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Discrimination of Karan Fries cow's individuality by the mean of their vocal acoustic features

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ABSTRACT

Sound is one of the most important means of conveying information over long distances as well as in close vicinity. Utterance of animals becomes unique for them when they communicate their individuality or physiological state to the other co species partner. Present study was based on hypothesis of discrimination of individual identity through vocal signal of lactating karan fries (KF) cows. For this 25 KF cows were selected for recording of their vocal signal. Vocal call was recorded after separation of animal from their living herd in the morning hours. Acoustic features of vocalization of individual cow were extracted with the help of PRAAT acoustic analysis software. Analysis of all acoustic features extracted from 250 voice samples of 25 KF cows revealed that differences for amplitude, Total energy, pitch, intensity, formants, pulse, periods, unvoiced frames, voice breaks, jitter, shimmer, mean noise/harmonic ratio and mean harmonic/noise ratio were found highly significant ($p < 0.001$). Out of these only few acoustic features *viz.* pulse, pitch, jitter, shimmer, voice break and formants were observed to have significant ($p<0.05$) difference between each and every individual KF cow. Among these feature formants frequency of every individual cow had a unique pattern in the distribution of frequency contour in their vocal spectrogram. Study concluded that vocal signal of KF cow have some unique feature at individual level, by which cow identification could be made.

Key words: Behavior, Cattle, Identification, Vocalization.

INTRODUCTION

There are many tools available to identified animals individuality and their physiological condition separately. Out of these tool vocalization could act as non invasive, remote sensing tools to identified animal individuality and make discrimination of their condition like pain, separation from the herds, estrus phase etc. vocalization provides information about the age, sex, dominance status and reproductive status of the caller (Watts and Stookey, 2000). It can be argued that vocalizations represent a form of commentary by an animal on its own internal state. The study of vocal behavior is therefore a useful means by which to investigate the physical and psychological functioning of that animal. Animals can recognize the calls of their offspring and vice versa (Clemins *et al.,* 2005; Lee *et al.,* 2006). In case of several vocal signals, the receivers can simultaneously gain information about the caller's identity, motivational state and communication context (Hauser, 1996). Vocal signal is a unique character of an individual animal on which discrimination of individuality could be possible (Yin and McCown, 2004). Few studies (Koene, 1997) have been carried out to discriminate individual animals through their unique voice signal. Therefore if animals could be identified through their vocal signal than it may potentially be used, at least in conjunction with other evidence, as clue to an individual's identity (Ikeda *et al.,* 2000). So main aim of present study was to find out those acoustic features of vocal signal by which one can discriminate dairy cattle individuality, effectively.

MATERIALS AND METHODS

In order to identify particular individual in a herd through their acoustic features and vocalization pattern, 25 Karan Fries cows were selected for voice recording purpose. Recording was done in the morning hours after separation of said animals from their herd. Their sound was recorded for a sufficient period of time so that we can get at least 50 clips (each clip including one complete vocal single made in single attempt) from the total recording of each animal. All the managemental practices (feeding, breeding, housing etc) were performed as per normal schedule of the institutional farm without any interference. Vocal signal was recorded by SONY camcorder than transfer them in to laptop for feature extraction. About 10 complete calls from each and every cow were taken for feature extraction. Following acoustic features were extracted with the help of PRAAT version 6.0.17 software.

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Parameters	Description
Call duration (S)	Total duration of vocalization
Total energy (Pa^2 s)	Energy present in a sound field. It causes mechanical vibration in any medium.
Number of Period	Period is defined as the time it takes to complete one cycle, or repetition.
Amplitude (P)	Magnitude of an oscillating quantity, it helps define the severity of the vibration
Pitch (Hz)	Subjective auditory sensation and depends on the frequency, the harmonic content
Intensity, (dB)	Sound Power per unit Area
Unvoiced Frame (%)	Frame of sound signal, where voice have noise only
Jitter (%)	Cycle to cycle frequency variation
Shimmer (%)	Cycle to cycle amplitude variation
Autocorrelation	Correlation between values of a signal at different times
Harmonic to Noise Ratio (dB)	Ratio of amplitude peaks of detectable harmonics to noise threshold
Formants, Hz (F1, F2, F3 and F4)	Local maximum frequencies in the sound spectrum

