Flavour Network and the Principles of Food Pairing

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***Abstract*—Food pairing is an interesting area of research, concerning which ingredient goes with which for getting an optimally like-able taste. Creating a flavor network enables us to study these pairings and their contribution in cuisine, whether gourmet or otherwise. Flavour networks have been used to suggest new recipes and discover new food pairings such as chocolate and blue cheese, based on the fact that they are very connected by the compounds present in them. Such studies have also gained considerable commercial success, leading to more avenues of building new recipes.**

In view of this, Barabasi had first studied such flavour networks, highlighting how Western cuisine tends to make similar tasting compounds their choice and utilise these in their recipes and how East Asian cuisine tends to utilise varied compounds for achieving different tastes. This highlighted major differences in how cuisine was prepared in such cultures.

In summary, our analysis tries to identify the significant patterns that characterize the way humans choose which ingredients they combine in their food.

We attempt to replicate the study and draw on it further specifically for Indian cuisine and East Asian cuisines.

***Keywords*—Food, pairing, ingredients, recipes, flavor, flavour components, Viruddha Aahaar.**

I. Introduction

Flavor networks have long been used to study food pairings, the pioneer in this study being Barabasi, whose paper [1] compared the varied food pairings for every cuisine present in the multitude of cultures present. The current diet that humans possess has been said to be influenced by a huge range of factors; from nutritional value, to health concerns and production ease keeping in mind climatic conditions. While this is true all over the world, Indian cuisine in particular is also of interest. India's cuisine has a unique blend of diversity due to the culturally and climatically diverse regions.

As discussed in [1], food choices are largely affected by flavour and smell even though other factors such as colors, texture, temperature etc. Regional cuisines are also influenced by regional factors such as climate, culture and genetics. Therefore flavour has become a point of reference for studying recipes using their ingredients.

Since both the positive and negative relation for the food pairings by virtue of their flavour has been studied, we attempt to look at the correlation that these recipes have with ingredients considered to be uncomplimentary and detrimental to the health of the digestive system and thus should not be eaten together.

These particular food pairings, termed "Viruddha Aahaar" for incompatible food combinations, few of which have been mentioned in Table I.

We focus on these food pairings and combinations and check how cuisines reflect these principles of using ingredients.

We analyse worldwide cuisines data available as a part of the food flavor network, and then analyse Indian data of various regions pertaining to the same.

II. Viruddha Aahaar

Ayurveda is an Indian system of medicine that bases the foundation and treatment of continued good health on the idea of balance of bodily systems. It consists of principles of well being that incorporate methods such as diet, herbal treatment, yoga as a combination to achieve a better state of living.

In keeping with the wisdom of solving all problems using digestive aids, Ayurveda dictates that some ingredients must not be used with others.

Ayurveda believes that when two or more foods having different tastes, energy and post digestive effect are combined, agni becomes overloaded, inhibiting the enzyme system and resulting in the production of toxins. Agni here refers to the digestive system, derived from the burning sensation that is caused by the hydrochloric acid in the stomach.

Few these combinations are listed in Table I, and we analyse what amount of cuisines are affected by this combination of ingredients.

III. The Food Network

The food network is built by the node representing the ingredients and the edges representing how many times they are used together in recipes.The weights of the edges are used as the gradient for the size of the nodes.

The degree distribution [Appendix B [1]] and the Eigenvalue distribution [Appendix B [4]] clearly follow the power law distribution which show the existence of a giant component and many small connected components. The average degree of the graph is 0.982 (approximately 1) which tells that all components at least have a single edge connecting. The number of small connected components [Appendix B [2]] are 1507. The modularity of the network [Appendix B [3]] is 0.955 (approximately 1) which shows that the network has the number of edges in between nodes exceed chance, but also they are seen only between modules and not overall which is quite evident as different flavour matching components or similar items will have more edges than between each other.

