

Introduction to Functional Food Science

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Textbook, First Edition

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Ayurvedic Approach to Functional Foods

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INTRODUCTION

The world is going through an unprecedented and extraordinary health scenario: unprecedented because ill health has become a fact of life and many diseases are vying with each other to take the top slot as a serious health hazard, and extraordinary because despite people being armed with nuanced details of human biology and sophisticated technologies for diagnosis and treatment, diseases are on the increase. Factors such as altered lifestyle and environmental conditions are contributing to new health threats, bringing into sharp focus the role of diet as well, and underscoring the need for preventive health. Although the importance of food in maintaining health and preventing diseases has been known for a long time, the increasing disease burden and the soaring costs of healthcare have revived the interest in diet and nutrition, as can be seen by novel concepts such as nutraceuticals, nutrigenomics and personalized nutrition gaining popularity in nutritional research [1-7].

As an increasingly health-conscious population also turns its attention to healthy eating, it is important to look at the large body of documented knowledge and experience of the indigenous medical system of India, namely ayurveda, which has perhaps the longest unbroken health tradition in the world [8, 9]. Its development is closely interwoven with the history and culture of India, where ayurvedic thoughts and methods have had a very deep impact on the lifestyle of its people. In almost every household, people have knowledge of ayurvedic ways for preventive health. Every family has their own time-tested cuisine and medicinal recipes passed down from one generation to another for maintaining health and treating a wide array of health conditions. Ayurvedic principles of healthy living are still incorporated in day-to-day practices, like the use of spices (such as pepper and fenugreek) and medicinal ingredients (turmeric, neem, and garlic) in traditional cuisine and daily regimen. Ayurveda's concepts and functional approaches to healthy living is a treasure house of knowledge that people all over the world should benefit from. This article, while exploring points of contact between ayurvedic and current approaches to diet and nutrition, also gives a bird's eye view of the ayurvedic functional perspective on health and disease.

REDUCTIONISM AND MODERN NUTRITION

Physics has been very influential in shaping the development of biology and medicine [10, 11]. Although its contributions to the advancement of medical diagnostics (such as ultrasound and Magnetic Resonance Imaging) and therapeutics (such as nuclear medicine and radiotherapy) are well known, very little is understood about the impact of its worldview on biology and medicine. The classical (physics) worldview, which considers the world as being made up of building blocks of atoms, views everything from the human body to the universe as a mechanical system composed of interacting material particles behaving in accordance with the physical laws [12, 13]. Moreover, according to this viewpoint, all physical objects can be reduced to the fundamental entity of matter. This perspective forms the platform from which everything, including the human system, has been viewed and understood by physicists [14]. This reductionistic model is hierarchical, with atoms at the lowest level, and molecules, cells, tissues, organs and organ systems at the succeeding levels. As in classical physics, the focus in biology and medicine has been on the physical aspects.

Reductionism as a systematic method to understand the world was proposed by Descartes, who suggested the world was clock-like and could be understood by reducing it to parts and studying the individual components [15, 16]. Breaking down a complex system into smaller parts and studying them individually has been a very successful approach in biology for studies ranging from understanding the working of cells to the unraveling of human genome [17, 18]. The Newtonian mechanistic worldview has also become the platform for the reductionistic approach in nutrition [19, 20]. Just as understanding of molecules and cells play a prime role in the study of human system in modern medicine, the current viewpoint of nutrition also focuses on physical components such as proteins, fats, carbohydrates, etc. A balanced, nourishing diet is considered to consist of a minimum of each of these components and their nutritional content calculated by calories. The ayurvedic perspective of nutrition differs from the above standpoint and has a functional approach [21, 22]. The following section outlines in brief, the functional viewpoint of ayurveda on human system before elaborating on its approach to nutrition.

FUNCTIONAL PERSPECTIVE OF AYURVEDA

The human body is a highly complex biological system with many structures, biochemicals, functions, and a range of activities like electrical and magnetic, thus providing a range of possible viewpoints. While the biological medical model is structure oriented, ayurveda has a functional perspective of the human body [23]. Functions are a result of complex interactions between several factors, ranging from structures to biochemicals. A functional perspective, therefore, will be an inclusive one, taking into consideration all these contributing factors. Ayurveda has identified three fundamental functions, namely, movement, transformation, and support and growth, making these the basis of its functional classification. These three functions are known respectively as *Vata (V)*, *Pitta (P)* and *Kapha (K)* in Sanskrit, the language of ayurveda. For convenience, these terms will be referred to as V, P, and K in the rest of the text. VPK covers functions not only in the physiological but also in the mental plane [24-26]. Implicit in this functional viewpoint is the lack of hierarchical functional specification with a fundamental unit. This is in contrast to the conventional structural hierarchy with atom as the

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fundamental entity. VPK thus represents a different perspective of human system than the currently held one in modern biology [27, 28].

VPK, in addition to functions, also include a set of system properties (physical, chemical and physiological in nature), such as dryness, pH and temperature, which impact the functions defined under V, P, and K. All these parameters are interconnected forming a network [29]. The core idea of the human system as interconnected functions and system properties and not merely a structure made of atoms and molecules is unique. This gives ayurveda its advantage in dealing with human body and other factors impacting health and disease in a holistic way. Although ayurveda recognizes the importance of the mechanical aspects of human body, it looks beyond the purely structural view by considering life as a complex interrelationship of forces. These are defined in the functional theory of VPK, which underpins ayurvedic understanding of not only human health and disease but also diet and nutrition.

DIET AND NUTRITION: THE FUNCTIONAL APPROACH OF AYURVEDA

Ayurveda considers diet and nutrition the most important factors in maintenance of health and prevention of diseases. It not only opines that food influences the being of a person but also teaches that many diseases arise from improper diet and activities.

Functional and practical classifications of food

Ayurveda considers food as medicine and uses a number of parameters of practical significance to understand the functional, nutritional and therapeutic attributes of food and the ingredients that make it up [24-26]. The most important ones are discussed below.