For the identification of differences between acoustic features of 25 KF cows, data were analyzed by using least squares technique (Harvey, 1987) and significance of difference among various subclass was examined by using Duncan's Multiple Range Test as Modified by Kramer (1957). Following least squares model was used to examine the significant difference between the different acoustic features of voice signals uttered by individual animals:

$$Y_{ij} = \mu + A_i + e_{ij}$$

Where Y_{ij} is the voice signal of i^{th} animal; μ is the overall mean; A_i is the effect of ith animal; e_{ij} is the residual error.

RESULTS AND DISCUSSION

The data extracted for various acoustic features from 250 voice samples of 25 KF cows were subjected to least square analysis in order to examine the significant differences between them.

Call duration, total energy, number of pulse and number of periods: Table 1 and Table 2, respectively have presented the least squares analysis of variance and least squares means for call duration, total energy, number of pulse and number of period for voice signals of KF cows. Least squares analysis of variance revealed that differences in vocal signals from KF cows for call duration, total energy, number of pulse and number of period was highly significant (p<0.001). Among all animals, KF 6592 uttered longest sound (2.28 ± 0.10 sec.) while KF 7263 had shortest sound duration (1.02 ± 0.07). Total energy of voice signal were found highest (0.13 ± 0.01 $Pascal^2$.sec) in KF 7203 while KF 7488 voice had lowest energy value (0.06 ± 0.01 $Pascal^2$.sec). Pulse is a short transient signal, which includes a complete waveform of definite shape and one which is repeated at a regular interval of time is called a periodic pulse. The voice signals obtained from KF cow 7343 was found most periodic where periodicity was observed to be 99.60 % (346.60 periodic pulse out of 348 pulses) while least periodic sound was observed in KF 6592 (92.91 % i.e. 224.2/241.3) cow.

Amplitude: In this experiment overall variation in the amplitude among all cows vocal signal were observed from -0.86 ± 0.01 to 0.86 ± 0.01 Pascal. On the basis of individual voice features, minimum variation in the amplitude was found in KF 7243(-0.59 ± 0.04 to 0.64 ± 0.06 Pascal) while maximum variation in amplitude (-0.98 ± 0.01 to 0.96 ± 0.01 Pascal) was observed in KF 6592 Range of amplitude were found highest and lowest in KF 6592 (1.95 ± 0.02 Pascal) and in KF 7243 (1.24 ± 0.09 Pascal), respectively. Overall mean value of amplitude in all experimental cows vocal signal were found -0.36 ± 0.34 Pascal.

Pitch: Least squares variance revealed that vocal signals of KF cows were differed significantly (p < 0.001) for mean, minimum, maximum and range subclasses of pitch. Mean pitch value for vocal signal of individual cow was differed significantly. However, most of the individual was not differed significantly from other individual for minimum, maximum and for range of pitch. Among all KF cow value of mean pitch was found lowest in KF 7488 (137.20 ± 1.6 Hz) while the highest values of mean pitch were observed for KF cow 6944 (292.70 ± 1.63 Hz). The highest pitch range (321.90 ± 32.78 Hz) was observed for KF 6592 while the lowest pitch range (15.60 ± 3.76 Hz) was observed for KF 7155.

Intensity: The least squares analysis of variance revealed that vocal signals of individual KF cows were differed significantly (p < 0.001) for mean, minimum, maximum and range of intensity values (Table 1). Highest fluctuation in intensity was found in KF 4390 (71.38 ± 7.05 dB to 83.17 ± 0.41 dB) while the least fluctuation in intensity (from 81.52 ± 0.31 dB to 84.54 ± 0.29 dB) was observed in KF 7263. Thus it implies that voice signals produced from KF 4390 were the least stable in nature.

