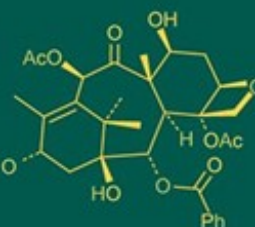
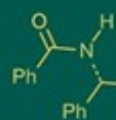


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Comparative assessment of physical, proximate and mineral composition of major ingredients used in ready-to-eat spices gravy formulation

Shantanu Sitaram Konde¹, BM Patil², RB Kshirsagar³, Kishor Anerao⁴, Sachin Giri⁵, Akshay Puri⁶, Rushikesh Karpe⁷

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ABSTRACT

Development of good quality Ready to Eat (RTE) spices gravy is possible through an extensive study of the physicochemical and nutritional properties of the ingredients used in the preparation of such products. The current research work was carried out to determine the physical properties, proximate analysis and mineral content of onion (*Allium cepa*), tomato (*Solanum lycopersicum*), garlic (*Allium sativum*) and ginger (*Zingiber officinale*) which are the major ingredients of RTE spices gravy. The fresh ingredients obtained from the local market were subjected to analysis employing standard methods. Tomato showed the lowest value for pH (4.28 ± 0.05) and highest for titratable acidity ($0.47 \pm 0.01\%$) and hence, the predominant factor responsible for acidification of the gravy preparation system. On the other hand, garlic showed the highest values for total soluble solids (34.5 ± 0.5 °Brix) and superior nutrient density in terms of high protein ($6.40 \pm 0.10\%$), carbohydrates ($33.10 \pm 0.40\%$) and ash ($1.50 \pm 0.04\%$) contents. Tomato showed the highest moisture content ($94.5 \pm 0.4\%$) and ginger showed the highest fat content ($0.80 \pm 0.03\%$). Mineral content analysis showed that garlic is an excellent source of calcium (181 mg/100 g), phosphorus (153 mg/100 g), iron (1.70 mg/100 g) and zinc (1.16 mg/100 g) while ginger had the highest potassium (415 mg/100 g).

Keywords: Garlic, Ginger, Mineral Composition, Onion, Physicochemical Properties, Proximate Composition, Ready-to-Eat Spices Gravy

Introduction

The RTE foods packed in retort pouches have gained commercial significance owing to their shelf life at ambient temperatures combined with sensory attributes close to fresh foods. Among the wide variety of RTE foods made available to both the Indian and international markets, the gravies and curry-based foods form an important category, since gravies form the basis of a number of food products and can be formulated for both vegetarian as well as non-vegetarian products. The development of such products relies not only on the choice of thermal process used but also crucially on the ingredients used in preparing the base paste (Girish *et al.*, 2018) [1].

Onion, tomato, garlic and ginger are the four basic aromatics which form an almost essential part of Indian cuisine and provide sweetness, acidity, pungency and flavor, respectively. Each ingredient adds a unique chemical property to the paste being prepared. Onions and garlic belong to the *Allium* group and are popular for their organosulfur and carbohydrate content. However, ginger, which is a rhizome of the *Zingiberaceae* family, is popular for its oleoresins and volatile oils which lend pungency and aroma to food dishes. Tomato is the key source of acidity, color and soluble solids in gravies and is also very important in imparting the required flavor to the dish prepared (Osanyinlusi & Kefale *et al.*, 2023; Olaniran *et al.*, 2013) [3, 2].

From a food processing perspective, the acid-base balance, moisture level and soluble solids of the raw material mixture have a direct bearing on the final pH of the sauce, which determines the extent of heat treatment necessary to achieve commercial sterility in the retort pouch. Given that spores of *Clostridium botulinum* need to be deactivated in low-acid products at a final pH of greater than 4.6, even the slightest variation in the ratio of the vegetables or their natural acidity will influence the final product to fall within the critical range, hence the requirement for F_0 value and processing time. It is therefore crucial that the raw materials are first analyzed for their physicochemical characteristics before being incorporated into the standard formula. (Leistner, 2000) [4].

