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PHENYLTHIOCARBAMIDE (PTC) TASTE SENSITIVITY AMONG INDIAN POPULATION WITH SPECIAL REFERENCE TO RONGMEI NAGA TRIBE OF MANIPUR, INDIA

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ABSTRACT

The taste sensitivity of Phenylthiocarbamide (PTC) among humans is a genetically inherited trait, which follows the Mendelian Law of inheritance. Its prevalence is widely studied among Indian populations but a comprehensive picture is lacking. The objective of the present study was to find out the PTC taste sensitivity in Rongmei Naga tribe of Manipur as well as to explore a comparative picture of distribution of gene among the Indian population and simultaneously to understand the association of the gene with alcoholism, tobaccoism and smoking. To achieve the objective PTC serial dilution method was used to find out the taster and non-tasters followed by computation of allele frequency using the Hardy-Weinberg methods. In addition, information on demographic details and dietary practices were also recorded. A total of 83.92% male, 87.03.09% female subjects were found to be tasters for Phenylthiocarbamide (PTC), among the Rongmei Naga Tribe of Manipur State. Allele frequency for taster TT (homozygous dominant) was found to be 0.47 whereas for non-taster (tt), it was 0.37 and for Tt (heterozygous) it was 0.26. It can be inferred from χ^2 test, odds ratio and correlation analysis that there is no association of PTC taste sensitivity with alcoholism, tobaccoism and smoking among the studied population. The tasters and non-tasters were found in the ratio of 3:1 among the Indian populations. There is wide variation in respect of prevalence of PTC taste sensitivity gene among Indians. It varies among ethnic groups, regions and states. However, the variation was found to be insignificant, as revealed by one-way-ANOVA analysis.

Keywords: Allele frequency, Mendelian trait, Tobaccoism, Alcoholism, odds ratio, One-way ANOVA.

INTRODUCTION

Taste ability among human is virtuous for survival and existence of the species. Generally, humans have five basic tastes: sweet, bitter, sour, salty, umami

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(tasty). It is essential for selection of nutritional food. Further, bitter perception has an important role, as it can protect us from ingesting toxic substances which typically taste bitter (Mueller *et al*., 2005) . In this way, it is an essential evolutionary adaptation of the dietary behaviour for the avoidance of toxic compounds present in the form of food (Kim *et al*., 2003). Phenylthiocarbamide ($C_7H_8N_2S$) (PTC) taste sensitivity is a genetic trait. It is one of the best-known Mendelian traits in human populations. The gene responsible for PTC taste sensitivity is located over chromosomes 5 and 7, in general (Depeursinge *et al*., 2010; Duffy *et al*., 2004; Tepper & Nurse, 1997), and known as TAS2R38 gene. Further, TAS2R38 polymorphisms that differ between individuals encode the functionally distinct receptor types, which directly affect the perception of bitter taste in the compounds containing N-C=S (Tepper *et al*., 2008). There are two major forms of this bitter receptor gene, which were identified in most of the world's population and designated as 'major taster' and 'major non-taster'. This is due to 3 different positions of amino acid, number 49, 262, and 296 (Sarmandal, 2012 and John *et al*., 2009). PTC taste sensitivity has been shown to be important in evolutionary perspective, forensic investigations, disease susceptibility (Davis, 1978), etc., as food selection affect metabolism and physiology at individual level (Peeples, 1962).

Many studies have indicated that PTC taste sensitivity and consumption of alcohol are associated (Peeples, 1962; Pelchat, and Danowski, 1992; DiCarlo and Powers, 1998; Durna dastan *et al*., 2015; Guo and Reed, 2001; Sao, 2017; Vinuthalakshmi *et al*., 2019; Linda and Alice, 1998). Vinuthalakshmi *et al*. (2019) mentioned that the polymorphiphism of the gene TAS2R38 is associated with PTC taste sensitivity, alcoholism, and tobaccoism. Further, the supertasters of PTC donot like drinking alcohol because they feel the oral burning and irritation from alcohol more severe than others (Bartoshuk *et al*., 1995).

Contrarily, some of the studies had not found this association, (Kranzler *et al*., 1998; Reid *et al*., 1968; Smith, 1972; Swinson, 1973). Perhaps PTC taster status may be related to the individual differences in the consequences of chronic alcohol consumption. Similarly, it may not be determined by the genetics only; food preferences and cultural tradition may also determine the use of alcohol.

The proportion of PTC tasters is highest in non-smokers and is statistically significant (Durna dastan *et al*., 2015). Hall and Blakeslee (1945) mentioned that there are four kind of effect of smoking on ability to tastes PTC, whereas (Sao, 2017) stated that there is strong correlation between non-tasters and smoking and alcoholism.

PTC taste sensitivity is a genetically inherited trait and follows the Mendelian Law of dominance. It is considered to be one of the most important genetic markers. It works as a tool which provides information about the human population diversity based on the tasting ability (Fareed *et al*., 2012). The tasters are able to taste the bitterness of the compound while the non-tasters unable to detect the actual taste of it; either they find it sweet, salty or sour in taste. The

people who can taste TSN 1 they are highly sensitive to these substances called supertasters. The genotype of such individuals can be homozygote dominant (TT) and heterozygote (Tt), respectively. The people who cannot get the taste of this substance are named as non-tasters and they have homozygous recessive (tt) genotypes (Bartoshuk *et al*., 1995; Duffy, 2004; Fox, 1932; Joiner andPerez, 2004). The allelic variation affecting the status of detecting the PTC/ Propylthiouracil (PROP) tasters are located over chromosomes 5 and 7, in general (Depeursinge *et al*., 2010; Duffy *et al*., 2004; Tepper and Nurse, 1997).

The PTC is a fundamental tool not only in genetics but it can also be employed in psychophysiology, ecology, evolution, nutrition, and even in science of education. This test is reliable to study the effects of natural selection of specific human gene and one of the fundamental traits which allows us to understand the origins of genetic variation in humans (Padmavathi, 2013). The prevalence of tasters widely varies all over the world.