Fraction of unvoiced frames, number of voice break, degree of voice break and jitter: The least squares analysis of variance revealed that vocal signals from KF cows differed significantly (p < 0.001) for various acoustic features viz. fraction of locally unvoiced frames, number of voice break, degree of voice break and jitter. Lowest value of unvoiced frames and degree of voice break were found in KF 7263 (0.00 ± 0.001) and KF cow CB 94 (0.00 ± 0.001), respectively. While, KF 6592 had highest value for both unvoiced frames (32.11 ± 5.46) and for degree of voice break (41.19 ± 7.18). Lowest value of unvoiced frame reveals that

Table 1: Least squares analysis of variance (mean squares only) for various acoustic features of KF cows.

Source of variation		Individual KF cow	Error
d f		24	225
call duration		1.38**	0.05
Amplitude (Pascal)	Mean	0.00001**	0.000013
	Minimum	0.10**	0.02
	Maximum	0.06**	0.01
	Range	0.29**	0.04
Total energy (Pascal² sec)		0.00**	0.00
intensity (dB)	Mean	35.05**	0.15
	Minimum	48.07**	22.78
	Maximum	10.61**	1.04
	Range	13.84**	5.694
pitch (Hz)	Mean	24807.09**	284.01
	Minimum	40606.95**	1693.18
	Maximum	59474.70**	8252.35
	Range	105597.06**	10038.66
Number of pulses		39927.04**	104.64
Number of periods		39839.32**	12451.28
Fraction of locally unvoiced frames (%)		466.78**	64.35
Number of voice breaks		19.50**	1.57
Degree of voice breaks (%)		793.08**	53.88
Jitter (%)		7.61**	0.03
Shimmer (%)		179.93**	0.41
Mean autocorrelation		0.08**	0.00
Mean noise-to-harmonics ratio		0.19**	0.01
Mean harmonics-to-noise ratio (dB)		349.50**	0.73
F1(Hz)		44997.33**	135.34
F2(Hz)		156662.85**	835.57
F3(Hz)		198793.10**	913.61
F4(Hz)		298147.69**	1358.70
F5(Hz)		89575.29*	57516.71

*P ≤0.05
**P ≤0.01

the voice of that particular animal was more periodic among all the animals. The jitter values (0.15 ± 0.01 %) for KF 7155 was observed lowest out of the 25 individuals it implies that the particular animal was least nervous. At the same time highest jitter (3.90 ± 0.11%) for KF 6592 revealed that her status was extremely nervousness one among all others individuals. As the difference for degree of voice breaks mean and jitter % was found to be significant for the entire 25 individuals hence it could be concluded that these acoustic features can be used in pattern recognition of KF cow.

Shimmer, Autocorrelation, NHR and HNR: It was found that least squares analysis of variance of vocal signals from all cows differed significantly ($p < 0.001$) for Shimmer, Autocorrelation, NHR and HNR values. Lowest value of Shimmer and Mean Autocorrelation were found in KF 6944 (2.68 ± 0.13) and KF 6592 (0.64 ± 0.01), respectively while, KF 6592 and KF 6944, respectively had highest value for shimmer and autocorrelation. Highest value of shimmer reveals that the voice of that particular animal was softer among all the individual cows. While, highest value of mean autocorrelation feature give the information about more coordination between all the acoustic features of vocal signal. The highest NHR and lowest HNR for KF 6592 reflected that her voice was least harmonic while the reverse values of these features (0.01 ± 0.01 % and 26.97 ± 0.94 dB) for KF 6944 indicated that its voice was most harmonic in nature. Shimmer % and HNR were found differed significantly among most of the individual cows, so theses feature could be use as pattern recognition of vocal signal for identifies individuality of dairy animals.

