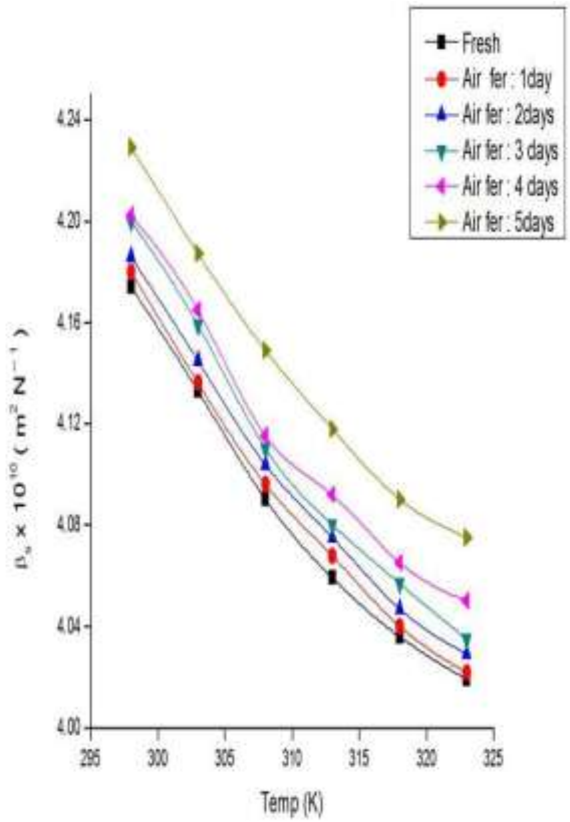

Fig. 1(b)

Fig. 1(a) - Variation of β_s with temperature for fresh and refrigerated coconut water

Fig. 1(b) - Variation of β_s with temperature for fresh and air - fermented coconut water

Analysis of Fig. 1(a) reveals that the curves for the refrigerated samples on consecutive days are crowded together and the curves retain almost the same shape as that of the fresh sample. This is a clear indication that the physical characteristics of the samples are not altered due to refrigeration. Also the value of β_s does not change appreciably from that of the fresh sample at all temperatures. Hence it is clear that the samples do not undergo any physical or chemical change on refrigeration.

Fig. 1(b) shows the variation of β_s with temperature for coconut water samples stored in air for 5 consecutive days (air – fermented samples) along with the fresh sample. A perusal of the graph shows that there is an upward shift in the curves of the samples stored open in air at room temperature. Or in other words, the compressibility values increase with fermentation

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period and the shift is maximum for the one kept for maximum number of days. The shape of the curves also differs with fermentation. This shows that air – fermented samples undergo both physical and chemical changes during fermentation. The curve of the fermented sample for the first day is not much different from the fresh one. This may be due to the fact that the fermentation process has not been completed on the first day. The curves for higher fermentation period are entirely different. This is due to the conversion of reduced sugars in coconut water into alcohol by fermentation. But such a change cannot be observed in refrigerated samples because the microorganisms responsible for fermentation cannot survive at very low temperature. In air – fermented samples, the increase in compressibility values with fermentation period reveals that there occurs reduction in the concentration of sugar content as it is converted into alcohol. It has been already established that a decrease in concentration of sugar increases the value of β_s [16].