Organoleptic property of taste

Taste, one of our fundamental senses, has always evoked and sustained scientific interest and research [30-42]. Till recently, the prevailing view of western food research had centered around four basic tastes: sweet, sour, salt and bitter [30]. In recent times, however, umami has been included as the fifth taste [33]. Pungent and astringent tastes, considered basic tastes in ayurveda, are conventionally considered by modern science to be sensations because they can be perceived through tongue as well as skin [43, 44]. Despite this, astringent and pungent group of drugs have been used and mentioned in pharmacology [31, 45]. However, there is now increasing interest in understanding the action of not only these two tastes [34, 36, 46] but that of taste and its perception in general [37-39, 41].

Ayurveda considers the organoleptic property of taste as the most important characteristic of any substance and uses it to identify the functional, nutritional and medicinal values of food. Just as body functions are classified into V, P, and K, all food substances are also similarly categorised. For this, all substances are first classified into taste, which is understood in terms of its actions on V, P, and K. There are six basic tastes mentioned in ayurveda: sweet, sour, salt, pungent/hot, bitter, and astringent. Each taste is identified with certain functions and pharmacological properties [24-26]. For example, the functionality of the sweet taste is being

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wholesome, soothing, invigorating and nourishing. It helps in growth of tissues, promotes strength and healthy skin. It alleviates thirst, burning sensation, pain and is antipoisonous. It is pertinent to note the scientific reports on the analgesic effects of sweet substances in relieving pain [35]. The function of the sour taste is to add deliciousness to food, stimulate appetite, cause salivation, nourish and energise the body. It also promotes strength, is refreshing and light. Saline taste is functionally carminative, laxative, and produces stickiness and salivation. It cures stiffness and clears obstruction in channels. Moreover, it adds taste to food.

On the other hand, the pungent/hot taste promotes digestion, lacrimation (production of tears), and helps in absorption of food. It also adds to the deliciousness of food. It induces weight loss and is used in treatment of obesity. A recent study demonstrated that ingesting chili powder can aid in weight loss and prevention of future weight gain. [47]. The bitter taste promotes firmness of skin and muscle, and is carminative, digestive, antitoxic, and germicidal. The astringent taste however, is constipative and causes stiffness and dryness. It slows digestion and is generally costive.

Each of the six tastes has a definite relationship to VPK, either increasing or decreasing one or two of them. The sweet taste increases K, in other words, certain functions and parameters in the body, and decreases P and V (certain other functions and parameters in the body). On the other hand, the pungent taste will increase P (predominantly) and V, and decrease K. Ayurvedic texts give in-depth information on the taste-function relationship [24-26]. Knowledge of the taste of a substance thus helps understand its functional effects on the body. Table 1 details the functional association between VPK and the organoleptic property of taste.

Taste	Increases	Decreases
Sweet	K	P, V
Sour	K, P	V
Salt	K, P	V
Pungent / Hot	P, V	K
Bitter	V	P, K
Astringent	V	P, K

Table 1: Taste-function relationship in Ayurveda

At this juncture it is pertinent to mention that ayurveda does not consider taste as a sensory stimulus, as the sole criteria for classification of substances. The functional aspect, i.e. effect of these on the body, also plays a very important role in the categorization. For example, although honey tastes sweet, ayurveda classifies it under astringent category because its action on the body and VPK is similar to that of astringent taste [24]. Interestingly, there is a growing body of evidence on the pharmacological properties of honey to support this viewpoint [48-52].

Among the six tastes, the sweet one nourishes the body the most, followed by the others in the order of sour, salt, pungent, bitter and astringent. A substance is either a single or a combination of tastes, and those in the same category can differ from one another in the grade of taste. For instance, sugar is sweeter than milk and wheat. It is to be noted that the sweet category

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does not include only absolute sweet items like sugar and jaggery but also includes substances like milk, wheat, rice and maize. This is true for all of the taste categories. The following are some examples of food items with single taste: milk, wheat, and rice are sweet; lemons, tamarinds and unripe pineapples are sour; all types of salt are salty; peppers, chili and ginger are pungent/hot; bitter melons/bitter gourds are bitter; witch hazel and banana skins are astringent. Examples of substances with more than one taste are as follows: olives are bitter and astringent, oranges and tomatoes are sweet and sour, carrots are sweet and bitter, onions are sweet and hot, yogurt is sweet, sour and astringent, garlic and goose berry (*Emblica officinalis*) have all six tastes but salt.

Sweet, sour and salt tastes are nourishing and contribute to general strength. They are also found in abundance in food substances. On the other hand, pungent, bitter and astringent tastes are associated with therapeutic properties. Even in modern pharmacology, medicines which are sweet, sour or salty are comparatively fewer compared to bitter medicines [42]. Although bitter, pungent and astringent tastes play an important role in medicinal preparations, ayurveda strongly advises their inclusion in daily diet indicating that it considers food also as medicine. People generally consume sweet, sour and salty foods out of pleasure, but bitter and astringent foods, due to their unpalatable taste, generally do not find place in one's regular diet [32]. Ayurveda mentions that over-indulgence in any particular taste and reduced consumption of other tastes lead to diseases, which can be prevented by restricting the tastes over-indulged in and increasing the lesser consumed tastes.

Ayurveda emphasizes the importance of including all six tastes in one's daily diet for maintaining health. It mentions categorically that intake of any one taste in excess and exclusion of other tastes will lead to diseases. The texts list the diseases that would arise from excess use of the different tastes [24-26] (Table 2). For example, intake of predominantly sweet taste and exclusion of hot and bitter tastes will lead to obesity. Ayurveda thus provides detailed information on the functional, nutritional and medicinal properties of food substances based on their tastes. This knowledge is widespread in India. If one analyzes the daily food of an average Indian, it generally consists of all six tastes: milk, rice and wheat (staple foods for most Indians) are sweet; buttermilk is sour and astringent; salt forms an integral part of many of the food preparations; many of the spices added in Indian cuisine are predominantly hot or bitter; vegetables are a source of bitter and astringent tastes.

Ayurvedic texts have in-depth information on the functional, therapeutic and nutritional attributes many food substances such as rice, wheat, milk and its products such as butter, ghee (clarified butter), buttermilk and yogurt, different kinds of grains, pulses and meat, various kinds of sugars and salts, oils from different sources, wines and alcohols, vegetables, fruits, herbs, as well as their preparations [24-26]. These ayurvedic concepts handed down from generation to generation guide many Indians in their dietary habits even today. It is interesting to note the increasing number of scientific studies which confirm some of the ayurvedic theories on diet and nutrition [39-41, 53-55]. For example, some of the recent reports demonstrating the presence of taste receptors in tissues other than tongue and the role of taste in spermatogenesis [39, 41] are compatible with some of the ayurvedic concepts on taste and body functions. My preliminary studies on phytochemical and spectroscopic analysis of food substances and plants grouped under different taste categories has also shown interesting differences (unpublished work).