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Corresponding Author:
Shantanu Sitaram Konde
Department of Food Engineering, College of Food Technology, VNMKV Parbhani-431402, Maharashtra, India

tion in the ratio of the vegetables or their natural acidity will influence the final product to fall within the critical range, hence the requirement for F_0 value and processing time. It is therefore crucial that the raw materials are first analyzed for their physicochemical characteristics before being incorporated into the standard formula (Owusu *et al.*, 2012; Kefale *et al.*, 2023, Machado *et al.*, 2025) [5, 2].

Although these four raw materials are extensively used in Indian food processing, there is no report on baseline data relating to the physicochemical characteristics of the raw material lot used in a particular product development experiment despite the fact that such data are required in order to interpret any changes in the gravy during processing and storage. The current study was therefore conducted as part of a larger experiment to develop retort-processed ready to eat (RTE) spices gravy. It focused on the objective of assessing the physicochemical characteristics of raw materials for use in the experiment. In this paper, the physical attributes, proximate composition and mineral content of onions, tomatoes, garlics and ginger used as raw materials in the gravy were reported and discussed.

The comparative compositional information in this context is valuable in itself outside the bounds of designing the process. With growing consumer awareness regarding the nutritional value of convenience food products, manufacturers of ready-to-eat (RTE) food are faced with increasing pressures to demonstrate and justify any nutritional claims made about the product as well as how the composition of raw materials contributes to the nutritional value of the end product. Therefore, in addition to being essential for safe thermal process design, the raw material characterization discussed above plays an additional role in facilitating the nutritional labeling of the developed RTE spiced gravy.

Materials and Methods

Fresh, disease-free bulbs of onion (*Allium cepa*) and garlic (*Allium sativum*), mature fruits of tomato (*Solanum lycopersicum*) and rhizomes of ginger (*Zingiber officinale*) were purchased from the local market as one lot in order to reduce variability between different lots. All the samples of the materials were selected for intactness and absence of diseases, washed in tap water and air-dried before analysis.

The physical attributes like shape, size and color were captured through visual inspection and measured using a digital vernier caliper. The titrable acidity of the plant was measured by titrating a weighed sample of the homogenized sample against a standardized solution of sodium hydroxide using phenolphthalein as an indicator. The pH was

measured using a digital pH meter according to standardized methods usually used for raw vegetables and spices. Total soluble solids were measured using degrees Brix using a refractometer (Owusu *et al.*, 2012; Machado *et al.*, 2025) [5, 6].

The proximate composition comprising moisture content, crude fat content, crude protein content, total ash content and crude fiber content were determined based on AOAC protocols, while the carbohydrate content was obtained indirectly (AOAC International, 2019) [7]. This is consistent with the protocols used in similar studies on the proximate composition of onion, tomato, garlic and ginger (Kefale *et al.*, 2023; Osanyinlusi, 2023) [2, 3].

Minerals such as calcium, iron, magnesium, phosphorous, potassium, sodium and zinc content were determined by conventional methods combined with atomic absorption spectroscopy, following the methodology adopted for the analysis of mineral content in raw *Allium* and *Zingiberaceae* species (Osanyinlusi, 2023) [3]. Nutritional values of reference onion, garlic and ginger data sourced from USDA FoodData Central were applied to validate the analyzed data obtained in the current study (USDA, 2023) [8]. All measurements were carried out in triplicate and results reported as mean $\pm$ standard deviation.

Analysis of the data was done using descriptive statistics only (mean $\pm$ standard deviation) for triplicate measurements. This was consistent with the method used for reporting the results of similar raw material characterization studies (Kefale *et al.*, 2023; Osanyinlusi, 2023) [2, 3]. Since the objective of this part of the study was to get a composition baseline of the specific batch of raw material for use in further recipe trials and not to compare the cultivar or the growth conditions, no other experiment was performed.

Results and Discussion

Physical characteristics of raw materials

The physical analysis in Table 1 shows that onion and tomato had relatively similar sizes (4-7 cm), while the size of garlic bulbs was relatively small (3-6 cm) and ginger rhizomes were relatively large and irregular compared to other raw materials used in this study (8-10 cm long). This difference in size and morphology is consistent with the description of the morphology of *Allium* and *Zingiberaceae* provided by comparative composition studies (Osanyinlusi, 2023) [3]. Size and morphological differences have practical importance in the process of gravy production, especially at the steps of cutting, peeling and grinding, as rhizomes with irregular shape like ginger require more effort for trimming than onion and tomato.