In some of the populations, especially in north-eastern states of India, high prevalence of PTC tasters (92.4%) were reported, especially among the Naga tribe of Manipur (Shah and Afzal, 2015). Naga is one of the largest tribal group of North-East India. They are divided into many small groups. For the present investigation, a group of Naga tribe known as Rongmei Naga were selected. They reside in Assam, Manipur and Nagaland. In the recent past, they were known as "Head hunters". Currently, there are around 66 groups of the Naga tribe. Most of them have adopted Christianity (Tohring, 2010 and Samson, 2012).

Manipur is geographically beautiful place as well as culturally and naturally very rich. The state is known for unique tradition and culture. The staple food of the state is rice. Chicken, Meat and Pork are favourite non vegetarian diet of the people of Manipur. Among Naga tribe, drinking of rice-beer is part and parcel of their cultural tradition.

Since long, the North-eastern part of India and its inhabitants are geographically and culturally secluded. They were always subject of general as well as academic curiosity. Still there are unexplored areas of culture or bio-cultural aspect. This region is cradle for a large number of indigenous populations. Among these indigenous populations, the Naga tribe is unique and subject of interest for different disciplines, including Anthropology and Human Genetics. The objective of present study was to investigate the prevalence of allele frequencies of PTC taste sensitivity among the Rongmei Naga Tribals of Manipur State of India and to find out the relationship of PTC taste sensitivity with alcoholism, smoking and tobacco chewing as well as to compare the present findings with studies among other Indian populations of different states.

MATERIALS AND METHODS

For present investigation, a sample survey was conducted during December,

2017 to January, 2018 for PTC taste sensitivity among Rongmei Naga Tribe living at Tarung Village, Imphal-West District. A total of 110 individuals, including 56 males and 54 females, aged 18 to 60 years were randomly selected to fulfil the purpose of the research. For data collection, we ensured that all procedures contributing to this work fulfilled the ethical guideline as per Helsinki Declaration of 1975 (Li *et al*., 2018). All participants were told about the objectives of this research, followed by their verbal or written consent.

An interview Schedule was designed which included socio-economic details. Before, PTC taste, the interview schedule was filled which contained: name, age, sex, occupation, food habits and other general and basic information. In addition, the schedule contained information about alcohol consumption, tobacco chewing and smoking, etc.

Table 1. Threshold number and concentration of PTC Solution

Threshold Number	PTC mg/1000 ml
14	1300
13	650
12	325
11	162.5
10	81.25
9	40.625
8	20.313
7	10.156
6	5.078
5	2.539
4	1.27
3	0.635
2	0.317
1	Distilled water

The serial dilution method was used to distinguish tasters, following the technique provided by Harris and Kalmus (1949). A solution of 0.13% of PTC was prepared by dissolving 130 mg of the material into 100 ml of the water (solution 14). The serial dilution from 14 through 1 was prepared taking 50 ml solution and adding 50 ml of distilled water to it, to make the solution 13; which was diluted to half of 14. In this way, the last solution was the most diluted and designated as solution no. 1 (Hussain *et al*., 2013). Different concentrations of PTC solutions are displayed in Table-1. The dilution is used for noting the threshold value. The solution number when tasted positive was recorded as a threshold number. If a participant did not taste even solution 14 (highly concentrated: 1300 mg/litre), then he/she was designated as non-taster. After the test, the participant was asked to spit out the chemical and rinse the mouth with normal water (Fareed *et al*., 2012; Harris and Kalmus, 1949; Hussain *et al*., 2013; Iqbal *et al*., 2006).

To find out the comparative prevalence of PTC gene, taster and non-taster among Indian populations, an extensive literature survey was carried out. A total of 21 sources were found to have information about 93 ethnic groups of 12 states based on a sample size of 22823 populations. This data was entered into excel worksheet for its further computation. SPSS software was used to analyse the data.

Statistical Analysis

Mean, Median, Mode, Standard Error, Standard Deviation (SD), Percentile, Kurtosis and Skewness were calculated by using SPSS and Excel Softwares. Chi-square test, OR (odds ratio) and correlation analysis was used to find out the association of PTC with addiction of alcoholism, smoking and tobaccoism. Similarly, One-way ANOVA analysis was computed to find out the variation of allele frequency among different Indian populations.

Allele frequency is measured by Hardy-Weinberg equation:

$$[p2 + 2pq + q2 = 1]$$

[Where 'p' is the frequency of dominant allele 'T'; and 'q' is the frequency of recessive allele 't'].

The PTC tasting allele (TT & tt) and the number of non-tasters (tt) were counted. This is q2. After determining q2, p2 can was calculated and finally the frequency of dominant allele and recessive allele were determined.

RESULTS

It is evident from Table-2 that among Rongmei Naga tribe of Manipur a total of 85.4% population were found tasters for PTC and 14.6% were non-tasters. There is slight variation between male and females with respect to PTC taste sensitivity. A total of 87.03% females were found to be tasters as compared to 83.92% males. The allele frequency was computed using Hardy-Weinberg law. It is apparent that the tasters constitute large proportion of the population with allele frequency homozygous dominant (TT= 0.47) and the non-taster are possessing recessive gene of the trait with an allele frequency of (tt=0.31) as well as the Heterozygous allele (Tt=0.29). In general, it could be inferred that the prevalence of tasters was almost three fourth of the sample as compared to the non-tasters. It can also be concluded that in the present sample, the inheritance of PTC taste sensitivity gene is as per Mendel's law of inheritance.

Table 2: Allele Frequency of PTC among Rongmei Naga Tribe of Manipur

Gender		Phenotype Distribution				Allele Frequency		
		Taster		Non-Taster		TT	*Tt*	Tt
	Sample size	N	%	N	%			
Male	**56**	47	83.92	9	16.08	0.36	0.28	0.40
Female	**54**	47	87.03	7	12.97	0.38	0.28	0.38
Total	110	94	85.4	16	14.6	0.47	0.29	0.31

TT = (AA) Homozygous dominant; Tt = (Aa) Heterozygous; tt = (aa) Homozygous recessive

The prevalence of tasters, as per threshold number of the solution, is displayed in Figure-1 and Figure-2, respectively, for male and females. It is evident that the solution number 7, 8 and 9 is threshold for largest proportion of male population whereas for females it is solution number 7 to 11.