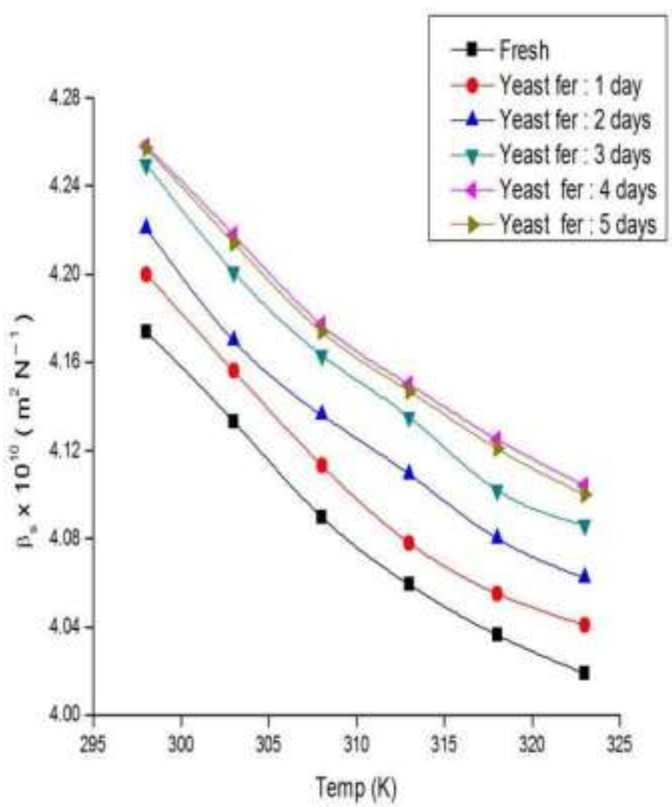

Fig. 1(c)

Fig. 1(c) - Variation of β_s with temperature for fresh and yeast - fermented coconut water

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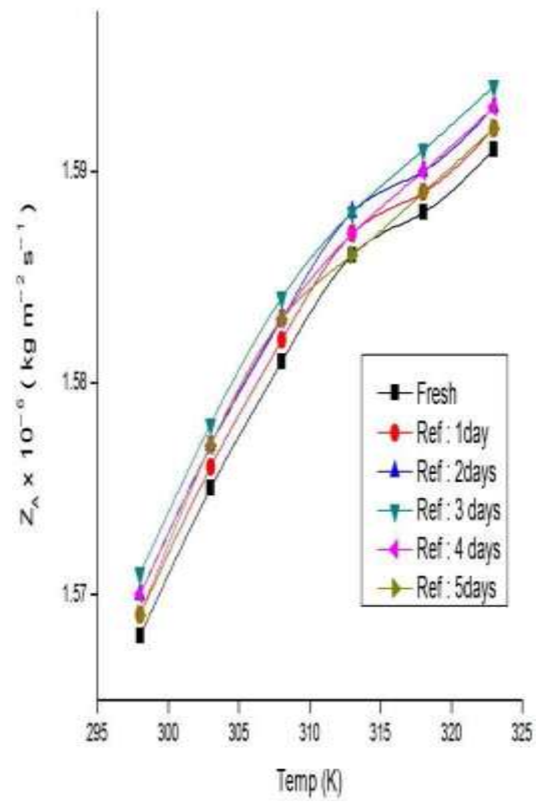
Fig. 1(c) shows the variation of β_s with temperature for coconut water samples fermented with yeast for 5 consecutive days (yeast – fermented samples) along with the fresh sample. It is observed that the relative shift in the curves increases when compared to normal fermented samples showing enhanced fermentation.

An exactly similar result is obtained with the parameter Z_A, specific acoustic impedance which shows a behaviour opposite to β_s. ie; Z_A decreases with decrease in concentration of sugar solution.