Thermogenic property

The other property ayurveda associates with substances is potency, although this is considered more important in therapeutics. All substances, be they food or medicine, are classified as either thermogenic (hot) or non-thermogenic (cooling) depending on their post-ingestion action [24-26]. The term ‘thermogenic’ is used in modern medicine as well and refers to substances which produce heat through metabolic stimulation [56-59]. Thermogenic drugs are used in modern medicine to reduce fat. These drugs work by increasing the basal metabolic rate and thereby the energy expenditure, which in turn helps in reduction of fat [58, 59]. Non-thermogenic substances have negative caloric balance, i.e. utilizes more energy to metabolise than recovered from food making the thermic effect more than the food’s caloric potential.

Ayurveda classifies all food substances/tastes as thermogenic and non-thermogenic (Table 2). For example, milk, ghee and butter are non-thermogenic / cold in efficacy whereas yogurt and pepper are thermogenic. Non-thermogenic substances increase V and K, and decrease P.

Taste	Properties	Examples of Food	Results of Excess
Sweet	non-thermogenic controls V and P fatty, heavy to digest nourishes tissues good for sense organs and skin ideal for children, aged and emaciated increases body bulk gives firmness to the body reduces burning sensation, dryness	milk sugar wheat rice pastries dates	cough, chronic cold respiratory problems obesity diabetes loss of digestion excessive sleep tumors worms diseases of the stomach
Sour	thermogenic increases K and P reduces V stimulates digestion easy to digest vitiates blood increases moisture in the body good for the heart	yogurt tamarind citrus fruits raw mango unripe fruits in general	thirst fever flabbiness of body loss of strength giddiness skin disease, itching pallor, skin eruptions
Salty	thermogenic controls V increases P and K improves taste of food increases digestive power lubricates, reduces rigidity in the	all types of salt	reduction of strength skin diseases vitiating of blood bleeding balding, greying wrinkles

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	body penetrates tissues clears obstruction of channels causes perspiration		
Pungent/ hot	thermogenic reduces K increases V and P improves digestion light to digest cures wet cough and cold alleviates indigestion, swelling dries up moisture and oiliness dilates and opens channels breaks up hard masses in the body	pepper chili mustard ginger garlic	thirst loss of strength cramps tremors constipation flatulence loss of virility and reproductive tissues
Bitter	non-thermogenic reduces K and P increases V easy to digest increases appetite improves digestive power dries up moisture and fat eliminates worms cures skin diseases removes nausea, thirst, burning, fever	neem bitter melon / bitter gourd fenugreek certain varieties of spinach	depletion of tissues disorders of V like constipation, flatulence and some digestive disorders
Astringent	non-thermogenic reduces P and K increases V heavy to digest hygroscopic heals ulcer and wounds dries up moisture and fat	black plum banana peel and flower raw wood apple areca nut honey	flatulence constipation thirst, emaciation loss of virility obstruction of channels

Table 2: Ayurvedic classification of food based on organoleptic property of taste [24-26]

Conversely, thermogenic substances increase P but decrease K. Sweet substances are in general cold in their potency whereas sour, salt and hot tastes are thermogenic, although there are exceptions to this thumb rule. Common spices like pepper, ginger, cinnamon, turmeric and chili are pungent in taste and thermogenic. Interestingly, a recent study on diet induced thermogenesis (DIT) and the effects of chili and medium chain triglycerides on diet has concluded that adding these meals increases DIT by over 50 %, which over a period of time could induce weight loss and prevent weight gain [47]. These findings are in line with the

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ayurvedic categorization of chili as thermogenic and the role of chili and other thermogenic substances in weight reduction. Table 2 outlines the ayurvedic classification of food based on taste, potency, and other parameters discussed below.

Digestibility of food

Food and its constituents constitute the diet whereas nutrition involves multiple factors such as digestion and absorption of food, transport of nutrients to tissues and their subsequent utilization for growth. In short, diet is what one intakes, and nutrition is what one derives from the diet. People may consume appropriate quantities of food but they may not be getting sufficient nutrients from what they eat. Ayurveda gives as much importance to digestion and absorption of food as it gives to the composition of food [24-26]. It categorically states that proper digestion is an indication of good health and poor digestion leads to many diseases. A well-nourished and functioning digestive system serves as a support for the body since the food ingested is converted into nutrients, which in turn nourishes all the tissues. Power of digestion therefore, controls the level of health. There are several factors which affect proper functioning of the digestive system, such as irregular eating habits, excessive or insufficient intake of food, irregular sleep, intake of too much water, and the psychological state (emotions like fear, grief, anger, and anxiety) of the dieter. Digestibility and digestion-enhancing properties of food are therefore given much importance. A proper diet in ayurveda should be digestion-enhancing and also nourish all the factors involved in digestion.

Tastes and food substances are therefore classified as digestion enhancing and dampening, and also as difficult (heavy) and easy (light) to digest (Table 2). For example, sweet taste is thought to dampen digestive power whereas hot and sour tastes in general, are digestion-enhancing. In addition, sweet foods are heavy to digest whereas bitter and astringent tastes are light. Examples of heavy foods are sweets and meat, and those of light are cow's milk, soup, and oatmeal. The importance of the digestive power of an individual is also emphasized in ayurveda. Individuals with inherently poor digestive capacity are generally advised to take nutritious but easy to digest food preparations. Excessive intake of food and drinks dulls the digestive capacity; at the same time, insufficient quantity of food weakens the digestive power. Ayurveda sees digestive capacity as a dynamic entity undergoing seasonal changes as well (discussed in a later section). Modern medicine has also started recognizing of the importance of gastrointestinal health and the role of food in digestion enhancement [60-62].

Functional approach to eating

Health is a dynamic condition which has to be maintained by not only proper diet but also by following a proper regimen. Ayurveda considers eating correctly as important as taking the right food.