The network formed seems to be divided into a some highly connected components and many sparsely connected components, as is visible in Fig 3. The graph depicts the sparsely connected nodes on the periphery, while the deeper connected components lie towards the center.This tells us that the evidence of a single giant component prevails and few components are very rarely used according to their flavour components.

If we filter out the nodes having 1 degree, we get a graph represented by Fig 4. This graph focuses on the ingredients used at least twice in recipes.

If we further filter out for more connected nodes, Fig 5 and Fig 6 showcases the clusters formed by the most used ingredients, zoomed in.

Lastly, Fig 7 shows the most used ingredients as almost singular nodes.These are most commonly used in the cuisines hence are located in the centre as the have a higher degree value and more matching flavour components.

In addition, we look at the distribution of the percentage of Viruddha Aahaar ingredients present in recipes used worldwide and those used specifically in different Indian cuisines.

IV. Graphs

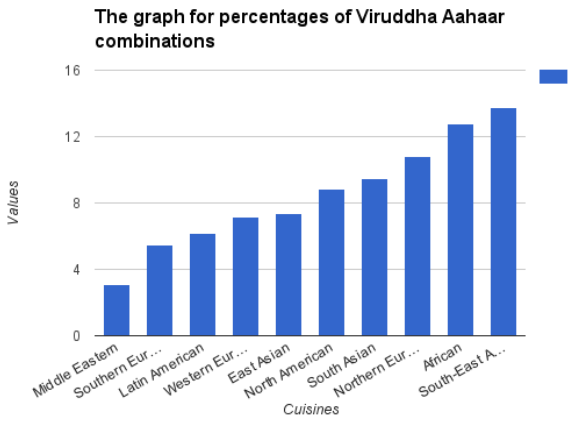

Fig. 1: The values show that the cuisines have very low percentages of Viruddha Aahaar with respect to the total combinations possible.

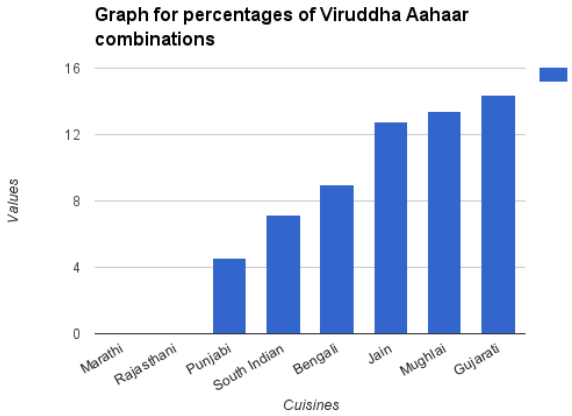

Fig. 2: The values of the Indian cuisines is far less than that compared to world which clearly shows that influence of Ayurvedic science in the design of the cuisines. We can see that two cuisines have absolute zero or no Viruddha Aahaar combinations.

V. Network

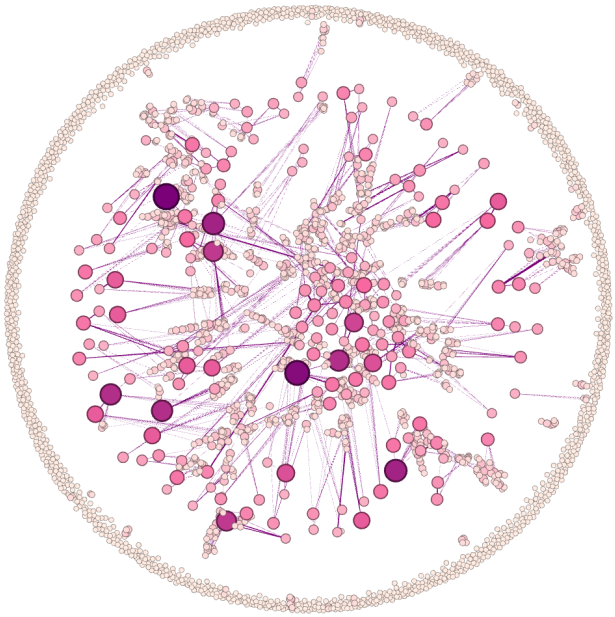

Fig. 3: The network shows the complete representation of the network with no overlaps and we can see the formation of a big connected component and small disconnected components which are independently used. The ingredients least used with any other recipe lie on the periphery of the graph, and those most used lie towards the center. The edges indicate ingredients connected by common recipes.