Formants (Resonance frequency): The least squares variance revealed that vocal signals from all KF cows differed significantly ($p < 0.001$) for all the four formants considered in our experiments (Table 1, Table 3 and Fig 1). Mean values of different formant frequencies indicated that F2, F3 and F4 formant frequencies seemed to be one fold integer multiple of fundamental frequency (F1), thus these might be harmonic overtones, Least squares mean values and Fig 1 clearly reflected that all the four formants differ significantly in all 25 KF cows; hence it can be used as one of the most suitable acoustic feature for individual identification through vocal signal processing.

Table 2: Least squares means (±SE) for Intensity (dB), Jitter (%), Shimmer (%), Mean harmonics-to-noise ratio (HNR) and Number of Pulse of individual KF cows.

Animal No.	Intensity (dB)	Jitter (%)	Shimmer (%)	HNR	Number of pulse
KF 7276	80.75^{i} ±0.23	1.36^{ef} ±0.08	11.86^{e} ±0.24	12.77^{jk} ±0.15	333.20^{f} ±3.17
KF 6592	81.30^{h} ±0.18	3.90^{a} ±0.11	18.71^{a} ±0.26	3.67^{p} ±0.16	241.30^{l} ±3.00
KF 7359	82.13^{f} ±0.11	1.73^{d} ±0.10	14.03^{c} ±0.20	9.26^{n} ±0.13	324.80^{f} ±2.53
KF 7467	80.37^{j} ±0.12	1.10^{g} ±0.04	9.60^{hi} ±0.27	13.68^{hi} ±0.07	303.00^{hi} ±10.53
KF 7234	81.59^{gh} ±0.08	1.21^{fg} ±0.06	11.83^{e} ±0.15	13.02^{ij} ±0.20	364.00^{d} ±2.11
KF CB 74	81.26^{h} ±0.12	1.48^{e} ±0.10	13.55^{cd} ±0.16	8.74^{n} ±0.14	256.80^{k} ±2.37
KF CB 94	83.61^{c} ±0.07	0.25^{lm} ±0.01	4.59^{m} ±0.14	21.80^{c} ±0.21	311.30^{gh} ±2.20
KF 6944	83.50^{cd} ±0.12	0.15^{m} ±0.01	2.68^{o} ±0.13	26.97^{a} ±0.94	296.00^{i} ±2.58
KF 7343	84.31^{b} ±0.12	0.24^{lm} ±0.01	3.90^{n} ±0.15	22.01^{c} ±0.21	348.00^{e} ±2.19
KF 7155	84.99^{a} ±0.11	0.15^{m} ±0.01	2.90^{o} ±0.20	24.92^{b} ±0.15	314.00^{g} ±2.48
KF 7263	82.60^{e} ±0.14	0.71^{hij} ±0.01	3.09^{o} ±0.17	24.89^{b} ±0.20	279.40^{j} ±1.91
KF 4390	81.71^{g} ±0.07	1.22^{fg} ±0.04	12.02^{e} ±0.21	11.85^{lm} ±0.23	355.00^{de} ±2.26
KF 4404	81.47^{gh} ±0.12	2.37^{c} ±0.07	12.07^{e} ±0.22	11.23^{m} ±0.25	346.20^{e} ±2.48
KF 4422	82.17^{f} ±0.09	1.54^{e} ±0.07	10.51^{g} ±0.18	14.88^{f} ±0.21	374.40^{c} ±2.79
KF 6774	81.32^{h} ±0.08	2.56^{b} ±0.09	16.47^{b} ±0.27	6.20^{o} ±0.15	251.40^{k} ±2.86
KF 7198	79.24^{k} ±0.10	0.88^{h} ±0.02	10.19^{gh} ±0.19	$12.22^{k\,l}$ ±0.17	327.10^{f} ±2.88
KF 7203	84.93^{a} ±0.13	0.24^{lm} ±0.01	6.85^{l} ±0.15	15.90^{e} ±0.19	310.80^{gh} ±2.62
KF 7261	80.57^{ij} ±0.09	0.69^{ij} ±0.02	9.06^{ij} ±0.19	13.07^{ij} ±0.24	283.40^{j} ±2.79
KF 7243	78.28^{l} ±0.22	0.56^{jk} ±0.02	8.40^{k} ±0.19	14.60^{fg} ±0.21	418.00^{b} ±2.18
KF 7302	79.28^{k} ±0.1	0.41^{kl} ±0.01	4.70^{m} ±0.12	18.11^{d} ±0.20	515.10^{a} ±2.27
KF 7343	83.21^{d} ±0.08	1.45^{e} ±0.07	10.03^{gh} ±0.04	13.82^{ghi} ±0.20	347.00^{e} ±2.57
KF 7350	82.22^{f} ±0.11	1.43^{e} ±0.06	11.20^{f} ±0.32	14.13^{fgh} ±0.21	409.30^{b} ±1.16
KF 7449	80.23^{j} ±0.11	1.45^{e} ±0.09	13.00^{d} ±0.20	9.23^{n} ±0.08	354.20^{e} ±2.60
KF 7488	77.79^{m} ± 0.14	0.83^{hi} ±0.02	8.99^{j} ±0.22	9.24^{n} ±0.21	253.90^{k} ±2.58
KF 7524	81.48^{gh} ±0.08	0.54^{jk} ±0.03	11.17^{f} ±0.24	11.41^{m} ±0.33	230.50^{m} ±2.78
Overall mean	81.61 ± 0.12	1.14 ± 0.06	9.66 ±0.27	14.30 ±0.37	325.92 ±3.97