Personalized nutrition

Although differences among individuals in terms of their response to dietary factors and interventions have puzzled nutritional scientists in recent years [4, 6, 7], they are well-known in ayurveda [24-26], which is a personalized form of medicine. The body constitution plays a very important role in this personalization[24-26, 63]. Every person is made up of a specific

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combination of V, P, and K with typically one or two of them dominating. This information helps characterize individuals based on their physical, physiological and psychological features. While the emerging interest in personalized medicine and nutrition is focusing on genomics [4-6], ayurveda takes a comprehensive view by considering a number of other factors which impact the health of an individual. According to ayurveda, a person's basic constitution plays an important role not only in health but also in determining the predisposition to diseases. In fact, this parameter is so central to the practice of ayurveda that it also plays a role in preventive health and formulating personalized diets. This takes into account individual variations the person's in digestive capacity, diseases the person is predisposed to, their individual preferences for the taste of foods, etc. These are elaborated further in the following sections. Current food research is also recognizing of some of these factors [34, 64, 65].

What to take?

As already mentioned, one should consume food which includes all six tastes. Excessive intake of one taste and the exclusion of others leads to functional imbalance and diseases. However, people should also take into account their constitution type for long-term maintenance of health and prevention of predisposed diseases. For example, constitution types with predominance of K should have reduced consumption of sweet taste, whereas those with a predominance of P must avoid pungent and sour tastes dominated diet and instead include bitter, astringent and sweet tastes in their food. On the other hand, a V-dominated constitution type should have a smaller intake of bitter, astringent and pungent tastes compared to sweet taste. The dominance of V, P, and K in determining the physical, physiological and psychological features of an individual is thus kept in check by appropriate food and regimen. The careful intake of food balances V, P, and K in their functions and system properties. In general, the food taken should be suitable to the individual. A major guiding factor in assessing the suitability of food is the individual's constitution. Recent studies on taste preferences and the underlying genetic factors [34, 64-66] support what ayurveda says about the association between one's constitution type and taste preferences. It is pertinent to note that studies have shown a genetic basis for the ayurvedic constitution types [67].

How much to take?

Quantity of food is an important consideration in food consumption and a crucial factor in maintaining good health. Ayurveda defines the proper quantity of food as one which, without disturbing the equilibrium of VPK, gets digested and absorbed in proper time. Food consumed in moderation in appropriate quantity stimulates, activates and strengthens the digestive system. Mention is also made of the indicators for the appropriate quantity. They include the absence of undue pressure or heaviness in the stomach and the region of heart or sides of the chest, as well as comfort with physical activities like standing, sitting, walking, breathing and talking following eating. Quantity of intake also varies according to the digestibility of the food and the digestive capacity of the individual. For proper digestion, both the difficult-to-digest (heavy) and easy-to-digest (light) foods need to be consumed in proper quantity. For example, heavy foods like sweets and meat should be consumed only up to half-satiation whereas light foods can be consumed to full satiation but not more. One should consume food (solid and liquid) only to

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three-quarters of the capacity of the stomach: half the stomach should be filled with solid foods and a quarter with liquid, and the remaining quarter should be left empty. In general, there has to be a balance of solid and liquid food as well. Studies have been reported on mechanisms involved in subjective indices like satiety and the role it plays in digestion [56, 68, 69].

When to take?

Regarding the time for intake of food, ayurveda teaches that one is ready for a meal only when one has appetite, when the body and the heart in particular feels light, when the belch is clean and the natural urges (which also includes activities such as sleeping) have been attended to [24-26]. Moreover, food should be consumed only after the previous meal has been digested. Ayurveda warns against eating before digestion of the previous meal.

How to take?

Ayurveda gives importance to the order in which food is taken. Food which is heavy to digest, oily, sweet and solid (eg. sweet dish) is consumed in the beginning of the meal. It is to be noted that sweet category also includes items such as wheat, rice, maize, etc., other than absolute sweet substances like sugar. When a person is hungry, the stomach is empty and there is increase in V. Since the sweet taste pacifies V (Table 1), sweet item should be taken first. Pacifying V will help start the digestion process smoothly. Moreover, sweet taste increases K, thereby moistening the ingested food. One of the parameters under K is the moistening/lubricating property. In addition, eating a sweet dish (heavy to digest) at the beginning also helps to estimate correctly the remaining quantity one needs to eat. In the middle of the meal, food with predominant sour and salty tastes is to be consumed. The rationale is that they pacify the remaining V and also increase P (Table 1) to start the digestion process, since the core function under P is digestion. Vegetables and other food preparations in Indian cuisine served at this juncture abound in these two tastes.

Lastly, pungent, bitter and astringent tastes should be consumed, as these not only aid digestion but also reduce K, which would have increased after ingestion of food. This final part of the meal should be light, liquid, easy to digest, and not oily. Rice with buttermilk (an astringent) is a classic example. Pungent and bitter tastes are found in pickles taken along with this food item. This order, if maintained, helps in smooth digestion of the consumed food. It is to be noted that these days, with the concept of dessert, one ends the meal with sweets. It is the relationship of VPK to the process of digestion that determines the order in which the food has to be taken. The rules mentioned above apply only to healthy people and are modified in pathological conditions. For example, in K disorders (such as obesity), initially pungent (such as ginger) and salty food should be used. Of these, the former reduces K while the salt moistens the food and also pacifies V. In conditions where salt, sour and pungent tastes (which increase P) have to be taken first, the sweet taste has to be used in the end to reduce the aggravated P.

When to take what

It is well-known that biological organisms adapt to live harmoniously with their environment. For example, when seasonal temperature variations cause heat loss or gain, physiological mechanisms serve to compensate these changes. Scientific studies have shown that seasonal variations cause changes not only in metabolism of plants and humans [70-74] but also in disease

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patterns [75-77]. Ayurveda discusses in detail the effect of seasonal variations on physiological functions and properties, and the importance of adapting one's food and habits to the changing seasons to maintain good health and prevent seasonal diseases. According to ayurveda, one is prone to more phlegm and bouts of cold in spring, aches in the body in rainy season, and dehydration and reduced energy in summer. The environmental changes taking place in the seasons influence V, P, and K, (the body's functions and the system properties), causing them also to undergo seasonal changes. For example, there is increase in temperature (P) and dryness (V) in summer. One should therefore consume cold food and avoid thermogenic food like yogurt in summer. In winter, food which is hot in both efficacy and temperature should be consumed. The diet has to be changed according to the fluctuating seasonal predominances of V, P, and K. Since tastes and VPK are associated, consumption of a particular taste and avoidance of others in particular seasons are advised [24-26].