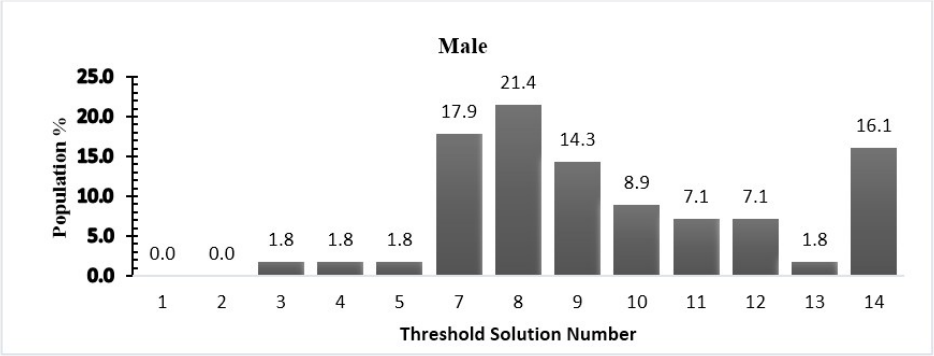

Figure 1: Histogram showing prevalence of male tasters as per TSN among Rongmei Naga Tribe of Manipur

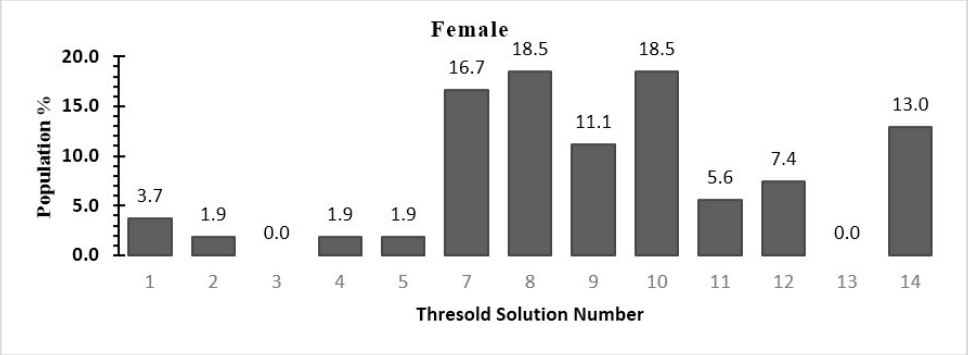

Figure 2: Histogram showing prevalence of female tasters, as per TSN, among Rongmei Naga Tribe of Manipur.

For further elaboration, Kaplan-Meier curve was drawn to understand the difference of level of threshold between males and females as well as prevalence of population on a particular level of threshold. It can be seen that prevalence of PTC taste sensitivity was highest at solution numbers 8 followed by 7, 9, 10, 11 and 12 (Figure-3). There is cumulative prevalence of PTC tasters for each threshold level. The solid line is representing the population of males, whereas dotted line is representing the prevalence of females. The height of vertical line indicates the prevalence at a particular solution number, e.g. it is highest for solution number 8, which indicates that most of participants have threshold number 8. Simultaneously, Kaplan meier curve also indicates that 50% of the population has threshold numbers in between 1 to 8.

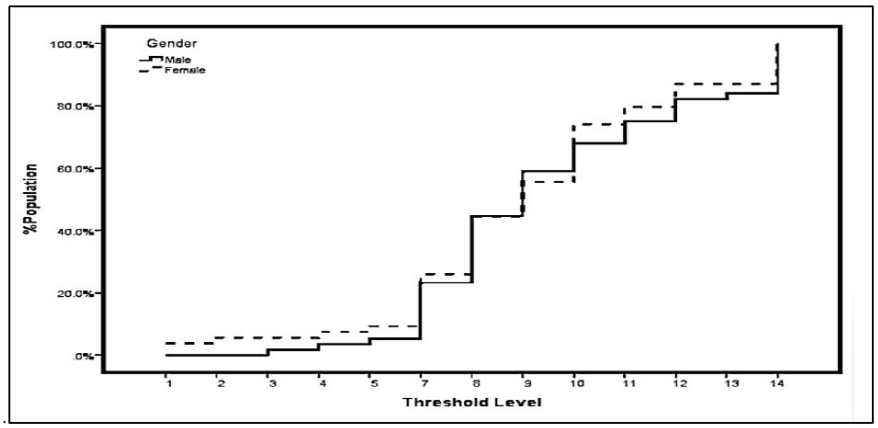

Figure 3: Kaplan-Meier curve showing Prevalence of PTC taste Sensitivity at different threshold level among Rongmei Naga Tribe of Manipur

Relationship of dietary preference and addiction to PTC taste sensitivity

Alcoholism and PTC: PTC taste sensitivity may affect dietary preferences and addiction to alcoholism, tobaccoism and smoking (Durna dastan *et al*., 2015). Hence to find out the correlation between addictions and this genetic trait an analysis is presented. Distribution of tasters and non-tasters, according to practice of alcoholism, is presented in Table-3. It has been found that 19.1% of the alcoholics and 80.9% non-alcoholics are PTC taster, while 18.8% of the alcoholic and 81.3% non-alcoholics belongs to PTC non- taster group. To understand the associated between PTC sensitivity and consumption of alcohol, a chi- square test was performed, which was not significant at ($\chi^2 = 0.06$, df = 1, P $\geq$ 0.05). Similarly, the odds ratio was also found to be nonsignificant. Hence it can be inferred that there is no association between PTC taste sensitivity and alcoholism.