Data with different superscript in the same column differs significantly from each other (p<0.05).

Table 3: Least squares means (±SE) for Formants Frequency of individual KF cows.

Animals No.	F1 (Hz)	F2 (Hz)	F3 (Hz)	F4 (Hz)
KF 7276	673.50^{o} ±2.56	1450.50^{gh} ±11.57	2618.10^{c} ±10.71	3929.70^{hi} ±6.94
KF 6592	917.20^{b} ±2.14	1663.30^{bc} ±7.74	2563.20^{d} ±8.72	3814.50^{lm} ±9.03
KF 7359	860.40^{f} ±2.38	1454.30^{gh} ±10.35	2290.70^{l} ±8.94	3875.70^{jk} ±13.07
KF 7467	803.40^{jk} ±2.29	1429.20^{h} ±8.37	2392.60^{i} ±9.33	3893.50^{j} ±13.87
KF 7234	842.50^{gh} ±2.58	1546.70^{de} ±4.48	2360.90^{jk} ±6.40	3907.50^{ij} ±8.77
KF CB 74	794.10^{k} ±1.83	1341.60^{j} ±9.46	2340.50^{k} ±9.36	3845.50^{kl} ±6.71
KF CB 94	801.10^{jk} ±2.33	1645.90^{c} ±10.07	2249.20^{m} ±8.52	3588.70^{o} ±10.80
KF 6944	745.30^{n} ±2.59	1560.00^{de} ±8.95	2345.10^{jk} ±8.68	3670.60^{n} ±8.85
KF 7343	992.90^{a} ±2.77	1648.60^{c} ±9.22	2471.70^{f} ±7.90	3782.60^{m} ±10.37
KF 7155	914.90^{bc} ±10.21	1722.10^{a} ±14.00	2546.70^{de} ±9.51	3671.10^{n} ±14.75
KF 7263	843.60^{gh} ±3.36	1428.30^{h} ±9.90	2366.20^{ijk} ±7.73	3544.20^{p} ±8.99
KF 4390	808.90^{ij} ±2.90	1517.60^{f} ±12.28	2449.30^{fgh} ±7.86	4070.90^{c} ±8.15
KF 4404	806.50^{ij} ±4.30	1377.20^{i} ±6.88	2534.00^{e} ±11.49	3959.60^{gh} ±14.22
KF 4422	782.50^{l} ±3.36	1286.50^{k} ±9.48	2427.20^{h} ±9.6	4029.40^{de} ±12.7
KF 6774	852.80^{fg} ±2.56	1574.40^{d} ±9.04	2464.70^{f} ±11.08	4135.40^{b} ±20.38
KF 7198	815.80^{i} ±2.62	1477.20^{g} ±9.54	2352.90^{jk} ±7.74	3844.40^{kl} ±10.68
KF 7203	898.50^{d} ±2.76	1458.60^{g} ±7.94	2459.80^{fg} ±10.23	3974.80^{fg} ±13.82
KF 7261	905.10^{cd} ±3.20	1538.10^{ef} ±8.89	2432.60^{gh} ±9.89	3977.30^{fg} ±11.87
KF 7243	762.80^{m} ±2.73	1667.90^{bc} ±6.31	2620.00^{c} ±10.09	3891.60^{j} ±13.02
KF 7302	806.10^{ij} ±4.00	1455.30^{gh} ±7.52	2596.30^{c} ±9.35	4033.10^{de} ±7.02
KF 7343	803.30^{jk} ±4.63	1384.20^{i} ±9.06	2373.60^{ij} ±10.39	3999.00^{ef} ±16.45
KF 7350	833.00^{h} ±5.48	1557.50^{de} ±5.43	2532.80^{e} ±9.45	4047.70^{cd} ±8.40
KF 7449	793.60^{k} ±3.05	1385.00^{i} ±9.75	2428.90^{h} ±10.72	4040.70^{cd} ±11.88
KF 7488	874.30^{e} ±2.26	1738.50^{a} ±7.75	2696.50^{b} ±10.40	4154.00^{b} ±8.78
KF 7524	918.80^{b} ±3.48	1683.10^{b} ±9.05	2885.30^{a} ±12.62	4239.40^{a} ±10.57
Overall mean	834.04 ±4.22	1519.70 ± 7.96	2472.00 ± 8.94	3916.80 ± 10.95