Table 1. Physical characteristics of raw materials

Parameter	Onion	Tomato	Garlic	Ginger
Shape	Round to oval	Round to oval	Bulb with multiple cloves	Irregular branched rhizome
Size (cm)	4-7	4-7	3-6	8-10 (length), 3.0-5.0 (width)
Colour	Red, pale red	Red	White, cream	Light brown skin, pale yellow flesh
Acidity (%)	0.28 $\pm$ 0.02	0.47 $\pm$ 0.01	0.18 $\pm$ 0.01	0.16 $\pm$ 0.02
pH	5.54 $\pm$ 0.03	4.28 $\pm$ 0.05	5.76 $\pm$ 0.04	5.61 $\pm$ 0.06
TSS ($^{\circ}$ Brix)	7.0 $\pm$ 0.2	6.5 $\pm$ 0.2	34.5 $\pm$ 0.5	8.3 $\pm$ 0.2

The tomato had the lowest pH value (4.28 $\pm$ 0.05) and the highest titratable acidity (0.47 $\pm$ 0.01%). These values are in very close agreement with pH and titratable acidity values that have been reported for tomatoes meant for industrial processing (Machado *et al.*, 2025; Owusu *et al.*, 2012) [6, 5]. Low pH of tomato plays a significant role in acidifying the blended gravy paste. This is pertinent from a process point of view since the final pH value of the retorted product classifies the food as low-acid or acidified foods (Leistner, 2000) [4].

Garlic showed the highest pH (5.76 $\pm$ 0.04) and the lowest titratable acidity (0.18 $\pm$ 0.01%) among the four raw materials in addition to the highest content of total soluble solids (TSS), being 34.5 $\pm$ 0.5 $^{\circ}$ Brix.

The high amount of soluble solids in garlic in comparison with other *Allium* and spices raw materials had been previously attributed to the low water content and high amount of soluble carbohydrates and organosulfur compounds in garlic (Kefale *et al.*, 2023) [2]. Onion and ginger ranked in between, having similar values for the pH, being 5.54 $\pm$ 0.03 and 5.61 $\pm$ 0.06, respectively, which implies that both ingredients do not contribute to the acidification of the gravy compared to tomatoes.

On the basis of formulation considerations, the differences that have been seen with respect to the acid-base balance of the four ingredients have some importance since the percentage of tomato in relation to

onions, garlic and ginger in the finished gravy formulation will play an important role in defining the pH of the prepared gravy mixture. This will help in establishing the retort cycle needed for the assurance of microbial safety of the product (Girish *et al.*, 2018; Leistner, 2000)

[1, 4]. The relatively higher total soluble solids (TSS) of the garlic also mean that an increase in the percentage of garlic in the formulation will affect the total TSS of the gravy formulation.

Proximate composition of raw materials

Table 2. Proximate composition of raw materials (g/100 g, fresh weight basis)

Parameter	Onion	Tomato	Garlic	Ginger
Moisture	89.1 ± 0.5	94.5 ± 0.4	58.6 ± 0.6	79.8 ± 0.5
Fat	0.10 ± 0.01	0.20 ± 0.01	0.50 ± 0.02	0.80 ± 0.03
Protein	1.10 ± 0.05	0.90 ± 0.04	6.40 ± 0.10	1.80 ± 0.06
Ash	0.40 ± 0.02	0.50 ± 0.03	1.50 ± 0.04	0.80 ± 0.03
Carbohydrate	8.60 ± 0.20	3.90 ± 0.10	33.10 ± 0.40	15.80 ± 0.30
Crude fibre	1.70 ± 0.06	1.20 ± 0.05	2.10 ± 0.08	2.00 ± 0.07

As shown in Table 2, the proximate composition of the raw materials revealed that tomato contained the highest moisture content (94.5 ± 0.4%), followed by onion (89.1 ± 0.5%), ginger (79.8 ± 0.5%) and garlic (58.6 ± 0.6%). The aforementioned trend, whereby tomato and onion have higher moisture content compared to garlic, is consistent with the comparative proximate compositions of *Allium* and spices raw materials by Kefale *et al.* (2023) [2] and Osanyinlusi (2023) [3], who have also revealed that garlic had the lowest moisture content among all.