Table 3: Alcoholism and PTC Taste Sensitivity among Rongmei Naga Tribe of Manipur

	Taster		Non-Taster		Total	
	N	*%*	**N**	*%*	**N**	***Chi-square Test***
Alcoholic	18	19.1	3	18.8	21	$\chi^2 = 0.06$
Non-Alcoholic	76	80.9	13	81.3	89	
Total	94	100	16	100	110	

Chi-square tests is not significant (P $\geq$ 0 .001)

Tobacco Chewing and PTC: It is apparent from Table-4 that 29.8% tobacco chewers and 70.2% non-chewers are tasters, while 18.8% tobacco chewers and 81.3% non-chewers are non-tasters. The chi-square test was found to be not significant ($\chi^2 = 0854$, *df= 1, P = 0.364*). Hence it can be inferred that PTC taste sensitivity has no association with tobacco chewing.

Table 4: PTC Taste sensitivity and tobacco chewing among Rongmei Naga Tribe of Manipur

	Taster		Non-Taster		Total	
	N	%	N	%	N	*Chi-square Test*
Tobacco chewer	28	*29.8*	*3*	*18.8*	31	χ^2= *0.854*
Tobacco non-chewer	66	70.2	13	81.3	79	
Total	94	100	16	100	110	

Chi-square tests is not significant (P $\geq$ 0 .001)

Smoking and PTC: The distribution of sample as per PTC taste sensitivity and prevalence of smoking is presented in Table-5. It is evident that 12.8% of smokers and 87.2% of non-smokers are PTC tasters, whereas 12.5% of smokers and 87.5% of non- smokers are non-tasters. The chi-square test was not significant (χ^2*=0.006, df = 1, P* $\geq$ *0.001)*.

Table 5: PTC Taste Sensitivity & Smoking among Rongmei Naga Tribe of Manipur

	Taster		Non-Taster		Total	
	N	%	N	%	N	*Chi-square Test*
Smoker	12	*12.8*	2	*12.5*	14	χ^2= *0.006*
Non-Smoker	82	87.2	14	87.5	96	
Total	94	100	16	100	110	100

Chi-square tests is not significant (P $\geq$ 0 .001)

Univariate logistic regression analysis was computed to know the association between PTC taste sensitivity and addiction habits, such as smoking, alcoholism and tobacco chewing. The findings are displayed in Table-6. It is evident that there was no significant association (p>0.05) between PTC taste sensitivity and the addiction habits under consideration.

Table 6. Univariate logistic regression analysis and correlation of addiction habits among Rongmei Naga Tribals of Manipur

	Odds ratio	**95% confidence**	**P value**
Smoking (Yes/ No)	1.33	0.43- 4.13	0.621
Alcoholic (Yes/ No)	2.24	0.825- 6.07	0.110
Tobacco chewing (Yes/ No)	1.49	0.646- 3.46	0.352
Non-tasters	1.24	0.497-0.827	0.648
Tasters	0.96	0.827-1.125	

Table 7: State wise mean prevalence of PTC tasters and non-tasters among Indian Populations

State of studies	Number of population	Sample (N)	Taster %		Non-Taster%		TT		Tt	
			MEAN	SD	MEAN	SD	MEAN	SD	MEAN	SD
Andhra Pradesh	5	815	76.94	5.74	23.06	5.74	0.53	0.06	0.47	0.06
Assam	3	668	64.63	2.86	35.70	3.26	0.41	0.02	0.59	0.02
Delhi	2	549	73.10	3.25	26.90	3.25	0.48	0.03	0.52	0.03

Gujarat	3	595	55.60	9.58	44.40	9.58	0.34	0.07	0.66	0.07
J & K	6	979	76.73	4.29	23.28	4.27	0.52	0.04	0.48	0.04
Karnataka	7	6564	67.74	8.85	32.26	8.85	0.44	0.09	0.56	0.09
Madhya Pradesh	2	325	60.10	2.40	39.90	2.40	0.37	0.02	0.63	0.02
Maharashtra	3	444	63.08	14.28	36.92	14.28	0.40	0.13	0.60	0.13
Manipur	7	1399	78.18	9.29	21.82	9.29	0.54	0.11	0.46	0.11
Rajasthan	1	235	80.40	-	19.60	-	0.56	-	0.44	-
Uttar Pradesh	58	13734	73.44	8.59	26.56	8.59	0.50	0.09	0.50	0.09
WestBengal	1	106	61.70	-	38.30	-	0.38	-	0.62	-
Orissa	4	592	48.95	9.15	51.04	9.15	0.29	0.06	0.71	0.07
Total	102	29979	71.37	10.35	28.64	10.36	0.48	0.10	0.52	0.10
F-value of one way ANOVA			5.332	5.344	4.118	4.182				

Note: F Values are significant (df= 12, P≤ 0.001)

PTC taste sensitivity among various Indian populations

It is evident from Table-7 that the PTC taste sensitivity has been widely studied throughout the Indian Union. A total of 29789 populations, belonging to 102 different ethnic groups, of 13 states have been screened in the past for the presence of the gene out of which 71.37% were tasters and 28.64% were non-tasters.

There is wide variation in the prevalence of PTC taste sensitivity gene among different ethnic groups of different Indian states, with highest prevalence of tasters (92.4%) reported among Naga tribe of Manipur by Shah and Afzal, (2015) followed by Rajput and Kshatriya of Uttar Pradesh with 91% and 89%, respectively, of tasters. The lowest prevalence of tasters (48%) was reported among Kapol Vaniya of Gujarat (Vyas, *et al.*, 2001).

To understand the regional variation in PTC taste sensitivity, the data was classified into state wise prevalence of the trait, which is displayed in Table-8. It is apparent that Rajasthan and West Bengal is represented by single study and small sample size, remaining states are represented by two or more studies and comparatively larger sample sizes. The prevalence of tasters was found highest for Rajasthan (80.4%), followed by Manipur (78.18%), Andhra Pradesh (76.94%) and so on (Figure-4). The lowest prevalence of taster was reported from Gujarat (55.60%). The regional variation was found to be non-significant with low F-value of One-way ANOVA.