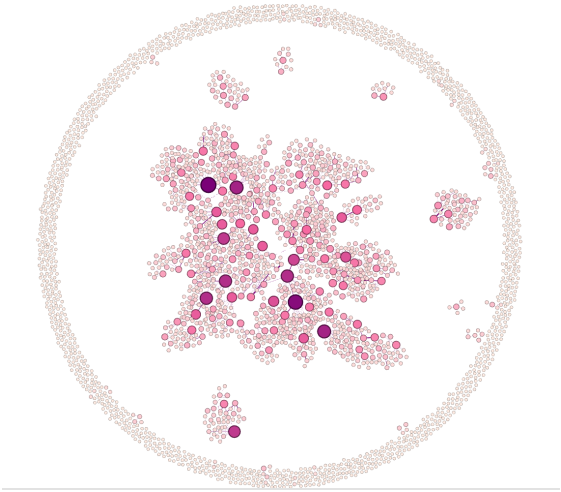

Fig. 4: The figure is representation of the graph after using Yifan Hu algorithm which helps in making clusters and also diverging the nodes with smaller edges to corners. Hence, we separate out the nodes with little no edges to eliminate.

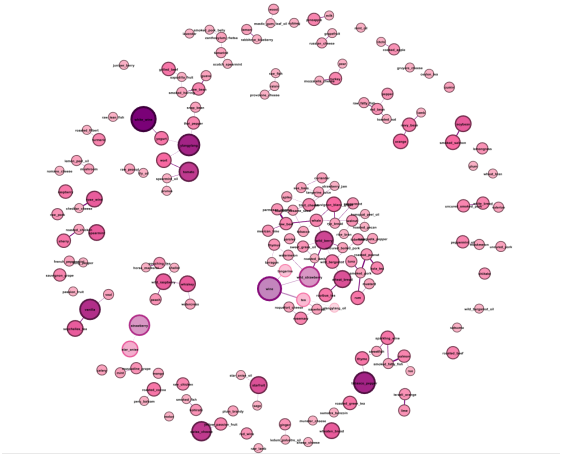

Fig. 5: The network represents only the nodes with more than 1 edge, hence shows the nodes with higher usage to give a clear image that ingredients with higher flavour components that match are used more, and are used more frequently together.

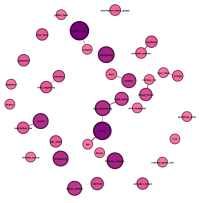

Fig. 6: The representation of the higher edge node that are widely used. Note how most of these are berries, or types of wine, derived from berries. Also note that they involve Viruddha Aahaar elements as well.

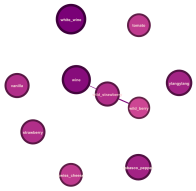

Fig. 7: The main and most used ingredients in the cuisines, i.e. the nodes with the higher degrees. Notice that these involve almost equal proportions of Viruddha Aahaar ingredients.

VI. Conclusion

We have looked at how ingredients are used in both Indian and worldwide recipes, whether positively similar flavour tastes as well as negatively correlated flavour tastes were used.

In looking at these, the data reflects from the graph that every cuisine has ingredients which have the higher degrees in the network and are therefore used most in preparing recipes for these cuisines. These most used ingredients are those which belong have similar flavours as well as those that have distinct flavours. In combining these, cooked food satiates all human tastes.