Ayurveda mentions that the digestive capacity also undergoes seasonal variations. One's diet must therefore be custom designed to balance the changes in this factor as well. For instance, in winter the digestive capacity is at its strongest for everybody. Therefore, the diet should consist of heavy to digest food to take care of the strong hunger pangs experienced in this season. However, in summer the digestive capacity is weak. In order to balance this, the diet should be easy to digest, cooling, liquid in nature, sweet in taste and refreshing. The underlying message is that one cannot follow the same diet and lifestyle pattern throughout the year but they should be altered to suit the season. Therefore, one needs also to understand the nature of seasons and their effects on the body. The seasons (spring, summer, rainy, autumn, early winter, late winter), their relationship to VPK, and some of the appropriate food and regimen to be adopted for different seasons to protect and maintain health are discussed below [24-26].

Summer: Summer is dehydrating and causes dryness, which aggravates V. The digestive power is generally weak and there is also depletion of K. The effects of this season on the body must be compensated for and countered by appropriate diet, and other regimens. The food consumed in summer should therefore be predominantly liquid, sweet, non-dry but easy to digest, and also cold in temperature and efficacy. Coconut water, sweet fruit juices and gruel made from par-boiled rice are examples of this type of diet. Avoiding excessive physical exercise (this increases V), staying away from alcohol (this increases P, which in turn will increase V as well), drinking water processed with cooling herbs are also suggested for this season. These practices prevent dehydration, compensate for the excessive dryness and overcome the severe effects of summer. Table 3 summarises these.

Rainy season: The effects of the rainy season are quite different from that experienced during the preceding season (summer). In rainy season, VPK (all three) in the body are increased. However, V which got aggravated in summer gets further vitiated due to the effect of the coldness (another parameter under V) and dampness of the season. The digestive power which was already weakened in summer gets further weakened. In this season, measures should be adopted to improve the digestive power (Table 4).

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Season	V	P	K	Digestive power	Food		Activities	
					To be taken	To be avoided	Yes	No
Summer	↑	↑	↓	weak	sweet taste non-dry but easy to digest cold in temperature and efficacy (non-thermogenic) ghee water processed with cooling herbs predominantly liquid diet. (sweet fruit juices, coconut water, thin gruels, milk, etc) meat of animals from desert-like regions	pungent, sour, salty tastes alcohol thermogenic substances	day sleep wear thin cotton clothes	excess physical exercise

Table 3: Regimen for summer season

Season	V	P	K	Digestive power	Food		Activities	
					To be taken	To be avoided	Yes	No
Rainy	↑↑	↑	↑	weak	sweet, sour, salty tastes oily but easy to digest hot in efficacy old rice, wheat and barley, soup of pulses processed with ginger and oil, drinks with honey and processed with ginger, pepper, etc.	pungent taste liquid food	day sleep	exercise

Table 4: Regimen for rainy season

Autumn: There is sudden warming of the environment in autumn which follows the rainy season. The heat pacifies the aggravated V but vitiates P. Therefore food and regimen should be designed to counter the aggravated P (Table 5).

Winter: In winter, the appetite and power to digest heavy foods is strong. Coldness is an inherent property of V and hence in this season, cold food and drinks which naturally increase V should

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be avoided. Cold also increases dryness (V) during this season. Table 6 outlines the diet and regimen during winter.

Season	V	P	K	Digestive power	Food		Activities	
					To be taken	To be avoided	Yes	No
Autumn	↓	↑↑	↓	weak	predominant in sweet, bitter, astringent tastes dry (non-fatty) and easy to digest cold in efficacy less in quantity sugar, honey, goose berry (<i>Emblica officinalis</i>), bitter preparations, medicated ghee (bitter), wheat, barley, green gram, special varieties of rice, meat of animals from desert-like regions, etc.	pungent taste strong alcohol over satiation yogurt, alkaline substances	apply coolant paste (prepared with cooling herbs) on the body wear light, cotton clothes	excess physical exercise day sleep

Table 5: Regimen for autumn season

Spring: By the end of winter and with the onset of spring, K gets aggravated with increased warmth. The increased K dampens the digestion and also gives rise to a number of K related disorders such as cold, cough and associated fever. During this season, people suffer from respiratory ailments as a consequence of the aggravated K. Cough and cold are common in this season. All food and regimen during this season should aim at reducing K and also improving the digestive capacity (Table 7). It is pertinent to note that this season is known for pollen allergy related respiratory problems [75-77]. The aggravated K reduces in the dehydrating heat of summer which follows spring.

The last seven days of a season and the first seven days of the following season are considered crucial. During this period, the regimen of the previous season should be discontinued gradually and those of the succeeding season adopted slowly. The change in food and regimen from one season to the next should not be abrupt but smooth and gradual to avoid illness. As seen, the interconnectedness of VPK with environment finds practical expression in the seasonal regimens suggested in ayurveda [24-26]. These routines consisting of suggestions

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for diet and activities take care of the body's response to seasonal changes and establish a functional harmony between the individual and environment.

Season	V	P	K	Digestive power	Food		Activities	
					To be taken	To be avoided	Yes	No
Early winter	↑	↓	↑	strong	sweet, sour, salty tastes fatty, heavy to digest thermogenic rice, wheat, meat, soup of pulses and meat, newly harvested grains, oily substances, products of sugarcane, milk, etc.	cold food & drinks	physical exercise oil massage sun bath	-
Late winter	Same as above but in stronger measures. Dryness (V) increases.							