Table 8: Year-wise distribution prevalence of PTC Tasters and Non-tasters

Years	Number of studies	Sample Population (N)	PTC Taster		PTC Non-Taster		TT		Tt	
			Mean	SD	Mean	SD	Mean	SD	Mean	SD
1956- 1960	12	1344	68.667	54.884	43.333	34.885	0.395	0.084	0.605	0.084
1961-1970	8	741	66.500	34.583	26.125	19.730	0.500	0.092	0.500	0.092
1971-1980	13	2795	155.000	80.522	60.000	40.544	0.486	0.097	0.514	0.097
1981-1990	2	325	97.500	4.950	65.000	9.899	0.370	0.019	0.631	0.019
2001-2010	7	7951	865.571	830.392	341.429	322.104	0.450	0.100	0.547	0.097
2011-2019	60	16823	208.350	235.894	72.033	84.905	0.496	0.096	0.505	0.097
Total	102	29979	72.498	9.310	27.513	9.319	0.487	0.092	0.512	0.092
F* value of One-way ANOVA			3.063*	3.050*	3.58*	2.997*				

Note: *All F value are significant (df= 15, P≤0.001)

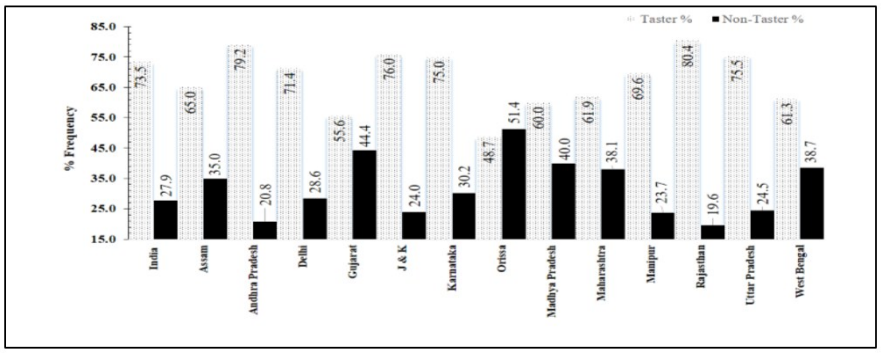

Figure 4: State wise mean prevalence of PTC tasters and non-tasters among Indian Populations.

Further, to understand the temporal trend of the gene among Indian population, the data has been classified into 6 decadal periods from 1956 to 2018 and the mean and standard deviation of prevalence of tasters and non-tasters as well as the allele frequency is presented in Table-9. The highest number of studies was reported during 2011 to 2019; whereas during 1981 to 2010 only nine studies were reported. The population coverage was also higher during 2011 to 2019. One-way ANOVA was computed to understand the temporal variation of the trait and it was found significant for four variables, i.e., prevalence of tasters (F=3.063,), non-tasters (F=3.050), allele frequency of TT (TT+Tt) (F=3.056) and tt (F=2.997) at df= 5, $P \leq 0.05$.

Table 9: State and population-wise distribution of prevalence of PTC taste sensitivity from 1956 to 2019

State/ Population	PTC Taster		Non- Taster		Sample Size (N)	Allele Frequency		Source
	N	%	N	%		TT	Tt	
Assam								
Muslims	186	64.4	89	32.6	275	0.432	0.568	Sengupte, (1980)
Vashya	117	61.9	72	39.1	189	0.384	0.616	Sengupte, (1980)
Brahmins	227	67.6	124	35.4	351	0.406	0.594	Sengupte, (1980)
Andhra Pradesh								
Brahmins	132	75.0	33	25.0	165	0.553	0.447	Chandraiah & Bahadur, (1979)
Reddis	151	82.5	32	17.5	183	0.590	0.410	Chandraiah & Bahadur, (1979)
Miuslims	108	82.4	23	17.6	131	0.553	0.447	Chandraiah & Bahadur, (1979)
Weavers	85	75.9	27	24.1	112	0.509	0.491	Chandraiah & Bahadur, (1979)
Schedule Caste	53	68.8	24	31.2	77	0.442	0.558	Chandraiah & Bahadur, (1979)
Delhi								
Rajputs	52	75.4	17	24.6	69	0.505	0.495	Delhi University, (1961)
Sondhi	340	70.8	140	29.2	480	0.461	0.539	Kerle, (1971)
Gujarat								
Shedule Caste	101	51.8	94	48.2	195	0.307	0.694	Vyas *et al.,* (1958)
Kapol Vaniya	97	48.5	103	51.5	200	0.282	0.718	Vyas *et al.,* (1958)
Lad Vaniya	133	66.5	67	33.5	200	0.422	0.578	Parikh *et al.,* (1969)
Jammu and Kashmir								
Gujjar and Bakarwal	167	69.30	74	30.7	241	0.450	0.550	Fareed *et al*., (2012)
Mughal	106	74.60	36	25.4	142	0.500	0.500	Fareed *et al.*, (2012)
Khan	133	77.10	39	22.9	172	0.530	0.470	Fareed *et al.*, (2012)
Malik	114	78.60	31	21.4	145	0.540	0.460	Fareed *et al.*, (2012)
Mir	120	79.50	31	20.5	151	0.550	0.450	Fareed *et al.*, (2012)
Syed	104	81.30	24	18.8	128	0.570	0.430	Fareed *et al.*, (2012)
Karnataka								
Unbiased	1086	84.84	194	15.16	1280	0.611	0.389	(Malini *et al* ., 2007)
Hindu	875	63.26	508	36.74	1383	0.374	0.606	(Malini *et al* ., 2007)