As expected on the fresh weight basis, the lower moisture content in garlic was associated with high levels of other proximate components in the garlic, having the highest carbohydrate (33.10 ± 0.40%) and protein (6.40 ± 0.10%) content among the four raw materials analyzed. Inverse correlations of moisture content and carbohydrate content or protein content of garlic have also been observed in comparison with onion and ginger in the nutritional composition study, where garlic has been found to be the most abundant source of carbohydrate and protein in the raw materials of *Allium* and spices (Osanyinlusi, 2023; Owusu *et al.*, 2012) [3, 5].

Fat contents were in the following order: ginger (0.80 ± 0.03%) > garlic (0.50 ± 0.02%) > tomato (0.20 ± 0.01%) > onion (0.10 ± 0.01%). The higher fat content seen in ginger is attributed to the high levels of oleoresins and volatile aromatic oils that are responsible for the pungent and distinct smell in the root of ginger, as described in the earlier compositional studies of ginger rhizome (Kefale *et al.*, 2023) [2]. The highest ash content, which is an indicator of the total mineral content, was found in garlic (1.50 ± 0.04%).

The crude fiber content displayed only slight differences between the four raw materials, ranging from 1.20 ± 0.05% in tomato to 2.10 ± 0.08% in garlic. Considering the minimal differences in fiber content between the raw materials, the fiber content may not be a major criterion used to differentiate the texture of the final gravy. This observation is consistent with other literature that shows the range in which crude fiber content in *Allium* and spices falls to be relatively narrow in comparison with the range of variations exhibited in moisture, protein and carbohydrate contents (Owusu *et al.*, 2012) [5].

Mineral composition of raw materials

Table 3. Mineral composition of raw materials (mg/100 g)

Parameter	Onion	Tomato	Garlic	Ginger
Calcium	23	10	181	16
Iron	0.21	0.27	1.70	0.60
Magnesium	10	11	2	43
Phosphorus	29	24	153	34
Potassium	146	237	401	415
Sodium	4	5	17	13
Zinc	0.17	0.17	1.16	0.34

The mineral composition of the four raw materials is shown in Table 3. Garlic was the largest contributor of calcium (181 mg/100 g) and phosphorus (153 mg/100 g). The numbers obtained correlate well with the information provided about the raw garlic's composition in USDA FoodData Central database (USDA, 2023) [8] and they correspond to the information given in scientific literature where garlic is found to have a much larger content of these minerals compared to onion, tomato, or ginger (Osanyinlusi, 2023) [3].

Ginger, on the other hand, showed the maximum amount of magnesium (43 mg per 100 g) and potassium (415 mg per 100 g) in the four ingredients studied. Potassium was found to be the major mineral constituent among the four ingredients with major contribution by tomato (237 mg per 100 g) and garlic (401 mg per 100 g). The dominance of potassium among the minerals studied is consistent with the results of a systematic nutritional and physicochemical profiling study conducted by Kefale *et al.* (2023) [2] on commonly used spices. A higher ratio of potassium to sodium is generally believed to be nutritionally beneficial and in this study, all four raw ingredients have

been found to contain extremely low levels of sodium (4–17 mg per 100 g), which implies that sodium content of the finished product will depend only on the quantity of salt added during the

Iron and zinc contents were found in relatively small quantities in all the four ingredients considered. Garlic had the highest values in terms of both the mineral elements mentioned (1.70 mg/100 g iron and 1.16 mg/100 g zinc). The results obtained confirm a comparative analysis of mineral composition in garlic, ginger and some spices, which revealed the presence of calcium and iron in much higher quantities in garlic than in the other raw materials analyzed (Osanyinlusi, 2023) [3]. The unique combination of small water content in garlic and high amounts of calcium, phosphorus, iron and zinc makes it an important source of microelements in the developed gravy, despite being used in lesser quantities than onions and tomatoes (Osanyinlusi, 2023) [3].