Table 6: Regimen for winter season

Season	V	P	K	Digestive power	Food		Activities	
					To be taken	To be avoided	Yes	No
Spring	↓	↓	↑↑	weak	pungent, bitter, astringent tastes dry, easy to digest thermogenic honey, barley, wheat, meat soup (animals from desert-like regions), alcohol, water boiled with ingredients like ginger, pepper and garlic, water with honey, etc.	sweet, sour tastes fatty, heavy to digest foods over satiation yogurt, citrus fruits, chilled food and drinks	exercise massage regular use of nasal drops gargling	day sleep

Table 7: Regimen for spring season

The case of a 45-year-old patient (personal communication) is discussed here to illustrate this point. The patient was suffering from heavy bouts of cough and cold every spring season for

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nearly six years and was on heavy antibiotics during the affected period. From an ayurvedic perspective, this K-related seasonal problem was identified as indulgence in diet and activities incompatible with the spring season, during which there is a general aggravated manifestation of K in everyone. The patient had been indulging in K-aggravating foods such as citrus fruits, yogurt and fruit juices, all of which are discouraged in the spring season. The patient's problem was addressed simply by correcting the diet and activities. Post-intervention, the patient has faced four spring seasons without recurrence of the problem. This example shows how a person's well-being is connected to seasonal changes and how ayurveda's diet regimens can be effectively and easily used to avoid season related disorders. Ayurveda is peppered with information on how to prevent seasonal diseases.

A balanced diet

A balanced diet in ayurveda is one which helps to maintain the equilibrium of VPK and the tissues. Food should include all the six tastes (sweet, sour, salt, pungent, bitter and astringent) but should be predominantly sweet in taste (eg. rice and wheat). One's diet should consist of rice, wheat, barley, meat of animals from desert-like regions, gooseberry, unrefined sugar, honey, milk and rock salt. Some of the food substances which should not be regularly consumed are yogurt, meat of domestic animals, sprouted grains, dried vegetables and curdled milk. All these ensure a balanced diet, and such food gives all the nourishment that the body requires and also prevents diseases. Ayurveda also mentions that a meal should not consist predominantly of vegetables alone (such as a salad), but should be freshly cooked and taken warm, and should not be reheated. Food prepared properly and consumed appropriately gives strength, nourishes all the tissue elements, sense organs and also the intellect, and gives a long healthy life.

Designing functional food with taste and flavor

Although food in general can be considered functional, the current nutritional research uses the term 'functional' for foods and food components known to provide specific health benefits beyond basic nutrition. Keeping this in mind, the focus of discussion in this section is on the medicinal ingredients suggested by ayurveda for use in cuisine. Ayurveda, apart from enumerating in detail the functional, nutritional and therapeutic values of daily foods such as rice, wheat, milk, ghee (clarified butter), oil, vegetables and fruits, also discusses at length the medicinal properties of spices. Ingredients like ginger, pepper, turmeric and fenugreek are not mere spices used to flavor the food but are known for their therapeutic properties and are ingredients of many ayurvedic formulations. Although ayurveda does not use the term bioactive compounds, it is obvious from the description of the therapeutic attributes of food ingredients that it indeed is referring to these. There is also a growing body of evidence of presence of bioactive components in many spices [78-82].

Traditional Indian cooking is based on ayurvedic principles. Incorporating spices (with medicinal properties) and cooking dishes with flavor and taste to suit the different climatic conditions and seasons has been the strength of Indian cuisine. Although bitter and astringent tastes are beneficial to health, they are generally not favoured by dieters due to their unpalatability. Traditional Indian cuisine offers several recipes to increase the palatability of bitter and astringent food substances by cooking and seasoning them with spices and other

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ingredients which can mask these tastes and at the same time retain their health benefits. My studies have shown that bitter and astringent tastes exhibit more flavonoids (unpublished data). Spices with these tastes therefore, are probably providing bioactive compounds such as curcuminoids from turmeric (*Curcuma longa*), galactomannan from fenugreek (*Trigonella foenum graecum*) and piperine from pepper (*Piper nigrum*).

Antidotes for ingredients with side effects are also inbuilt into the multi-ingredient cuisine. For example, the thermogenic effects of chili and pungent spices are brought out by cooking them in oil or ghee, which helps them retain their medicinal properties. Another example is preparation of sweet dishes, Ghee, which in ayurveda is considered to reduce K [24-26, 83, 84] is added to the sweet preparation, which has an inherent property to increase K. Ingredients like saffron (*Crocus sativus*) and cardamom (*Elettaria cardamomum*, added as flavoring agents to the sweet dish reduce K. While saffron is bitter and pungent (both these tastes reduce K), and cardamom is pungent and sweet, and they both have thermogenic properties which reduces K. Both these flavoring agents not only act as antidote to the K-increasing property of sweet dishes but also contribute their other medicinal attributes. Over centuries, numerous recipes have been developed across the country taking into account regional variations in climate, season, vegetation, culture, occupation of people, etc., effectively converting food into functional food with judicious and ingenious use of ingredients with bioactive compounds.

The ayurvedic approach is to use complete foods without losing taste and flavor by designing food in forms and combinations that can be relished and easily assimilated. Information from ayurveda can thus help develop food products with bioactives without compromising the sensory or taste attributes of foods while maximizing their beneficial and health promoting properties. It is also important to note that bioactivity is not associated with a single compound. Studies have shown differences in the pharmacological activities between purified compounds and whole extracts [85, 86]. Hence, it is a moot point whether physiological benefits from a purified compound will be the same as that when given as part of a food matrix or combination, since the bioactives may also have synergistic or additive effects. A multi-ingredient diet is a rich source of many bioactive substances and hence has the potential to have increased health and prophylactic benefits. More importantly, natural bioactives such as those present in food components and edible plants are likely to be safer compared to their synthetic counterparts.

DIET, NUTRITION AND DISEASES IN AYURVEDA

Ayurveda considers the overall nutritional status of a person to influence his or her susceptibility to disease. Diet and nutrition are therefore considered to be the most important factors in maintenance of health and prevention of diseases. It is well-known in modern medicine that food plays an important role in the development and prevention of many diseases [87, 88]. There is now overwhelming evidence from a number of studies that many of the chronic diseases such as coronary artery disease, ischemic stroke, diabetes, and some cancers are due to inappropriate diet and lifestyle [89, 90]. This is important, since these diseases can be prevented with changes in diet and lifestyle, and without many drugs or expensive medical interventions. The responsibility now lies heavily on the shoulders of nutritional researchers to make this a reality.