Muslims	466	58.15	195	41.85	466	0.354	0.646	(Malini *et al* ., 2007)
Cristian	153	64.70	54	35.30	153	0.406	0.594	(Malini *et al* ., 2007)
Total	3282	71.03	951	28.97	3282	0.462	0.538	(Malini *et al* ., 2007)
NA	710	61.6	442	38.40	1152	0.384	0.616	(Malini *et al* ., 2007)
NA	1286	70.6	536	29.41	1822	0.470	0.530	Shivaprasad *et al.*, (2012)
Orissa								
Kuntu	57	62.0	35	38.0	92	0.384	0.616	Vinuthalakshmi, (2019)
Ontu	30	42.3	41	57.7	71	0.259	0.759	Vinuthalakshmi, (2019)
Soppu	57	42.9	76	57.1	133	0.249	0.751	Vinuthalakshmi, (2019)
Konds	144	48.6	152	51.35	296	0.284	0.716	Vinuthalakshmi, (2019)
Madhya Pradesh								
Shia (Muslims)	94	61.8	58	38.2	152	0.383	0.617	Khan, (1984)
Sunni (Muslims)	101	58.4	72	41.6	173	0.356	0.644	Khan, (1984)
Maharashtra								
Khastha	107	53.5	93	46.5	200	0.318	0.682	Sanghvi & Khanolker, (1977)
Chareseniya	105	79.5	27	20.5	132	0.548	0.452	Mukharjee *et al.*, (977)
NA	63	56.3	49	43.8	112	0.340	0.660	(Rathod *et al.*, 2016)
Manipur								
Sheikh	318	73.3	116	26.7	434	0.481	0.519	Shah & Afzal, (2015)
Pathan	173	64.1	97	35.9	270	0.401	0.599	Shah & Afzal, (2015)
Syed	120	73.6	43	26.4	163	0.486	0.514	Shah & Afzal, (2015)
Moghul	61	76.3	19	23.8	80	0.513	0.487	Shah & Afzal, (2015)
Meiter	120	82.2	26	17.8	146	0.578	0.422	Shah & Afzal, (2015)
Naga	181	92.4	15	7.7	196	0.723	0.277	Shah & Afzal, (2015)
Ronmei Naga Tribe	**94**	**85.5**	**16**	**14.5**	**110**	**0.620**	**0.380**	**Present Study**
Rajasthan								
Rajputs	189	80.4	46	19.6	235	0.560	0.440	Luxmi & Kapoor, (2001)
Uttar Pradesh								
Brahmins	52	75.4	17	24.6	69	0.504	0.496	Shrivastav, (1959)
Kayasthas	39	75.0	13	25.0	52	0.500	0.500	Shrivastav, (1959)
Vaishya	33	62.3	20	37.7	53	0.386	0.614	Shrivastav, (1959)
Khattri	21	70.0	9	30.0	30	0.452	0.548	Shrivastav, (1959)
Muslims	41	61.2	26	38.8	67	0.377	0.623	Shrivastav, (1959)
Hindus	38	52.1	35	48.0	73	0.318	0.683	Shrivastav, (1959)
Rajput	41	91.2	4	8.9	45	0.702	0.298	Shrivastav & Tyagi (1967)
Muslims	31	79.5	8	20.5	39	0.547	0.453	Shrivastav & Tyagi (1967)
Brahmins	97	73.5	35	26.5	132	0.488	0.512	Shrivastav & Tyagi (1967)
Khattris	53	71.1	22	29.0	75	0.462	0.538	Shrivastav & Tyagi (1967)
Kayasthas	81	71.1	33	29.0	114	0.462	0.538	Shrivastav & Tyagi. (1967)
Vaishyas	44	65.7	23	34.3	67	0.414	0.586	Shrivastav & Tyagi, (1967)
Brahmins	81	75.0	27	25.0	108	0.500	0.500	Sirsat, (1956)
Gujjars	34	49.3	35	50.7	69	0.288	0.712	Seth *et al.*, (1969)
Punjabi	222	68.9	100	31.0	322	0.442	0.558	Sharma, (1959)
Rastogi	268	89.3	32	10.7	300	0.677	0.323	Rastogi, (1975)
NA	136	68.0	64	32.0	200	0.440	0.560	T&om & P&ey (1978)
Syed	126	73.3	46	26.7	172	0.484	0.516	Hussain *et al.*, (2014)
Sheikh	106	67.5	51	32.5	157	0.431	0.569	Hussain *et al.*, (2014)
Pathan	77	64.2	43	35.8	120	0.402	0.598	Hussain *et al.*, (2014)
Sherwani	68	70.1	29	29.9	97	0.455	0.545	Hussain *et al.*, (2014)
Shia	76	67.9	36	32.1	112	0.679	0.321	Hussain *et al.*, (2014)
Ansari	92	56.4	71	43.6	163	0.341	0.659	Hussain *et al.*, (2014)
Brahmins	228	75.5	74	24.5	302	0.500	0.500	Singh & Singh, (2011)
Kshatriya	183	89.7	21	10.3	204	0.680	0.320	Singh & Singh, (2011)
OBC	205	67.4	99	32.6	304	0.520	0.480	Singh & Singh, (2011)
Schedule Caste	31	62.0	19	38.0	50	0.430	0.570	Singh & Singh, (2011)
Kayasthas	46	76.7	14	23.3	60	0.380	0.620	Singh & Singh, (2011)
Muslims	397	75.2	131	24.8	528	0.500	0.500	Singh & Singh, (2011)
Hindus	693	75.3	227	24.7	920	0.500	0.500	Singh & Singh, (2011)
Brahmins	223	79.8	57	20.2	280	0.550	0.450	Singh & Singh, (2011)
Kshatriya	198	85.3	34	14.7	232	0.620	0.380	Singh & Singh, (2011)
OBC	221	73.2	81	26.8	302	0.480	0.520	Singh & Singh, (2011)
Schedule Caste	53	60.9	34	39.1	87	0.370	0.630	Singh & Singh, (2011)
Kayasth	80	76.9	24	23.1	104	0.520	0.480	Singh & Singh, (2011)
Muslims	249	78.5	68	21.5	317	0.540	0.460	Singh & Singh, (2011)
Hindus	806	72.7	303	27.3	1109	0.480	0.520	Singh & Singh, (2011)
Brahmins	159	77.2	47	22.8	206	0.520	0.480	Singh & Singh, (2011)
Kshatriya	162	86.2	26	13.8	188	0.630	0.370	Singh & Singh, (2011)
OBC	191	74.6	65	25.4	256	0.500	0.500	Singh & Singh, (2011)
Schedule Caste	69	65.1	37	34.9	106	0.410	0.590	Singh & Singh, (2011)
Kayasthas	64	77.1	19	22.9	83	0.520	0.480	Singh & Singh, (2011)
Muslims	228	78.9	61	21.1	289	0.540	0.460	Singh & Singh, (2011)
Hindus	739	78.0	209	22.0	948	0.530	0.470	Singh & Singh, (2011)
Brahmins	204	78.5	56	21.5	260	0.540	0.460	Singh & Singh, (2011)
Kshatriya	198	85.3	34	14.7	232	0.620	0.380	Singh & Singh, (2011)
OBC	189	84.8	34	15.2	223	0.610	0.390	Singh & Singh, (2011)