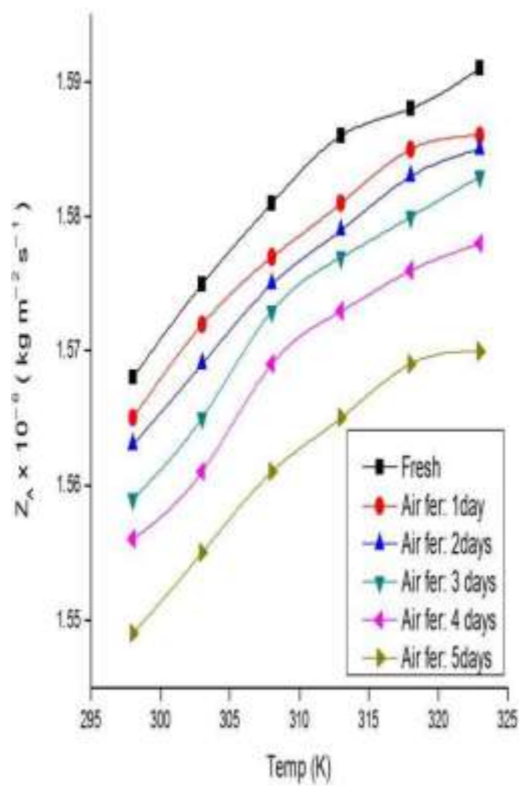


Fig. 2(a)

Fig. 2(b)

Fig. 2(a) - Variation of Z_A with temperature for fresh and refrigerated coconut water

Fig. 2(b) - Variation of Z_A with temperature for fresh and air - fermented coconut water

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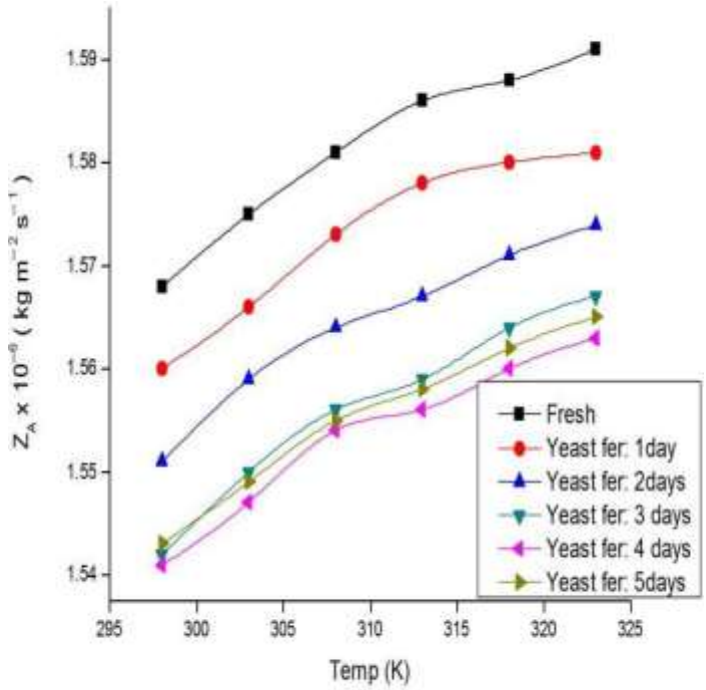

Fig. 2(c)

Fig. 2(c) - Variation of Z_A with temperature for fresh and yeast - fermented coconut water

Fig. 2(a) shows the variation of Z_A with temperature for fresh as well as refrigerated samples for five consecutive days. It can be seen that the curves are identical with the fresh one and are crowded together. This again confirms that there is no appreciable change in the physical or chemical characteristics of the samples on refrigeration. Variation of Z_A versus temperature for fresh and coconut water samples exposed to air at room temperature for 5 consecutive days is depicted in Fig. 2(b). There is an irregular downward shift in the curves on each successive day with the shift maximum for the sample kept on the 5th day. Since the shape and slope of the curves changes with increase in number of days, it can be assumed that both physical and chemical changes takes place in air – fermented samples. The shift and change in the shape of the curve confirms our earlier findings that there is subsequent reduction of sugar content in the samples exposed to air and conversion of sugar to alcohol takes place during fermentation.