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All these are in tune with ayurveda's categorical statements about diet being a causative factor for many diseases. Medical nutrition therapy is part of all ayurvedic treatments. Depending on the aggravated V, P, and K, the treatment recommends the appropriate foods to eat or to avoid. . For example, in a V-related condition like constipation, the food recommended would include substances which are sweet, sour and salty in taste and thermogenic in potency as these help reduce the deficient V. Similarly, for an instance of aggravated P (such as an ulcer), the food should be sweet, bitter and astringent in taste and non-thermogenic. In the case of aggravated K (such as a wet cough), the choice would be bitter, pungent and astringent tasting food with thermogenic properties. In all clinical conditions, ayurveda gives prime importance to the dietary history of the patient since that is likely to be a contributing factor for that disease. For instance, excess intake of sweet substances is considered one of the causative factors of diabetes. In this condition, food with sweet taste should be avoided and those with bitter and astringent tastes included.

Taking the example of anemia, the ayurvedic concept of nutrition and its role in diseases is explained further. Anemia is a common and debilitating condition among women and children in India. Statistics show that more than half of Indian women and three-quarters of Indian children are anemic [91-96]. Despite the measures (distribution of iron and folic acid tablets) taken to control anemia in the last two decades by the National Nutritional Anemia Prophylaxis Program, the Indian women and children continue to be chronically anemic, suggesting that these measures have not been effective. The severity of nutritional anemia continues to remain a public health issue of great magnitude. It is also an additional cause of great concern since in women, anemia becomes the underlying cause of maternal and perinatal mortalities.

Interestingly, statistics indicate that the Indian states with a high per capita Net State Domestic Product (NSDP) and high caloric intake are not those with low anemia levels among women and children[94-96]. For example, the state of Kerala, where the per capita calorie consumption is below the national average and below that in most of the other Indian states, has by far the lowest levels of anemia among women and children. Some of the states which have a relatively high caloric intake are also those where the levels of anemia among women are more than double that of Kerala. The same also holds true for states with high protein and fat intakes. Therefore, it seems that a diet high in calories, proteins and fats, also supplemented with iron and folic acid tablets, still does not ensure a corresponding reduction in the levels of anemia. Another paradox is that the level of anemia does not seem to have any relationship with the material affluence of the States (measured in terms of NSDP). Ayurveda can provide an explanation for this paradox [96]: by the standards of modern nutrition, the diet of Kerala is deficient. Yet the reason this state has the lowest levels of anemia is perhaps because the diet of the people of Kerala remains largely traditional and based on ayurvedic principles.

In ayurveda, anemia occurs when blood is vitiated resulting in a loss of its quality and quantity [24-26, 96]. Although there are various factors leading to a deficiency in blood, improper food is considered an important cause for anemia in ayurveda. Excessive intake of sour, salty and pungent tastes is one of the causative factors for anemia. A diet high in terms of calories and yet has predominance of sour, salt and pungent tastes will cause anemia. In addition, consumption of alcohol and physical exertion also have a causative role. Therefore, combination of excessive physical exertion and inappropriate food will cause anemia. A person who takes

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iron tablets and eats enough calories may still be anemic if the diet, work and regimen are not proper. It is pertinent to note that the diet and regimen suggested in ayurveda for pregnant women are the same as those for a person with anemia [24-26]. In the words of an ayurvedic physician with extensive clinical experience in mother and child care, 'The food and regimen recommended in ayurveda for a pregnant mother ensures an anemia-free pregnancy. ... The subject of anemia clearly shows that without an appreciation of Indian Systems of Medicine, we will come to utterly wrong conclusions' [96].

FUNCTIONAL FOODS AND BIOACTIVE COMPOUNDS: APPROACH OF MODERN NUTRITION AND AYURVEDA

The fundamental difference between the current approach and that of ayurveda largely stems from their different perspectives: the former focuses on parts, and ayurveda on the entire system, be it in understanding the physiology or food. Reductionism remains an excellent and successful approach for an in-depth understanding of system components. Modern nutrition is as much an outcome of the reductionistic approach as modern medicine is. The food is viewed as a sum total of its parts, i.e. chemical components (carbohydrates, fats, proteins, vitamins and minerals), with their nutritional value assessed in terms of calories. The calorie, a unit of heat, measures the potential energy the food possesses. Our bodies burn calories in food through metabolic processes in which enzymes break down carbohydrates to glucose and sugars, fats to glycerol and fatty acids, and proteins to amino acids.

While this knowledge is important, a system perspective helps us better understand the final outcome. Food is not a stable combination of discrete compounds, and the human body does not metabolise and burn the calories in accordance with physical laws. There are many intrinsic and extrinsic factors involved in digestion and assimilation of nutrients. For instance, the body should have sufficient metabolic enzymes for digestion, individuals may differ in their ability to digest specific nutrients, and the nutritional content of foods itself will be influenced by factors such as the breed and source (soil) of the raw ingredients, the harvest conditions, and the climatic conditions in which the plants are grown. These differences multiply when the food is also processed as a multi-ingredient dish. The chemical components of food and the calories associated with them convey only a partial picture. A system approach is required to understand in entirety the food and its effect on physiology. Such an approach is offered by ayurveda. Before elaborating on this in the context of functional foods and bioactive compounds, it is important to point out how ayurveda and the prevailing nutritional science perceive the properties of the same substance differently. The reason is the different approaches of the two systems: that of current understanding, based on chemical components, and that of ayurveda, based on physiological effects.

Here's an example of vegetables (pulse proteins) and meat, both of which constitute the protein-rich part of our diet. According to modern nutrition, both are similar in properties and action. However, ayurveda mentions that pulse proteins increase V whereas those from meat control V [24-26]. When large quantities of pulses in the form of sprouts and vegetables are consumed in an effort to increase the protein intake, V gets aggravated. On the other hand, since meat pacifies V, its intake will increase proteins without aggravating V. In fact, meat soup is

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advised and prescribed in many V-related diseases. Meat and meat soup are generally heavy to digest and hence are avoided in K-related diseases. Soup made of vegetables is easier to digest and hence considered an ideal diet in K-related disorders. Thus, even though both meat and vegetables contain proteins, they possess opposing functional qualities according to ayurveda and are used differently. Another case in point is use of ghee (clarified butter). According to modern nutrition, ghee is a saturated fat with potential to increase cholesterol levels [97] whereas in ayurveda it is known to pacify all the three functional categories (i.e. V, P, and K), and has many medicinal properties [24-26]. Interestingly, there are now scientific reports confirming the beneficial effects of ghee and also demonstrating that it does not have adverse effects on lipid profile (serum cholesterol, triglycerides, etc.) [83, 84].