Data with different superscript in the same column differs significantly from each other (p<0.05).

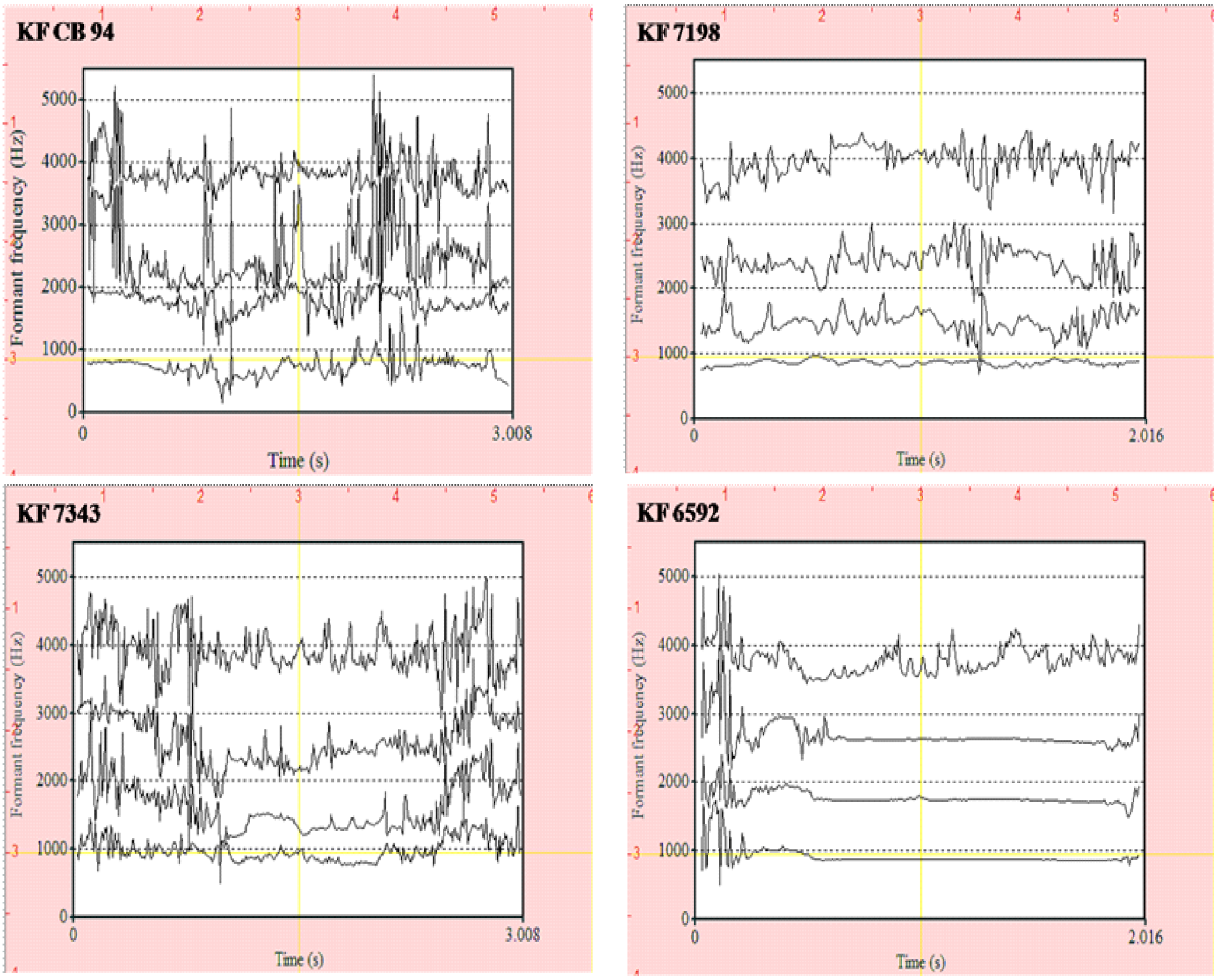

Fig 1: Comparison of Formant frequency (F1, F2, F3 and F4) contour in four KF cows for discrimination of their individuality.

Result suggests that call duration, pulse and period of vocal signal were not differing significantly at all individual bases. So these features are not good enough to consider as a discriminating acoustic features. Mean intensity and pitch play some role in individual identification through their vocal signal. This result was in the agreement of the finding of Mielke and Zuberbühler (2013) in blue monkey. Acoustic features like Degree of voice break, unvoiced frame and jitter % were seemed very crucial in this experiment. Unvoiced frame in the voice reveal the periodicity of voice hence lowest value of unvoiceness reflect more periodic sound of that particular animal. As the difference for degree of voice breaks mean and jitter % was found to be significant for the entire 25 individuals hence it could be concluded that these acoustic features can be used in pattern recognition of KF cow. Highest value of shimmer reveals that the voice of that particular animal was softer among all the individual cows. While, highest value of mean autocorrelation feature give the information about more coordination between all the acoustic features of vocal signal. NHR and HNR suggest the noisiness or hormonocity in the vocal signal of given animal. Shimmer % and HNR were found differed significantly among most of the individual cows, so theses feature could be use as pattern recognition of vocal signal for identifies individuality of dairy animals. Singh *et al.* (2013) also obtained the same result for individual identification of karan fries cow. Formants distribution in the vocal signal was differed highly significant in all individual cows. The relative raising or lowering of the formants (F1, F2, F3, etc.) depends on the length of the vocal tract, the configuration of the pharyngeal regions and oral and nasal cavities, and the opening of the mouth (Fant, 1960; Fitch and Hauser, 1995). Least squares mean values and Fig 1 clearly reflected that all the four formants differ significantly in all 25 KF cows; hence it can be used as one of the most suitable acoustic feature for individual identification through vocal signal processing as suggested by Ikeda *et al.*, (2008).

CONCLUSION

The results of this study concluded as analysis of vocalizations could be an indicator of KF cow's individuality in the large herd. Acoustic features like pulse, intensity, jitter, shimmer, HNR and Formant frequency were proved to be the best acoustic features for context independent speaker identification in dairy animals. Out of these, formants frequency was found most unique acoustic feature to discriminate individual animal through their vocal signal.

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