However, it can be observed that there are some combinations of ingredients that should not be used together, as articulated by Ayurvedic principles. Whether or not these affect a person adversely is a matter that requires more research, but we conclude after analysing what percentage of worldwide and Indian cuisines utilise such ”Viruddha Aahaar” combinations that might be detrimental to health.

References

[1] http://www.barabasilab.com/pubs/CCNR-ALB_Publications/201112-15_Nature-Flavor/201112-15_Nature-Flavor.pdf

[2] http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0139539#sec002

[3] http://www.medindia.net/patients/lifestyleandwellness/dietary-dos-and-donts-of-ayurveda-incompatible-food-combinations-virudh-aahar.htm

[4] http://www.cnn.group.cam.ac.uk/Resources

[5] https://gephi.org/

[6] http://www.wikiwand.com/en/Modularity_(networks)

Appendix A
Source Codes

1) Code for sorting out Indian recipes
2) Code for analysing Indian recipes
3) Code for analysing worldwide recipes

Appendix B
Graphs for Network Analysis

1) Average Degree Distribution Graph
2) Connected Components Graph
3) Modularity Graph
4) Eigenvector Centrality Graph

Appendix C
Tables for data used for plotting the graphs

TABLE I: Combinations of Viruddh Aahaar not to be taken together according to Ayurvedic principles

Pairs	Item1	Item2	Pairs	Item1	Item2
P1	Milk	Fish	P6	Milk	Chicken
P2	Milk	Banana	P7	Yogurt	Banana
P3	Milk	Melon	P8	ButterMilk	Banana
P4	Milk	Orange	P9	Chicken	Sesame
P5	Milk	Lemon	P6	Fish	Sesame

These are the some of the combinations used to analyse the results. They are the pairs that were searched for in the recipes.

TABLE II: Table for World cuisines

Cuisine	Total Recipes	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	Percentage
African	352	0	1	0	3	19	19	0	0	3	0	12.78
East Asian	2512	0	4	0	6	1	25	0	0	38	111	7.36
Latin American	2917	17	33	0	14	12	88	3	0	13	0	6.17
North American	41525	147	451	34	446	865	1389	116	76	146	17	8.87
Western European	2659	36	13	0	50	31	56	2	2	0	0	7.14
Southern European	4180	17	0	0	57	78	76	0	0	0	0	5.45
Northern European	250	0	0	0	6	6	15	0	0	0	0	10.8
South Asian	621	0	1	0	0	7	45	4	0	2	0	9.50
Middle Eastern	645	0	0	0	4	6	2	0	0	8	0	3.10
South-East Asian	457	30	1	0	2	4	13	0	0	4	9	13.78

We can see that the values of the percentages are pretty low in all the world cuisines with the lowest value lying in Middle Eastern region. Thus cuisine generally reflects how Viruddha Aahaar ingredients are not used together.

TABLE III: Table for Indian cuisines

Cuisine	Total Recipes	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	Percentage
Bengali	156	0	5	0	7	2	0	0	0	0	0	8.97
Gujarati	392	0	0	0	1	0	0	0	56	0	0	14.36
Jain	447	0	3	0	0	2	0	0	52	0	0	12.75
Marathi	130	0	0	0	0	0	0	0	0	0	0	0
Mughlai	179	0	6	3	0	15	0	0	0	0	0	13.40
Punjabi	1013	0	0	11	0	22	0	0	13	0	0	4.54
Rajasthani	126	0	0	0	0	0	0	0	0	0	0	0
South Indian	474	0	0	0	0	11	0	0	23	0	0	7.17

We can see that the values of the percentages are quite similar in most of the regional Indian cuisines as compared to the cuisines used all over world. However, there are cultures that avoid the usage of such ingredients altogether, such as the Marathi and Rajasthani cuisine. Also, the percentage for the Indian cuisines as compared to the world cuisines could be a bit skewed due to less amount of data being available to perform analysis.