It is apparent that ayurvedic diet is designed not only for basic nutritional purposes but also for maintaining and promoting health, and preventing diseases. This is evident from the functional classifications (eg. antidiuretic, hemostatic, sedative, galactagogue) and functional properties (anti-inflammatory, cardiac tonic, nourishing, wound healing) enumerated for the food ingredients [24-26]. For instance, ayurveda classifies garlic (*Allium sativum*), used extensively in Indian cuisine, as a rejuvenator, an eye tonic, and a nourishing substance among other attributes. It is evident that the property of garlic as a rejuvenator will be because of its high antioxidant potential [98, 99]. Garlic also reduces K and V. A condition like atherosclerosis is considered in ayurveda as a KV-related disorder, and since garlic can reduce both, it is effective in treating this condition. It is pertinent to note the scientific reports on garlic's role in prevention and treatment of atherosclerosis [100, 101]. The bioactive compounds ajoene and allicin are found to inhibit the expression of inducible Nitric Oxide (iNO) synthase, which are expressed in the inflammatory environment in human atherosclerotic lesions [100].

Thus, although ayurveda does not specifically use the term bioactive compounds, it is obvious that its approach encompasses the subject of food bioactives. This is obvious from the fact that, in addition to basic nutrition, ayurveda also discusses food/ingredient properties which can modify the etiopathological processes like inflammation. The proof also lies in the increasing number of bioactive components identified in spices used in Indian cuisine [78-82]. By adding spices, bioactives are in fact added to food, and their prophylactic properties are made available in the food matrix to help prevent diseases. The range of food ingredients and foods used in traditional Indian/ayurvedic diet is far more than those in the common diet seen in Western countries. Although this could be due to availability of a wide variety of plants and plant products in India, the extensive discussion on plants, spices, their medicinal properties and their specific usage in cuisine indicate that they are not only used as food but also in promotive and preventive health. The various methods used in processing food (such as seasoning spices in oil or ghee, or adding aqueous solutions of spices) could indicate different methods of extraction and/or delivery of bioactive compounds. Spectroscopic profiling of aqueous preparations of *Piper nigrum* and *Zingiber officinale* prepared by different methods shows significant differences indicating that different compounds are extracted by the different methods (unpublished data from my work).

Understanding the role of bioactive compounds in foods is gaining momentum in current nutritional research. There are two aspects to these studies: (a) to identify and demonstrate the activities of bioactives, and (b) to understand their beneficial health effects. These studies

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consider not only purified bioactive compounds but also food fractions and whole foods. Ayurveda discusses whole foods, where each ingredient contains numerous phytochemicals that may influence the physiology through a wide variety of mechanisms. The final effect could hence be due to synergy between the various phytochemicals and not from a single bioactive compound. Studies have reported synergy between various diet components, such as garlic and dietary components in a food matrix [102, 103], and components of whole grains [104]. Moreover, pleiotropic effects of bioactives can also contribute to their prophylactic properties [105]. Considering the many factors in functional food, a comprehensive approach is required. In this context, it would be interesting to assess scientifically the overall characteristics (eg. antioxidant potential, hypolipidemic property, glycemic load, etc.) of different ayurvedic food preparations.

The effect of food on health and prevention of diseases can be seen only after consumption of the complete diet. Some effects may require sustained consumption and dietary exposure to bioactive compounds over long periods of time [100, 106]. The health effects of various food ingredients documented in ayurvedic texts are a result of observations on large populations over very long periods of time. By linking specific food ingredients (bioactives) to biomarkers for disease (in ayurvedic terminologies), ayurveda discusses the endpoint effect of food and gives not only a framework for food synergy but also testable hypotheses. Ayurvedic perspective can be used in current nutritional research as a guide for a top-down approach and complemented by a bottom-up approach. While important information can be extracted from the former, the bottom-up approach can also provide clarity about the biological effects of food by isolating and identifying bioactive compounds.

CONCLUSION

Hippocrates said, *Let food be your medicine and medicine be thy food*. Ayurveda declares, *You are what you eat*. The current health scenario reinforces these statements. Be it the current or ayurvedic perspective, it is now clear that improper food and lifestyle affect the health of people. There are a number of factors other than the composition of food which modulates the nutritional status and dietary needs of a person. Factors such as the season, the source of food materials, the dietary pattern of different cultures, an individual's capacity to digest and assimilate food, and the taste preferences of individuals pose a real challenge for nutrition scientists to arrive at a common set of parameters to understand diet and nutrition. In modern theories of nutrition, food is generally understood in terms of calories and components (carbohydrates, proteins, fats, etc.). These classifications, however, do not address questions such as which foods can help in digestion, which ones improve appetite, which properties of foods can prevent diseases, or what should be taken and avoided in the different seasons. Answers to these practical questions can be found in ayurveda, which is why the ayurvedic perspective becomes important.

The ayurvedic diet goes beyond the basic function of supplying nutrients. Ayurveda, with its practical and functional classification of the intrinsic and extrinsic factors involved in dietetics, can help in functional food research and also bring personalized nutrition to households. It can be a practical guide to people who have different constitutions. It can help them plan their diet according to their constitution, digestive capacity, disposition, the prevailing season, etc. By offering several methods to stay healthy and prevent diseases, ayurveda

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empowers a person by taking health into the realm of one's personal responsibility. Ayurvedic concepts of diet and nutrition are universal and can be adapted to every country's cultural, dietary, seasonal and climatic requirements, and incorporated into people's daily life and cuisine. Classification of foods and their components into taste and VPK is not overly simplistic but gives a broad framework to classify any food type. Preliminary results from my research work has shown scientific basis for these classifications [107, 108].

Modern and ayurvedic nutrition provide two different approaches to functional food. Each has its own strengths, weaknesses and answers to specific questions, and there is no one right or wrong approach. The most suitable model is determined by a number of factors, such as local/cultural requirements and resources. The point of intersection between the reductionistic modern dietetics and system approach of ayurveda is human health with both systems working towards its improvement. All existing knowledge of nutrition should therefore be used for the betterment of human health. In this context, ayurveda's experience and expertise, accumulated and documented over several millennia, should be used to benefit humanity. More importantly, pooling the knowledge from the two different perspectives raises the interesting possibility of collaboration between the two systems. This can give rise to new models and parameters for systems research in nutrition. The prospects are very exciting.

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