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Variation of Z_A with temperature for yeast added sample along with fresh sample is illustrated in Fig. 2(c). Here also it can be seen that the relative shift in the yeast – fermented samples is greater when compared to air – fermented samples showing enhanced fermentation. It is observed that for air – fermented samples [Fig. 1(b)], there is a regular upward shift for β_s values on all consecutive days whereas for yeast – fermented samples the β_s values increase till the 4th day and there after it decreases on 5th day [Fig. 1(c)]. A similar abnormality is observed for Z_A values also, in which there is a regular downward shift for the curves on all five days under study for air – fermented samples [Fig. 2(b)] whereas the Z_A values decrease till the 4th day for yeast – fermented samples and then shows an increase on 5th day [Fig. 2(c)]. This may be due to the fact that the process of fermentation by yeast may have completed with increase in number of days and certain other microbiological and chemical analysis would have taken place in the sample which causes a decrease in the value of β_s and an increase in the value of Z_A on the 5th day of fermentation. This abnormal behavior shown by yeast – fermented samples has to be studied further.

5. Conclusion

It is obvious that refrigeration is an effective means of storage of food stuffs. In the present paper, a new technique Thermo – Acoustic Analysis (TAA) has been employed to study the refrigeration and fermentation effect of coconut water and has scientifically arrived at the conclusion that the physical characteristics of tender coconut water are not altered by refrigeration whereas there occurs changes in physical and chemical properties due to fermentation, which is greater for yeast – fermented samples. Also it is evident from the observations that the samples do not have any chemical or physical change in the period of present study if refrigerated. Hence TAA is an effective method to study the physico – chemical changes of any liquid samples in a given range of temperature.

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References

1. Alexia Prades, Manuel Dornier, Nafissatou Diop & Jean – Pierre Pain, *Fruits*, 67(2012)157.
2. Prithviraj V, Ravi Pandiselvan, Ardra C Babu, et.al, *LWT–Food Science and Technology*,149 (2021) 111850.
3. KulalRajashri, Navin Kumar Rastogi & Pradeep Singh Negi, *Food Reviews International*,

(2020) 1.https://doi.10.1080/87559129.2020.1847142.

4. IsaraVongluanngam, Nidhiprabha Tocharoenvanith & Kitipong Assatarakul, *J.Food ProcessPreserv*, 45 (2021) 1.https://doi.org/10.1111/jfpp.15229.
5. Chathuri Gunathunga, Sashie Abeywickrema &Senaviratne Navaratne, *International Journal of Food Science and Nutrition*, 3 (2018) 15.
6. Lavanya K, Prasad B V S, Hari Mohan Naidu B, Kalyani G et.al, *The Andhra Agric.J*, 58 (2011) 209.
7. Mithila Jayasundera & Anil Dharmasena, *Annals. Food Science and Technology*, 15 (2014)111.
8. Joseph Adubofuor, Isaac Amoah & Irene OseiBonsu, *Food Science and Quality Management*, 54 (2016) 26.
9. MalithilOmekaWelivitiyeKankanamge,ChandiYalegama&PrasannaPriyanthaGunathilake KD, *Annals. Food Science and Technology*, 18 (2017) 38.
10. Mohan Naik, Sunil C K, Ashish Rawson &Venkatachalapathy N, *Food Reviews International*, (2020) 1. https://doi:10.1080/87559129.2020.1785489.
11. Adingra Kouassi martial Didier, BrouKoffii Simeon, CamaraFatou, KouadloN'guessan Eugene Jean Parfait et.al, *International Journal of Scientific and Engineering Research*, 8 (2017) 1745.
12. Gobin A, Falade K O &Akingbala J O, *Journal of Food, Agriculture & Environment*, 7 (2009) 62.
13. Anthony R & West, *Basic Solid State Chemistry*, (John Wiley & Sons, Chichester), 1988, p.196.
14. Marcus Y, *Introduction to liquid state chemistry*, (John Wiley & Sons, New York), 1977, p.136.
15. Mohanan S, Vaidyan V K &Kurian K V, *Applied Physics Letters*, 70 (1996) 805.
16. Mohanan S, Lilly Iype, Bindu R G, Laila M et.al, *Acoustics Letters*, 24 (2001) 171.