When integrated across all three sets of physical, proximate and mineral data provided in Tables 1 to 3 above, the four raw materials have a clear compositional hierarchy. Tomato is identified as the major

acidifier and source of moisture in the blend. Garlic is characterized by low moisture content and high energy, protein and minerals. Ginger is characterized by its role as an intermediate moisture provider and a certain level of fat, magnesium and potassium. Onion is recognized as a relatively acid and moist raw material that acts as a link in the composition of tomato and garlic raw materials (Kefale *et al.*, 2023; Osanyinlusi, 2023; Owusu *et al.*, 2012) [2, 3, 5].

Implications for recipe standardization and process design

The physico-chemical parameters determined during this objective have direct and practical importance for future stages of product development. Since the final pH value of the product after retort process determines the degree of heat treatment required to eliminate the spores of *Clostridium botulinum* and provide commercial sterility, it will be used as an important factor for regulating the pH of the mixture of gravy in recipe formulation due to the lower pH and higher titratable acidity of tomato compared to onion, garlic and ginger (Leistner, 2000; Girish *et al.*, 2018) [4, 1].

Along with thermal treatment, the inherent qualities of the raw material also affect other aspects of preservation in conjunction with such aspects as water activity, barrier properties of the packing and storage temperature, in line with the principles of hurdle technology. It is based on the assumption that the use of several preservation factors improves the microbial stability, sensory characteristics and nutritional qualities of a product better than just using one factor (Leistner, 2000) [4]. The rather low moisture level and high solids content of the garlic, for instance, can be seen as contributing to the low water activity of the paste as a result of blending with tomatoes and thermal lethality from retorting.

Studies on other retort-processed Indian-style curries and gravies too have stressed that the characteristics of the raw materials used along with the appropriately designed heat process are capable of resulting in an ambient-storable product of acceptable sensory quality for long periods of time ranging from nine to twelve months or even beyond (Girish *et al.*, 2018) [1]. The physico-chemical characteristics determined in the current study of onion, tomato, garlic and ginger therefore serve as a suitable starting point for the formulation of the recipes and the optimization of the heat process, which is the next step in this study.

Conclusion

The physico-chemical analysis of onion tomato garlic and ginger demonstrated considerable variation in their compositional characteristics and highlighted their distinct functional roles in the formulation of RTE spices gravy. Tomato exhibited the highest acidity and lowest pH making it a key ingredient for product acidification and effective retort processing. Garlic contributed higher levels of protein carbohydrates and essential minerals while ginger provided appreciable amounts of potassium magnesium and fat. The observed variations in composition emphasize the importance of selecting suitable raw materials for developing a nutritionally balanced and shelf-stable product. The analytical results were consistent with values reported in the

scientific literature confirming the reliability of the study. Overall, these findings provide a strong scientific basis for recipe standardization process optimization and quality evaluation thereby supporting the development of a safe nutritious and commercially viable RTE spices gravy.

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Authors

Shantanu Sitaram Konde

Department of Food Engineering, College of Food Technology, VNMKV Parbhani-431402, Maharashtra, India

BM Patil

Assistant Professor Department of Food Engineering, College of Food Technology, VNMKV Parbhani-431402, Maharashtra, India

RB Kshirsagar

Professor and Head, Department of Food Engineering, College of Food Technology, VNMKV Parbhani-431402, Maharashtra, India

Kishor Anerao

Ph.D. Research Scholar, Department of Food Microbiology and Safety, College of Food Technology, VNMKV Parbhani-431402, Maharashtra, India

Sachin Giri

Ph.D. Research Scholar, Department of Food Engineering, College of Food Technology, VNMKV Parbhani-431402, Maharashtra, India

Akshay Puri

Department of Food Engineering, College of Food Technology, VNMKV Parbhani-431402, Maharashtra, India

Rushikesh Karpe

Department of Food Process Technology, College of Food Technology, VNMKV Parbhani-431402, Maharashtra, India