Schedule Caste	51	69.9	22	30.1	73	0.450	0.550	Singh & Singh, (2011)
Kayasthas	45	80.4	11	19.6	56	0.560	0.440	Singh & Singh, (2011)
Muslims	176	80.0	44	20.0	220	0.550	0.450	Singh & Singh, (2011)
Hindus	798	79.3	208	20.7	1006	0.550	0.450	Singh & Singh, (2011)
Brahmins	193	72.3	74	27.7	267	0.470	0.530	Singh & Singh, (2011)
Kshatriya	142	67.9	67	32.1	209	0.430	0.570	Singh & Singh, (2011)
OBC	152	76.8	46	23.2	198	0.520	0.480	Singh & Singh, (2011)
Schedule Caste	52	75.4	17	24.6	69	0.500	0.500	Singh & Singh, (2011)
Kayasthas	74	76.3	23	23.7	97	0.510	0.490	Singh & Singh, (2011)
Muslims	239	68.7	109	31.3	348	0.440	0.560	Singh & Singh, (2011)
Hindus	770	79.8	195	20.2	965	0.550	0.450	Singh & Singh, (2011)
West Bengal								
NA	65	61.7	41	38.3	106	0.380	0.620	Bhattacharjee, (1956)
Statistical Summary								
Total (N)	22826		8351		29979			
Minimum	21.0	42.3	4.0	7.7	30.0	0.249	0.277	
Maximum	2580.0	92.4	951.0	57.7	3282.0	0.723	0.759	
Mean	216.9	71.4	81.9	28.6	293.9	0.477	0.523	
Median	120.0	73.3	42.0	26.7	172.0	0.485	0.515	
Mode	52.00[a]	62.00[a]	34.00[a]	14.70[a]	69.00[a]	0.500	0.500	
Std. Deviation	330.2	10.4	126.3	10.4	432.5	0.099	0.099	
SE of Mean	32.7	1.0	12.5	1.0	42.8	0.010	0.010	
Skewness	4.5	-0.6	4.4	0.6	4.3	-0.003	0.027	
Kurtosis	26.8	0.3	24.5	0.3	23.8	-0.039	0.019	
Percentiles								
10^{th}	41.9	56.9	17.0	15.9	67.6	0.345	0.389	
25^{th}	64.8	64.6	26.0	21.5	102.3	0.406	0.458	
75^{th}	199.5	78.5	77.3	35.3	276.3	0.542	0.594	
95^{th}	804.8	86.1	291.6	50.3	1145.6	0.670	0.709	

DISCUSSION

The high prevalence of PTC tasters among the studied population is deviation from Mendel's law of inheritance, although the present findings are similar to previous studies conducted among various Indian populations as well as global populations (Cohen and Ogdon, 1949). When two racial groups are compared, they differ in phenotype as they differ in genotype, because allele frequencies for the bitter taste gene, TAS2R38, vary by racial/ethnic group (Shah and Afzal, 2015). Many genetic factors like mutation, natural selection, inbreeding, genetic drift and miscegenation play important role in producing the variation in the gene frequency (Wooding *et al*., 2004). There is difference in PTC sensitivity between different communities depending on ethnic differences, variations in the experimental group and homogenization.

In the present study, the dominating threshold number are 8 and 10. The comparison of some of the previous studies suggest that the level of PTC threshold is a random gene process which is not depended on a single factor. Olson *et al*. (1989) and Reddy *et al*. (1989) found that variability in thresholds is controlled by a major locus with incomplete dominance as well as by a multifactorial component. The data fitted in a two-locus model in which one locus controls PTC tasting and the other locus controls general taste ability (Salmon and Blakeslee, 1935). The tasters and non-tasters were essentially a reflection of the bimodal distribution of taste thresholds. Falconer (1954) and Hartmann (1939) pointed out that one of the difficulties which arise out of this method is that people differ in the degree of sensation, which they consider to be a positive taste and lowest concentration at which an individual recorded a distinct taste was regarded as the threshold. In the present study, threshold solution numbers

8 and 10 have higher prevalence whereas Luxmi *et al*. (2017) have reported that 9 and 4 threshold solution numbers are highly active and Hussain *et al*. (2013) concluded that the threshold numbers 6, 7 and 8 were highly diluted in both genders. There can be many reasons of it, such as aging, nutrition, environment, etc. (Harris and Kalmus, 1949). Fisher *et al*. (1939) had hypothesized that PTC perception is due to balancing natural selection.

Many studies have reported that, in world population, the ratio of taster and non-taster is 3:1and approximately 70% are tasters and 30% are non-tasters (Drayna, 2005; Durna dastan *et al*., 2015; Shivaprasad *et al*., 2012). But there is a wide variation in the distribution of tasters and non-tasters. The prevalence of non-tasters varies from 2.3-36.5% (Africa), 5.1-23% (China), 4.8-66.7% (India), 2.0-27.5% (Asia), 4.1-20.0% (Turkey), 49.3-50.0% (Australia), 6.9-36.8% (Europe) and 0.0-43.0 (USA), respectively (Allison and Blumberg, 1959; Durna dastan *et al*., 2015; Enoch *et al*., 2001; Tepper, 1998; Tepper & Nurse, 1997; Saraswathi *et al*., 2011). Further, the prevalence of PTC tasters among Caucasian of Western Europe and North American population was around 70% (Cohen and Ogdon, 1949). The range of PTC Tasters in American Caucasians varies from 60% to 82% (Allison & Blumberg, 1959; Guo and Reed, 2001; Enoch *et al*., 2001; Tepper, 1998; Tepper and Nurse, 1997; Saraswathi *et al*., 2011). Among White North Americans approximately 30% of non-tasters were reported. According to Singh, *et al*. (1994), among Mongoloid population, like Himalayan from the Western to Eastern end, 80% are PTC tasters. Similarly, 80% of tasters were also reported among Indian tribes, viz. Siddis (Shivaprasad *et al*., 2012). In contrast, frequency of non-tasters is very high, approximately 40-60%, among the tribal population of Central India (Shivaprasad *et al*., 2012). The countrywide review presented in Table-7 clearly indicates that there is wide variation in the prevalence of PTC taste sensitivity gene among different ethnic groups of different states of India with highest prevalence of tasters (92.4%) reported among Naga tribe of Manipur by Shah and Afzal (2015) followed by Rajput and Kshatriya of Uttar Pradesh with 91% and 89% of tasters, respectively. The lowest prevalence of tasters (48%) was reported among Kapol Vaniya of Gujarat (Vyas, *et al*., 2001). In comparison, the mean prevalence of tasters and non-tasters, for Indian population, was computed to be 72.5% and 27.5%, respectively.

Hence, it can be concluded that the present findings corroborate previous findings, especially in reference to prevalence of tasters and non-tasters, as 85.4% of the Rongmei Naga tribe of Manipur State were diagnosed as taster.

There are many studies focusing on the distribution of taster phenotypes and non-tasters among the different geographic locations in India (Malini *et al*., 2010; Padmavathi, 2013: Krishnamoorthy, 2013). Among Indian population, the relationship between PTC taster status has been linked to various parameters like, alcoholism, tobacco chewing (Shivaprasad *et al*., 2012), Epilepsy (Pal *et al*., 2004), premenstrual syndrome (Sharma *et al*., 2013), adolescent growth trends, (Sharma and Kaur, 2014) early childhood caries (Pidamale *et al*., 2012),

and obesity (Deshaware and Singhal, 2017; Gupta *et al*., 2018; Veluswami *et al*., 2015).

There is a significant positive correlation between PTC tasting ability with alcoholism (71%) (DiCarlo and Powers, 1998). DiCarlo and Powers also reported that non-tasters are more prone to alcohol consumption than taster group (Drayna, 2005). According to previous studies, the supertasters of PTC donot like drinking alcohol that much and it has been thought that they feel the oral burning and irritation from alcohol more severely than others. Various authors (Vinuthalakshmi *et al*., 2019; Durna dastan *et al*., 2015; Sao, 2017) reported that PTC taste sensitivity and perception of alcohol, smoking and tobacco addiction is statistically significant but in the present investigation it was found otherwise (χ^2 value is less and insignificant). The contradiction was also reported by Durna dastan *et al*., (2015) in reference to the previous studies.

In this way, addiction to alcoholism, tobacco chewing and smoking was found to be determined by a number of factors, e.g., age, cultural practices, socio-economic status, level of education, geo-climatic conditions, etc. Singh & Ladusingh (2014) highlighted that tobacco use was higher among males, the less educated, the poor, and the rural population in India. It also varies from state to state (Thakur and Paika, 2018). In tribal societies, alcoholism is part of their cultural tradition (Neufeld *et al*., 2005) rather than its biological association.

People from scheduled castes and tribes were 1.4 times more likely than their non-scheduled counterparts to be regular smokers, and 1.5 times more likely to regularly use chewing tobacco products. People from scheduled castes and tribes were also 3.4 times more likely to be regular users of alcohol (Neufeld *et al*., 2005). Poverty also has relationship with addiction to tobaccoism and alcoholism; similarly the rural people are more addicted as compared to the urban counterparts (Neufeld *et al*., 2005).

Further, a study from the state of Arunachal Pradesh revealed significant variation in the prevalence of use of alcohol and tobacco based on specific tribe membership, in addition to other variables including ethnicity, altitude of residence, occupation, and religion (Chaturvedi and Mahanta, 2004).

Crum and colleagues (Crum *et al*., 1993) also reported inverse relationship between education and problematic alcohol use in the Epidemiologic Catchment Area studied in the United States. Heavy drinking was found to vary inversely with socio-economic status (measured by educational background) in Holland (Crum *et al*., 1993) and in a prospective survey in Winnipeg, Canada (Khan *et al*., 2002).

Global comparisons of alcohol use by country and region reveal very different patterns with the Americas and Europe reporting the greatest per capita consumption and the Eastern Mediterranean countries reporting the lowest. It is hypothesized that some of these differences are explained by the influence of religion, with more permissive attitudes toward alcohol in nations where

Christianity predominates and little or no tolerance in Islamic nations (World Health Organisation, 2011).

Hence, no association between alcoholism and PTC taste sensitivity in the present study can be explained in the similar fashion. Being a tribal group and Christian by religion, the alcoholism is a common cultural practice among the Rongmei Naga of Manipur. Saldanha (1995) and Chaturvedi and Mahanta (2004) also concluded that the tribes have least prohibition against alcohol use.

Blakeslee and Fox (1932), and Rozin and Vollmecke (1986) reported that there are a certain few individuals for whom PTC tastes sweet. Almost all investigators report a small portion of the population for whom PTC tastes sour, salty, camphory, sulphury, etc.

Hence, in context of present study it can be inferred that the allele frequency of PTC taste sensitivity is deviating from the Mendel's law, although it is in equilibrium as stated by Hardy Weinberg law. Further, the association of the gene with alcoholism and tobaccoism was not found, although, it is still debatable, because the findings in this respect are contradictory.

CONCLUSIONS

The prevalence of PTC tasters varies widely among different ethnic groups of Indian population with very high prevalence of tasters among Naga tribe of North-east India. In the present investigation dietary habit like alcoholism, tobaccoism and smoking were not found to be associated with PTC sensitivity.

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