DOI: *10.15613/fijrfn/2024/v11i2/47840*
*ISSN (Print) : 2349-8897*
***FoodSci*: Indian Journal of Research in Food Science and Nutrition,** *Vol 11(2), 39-46, July-December 2024* *ISSN (Online) : 2350-1006*

# Real-Time Application of ATR-FTIR Spectroscopic Technique for the Green Authentication Analysis of Children's Health Nutrition Powders

**Rekha Pachaiappan[1], G. J. Bhagavathiammal[2*], E. Melinda Jesse[3] and P. Aruna[2]**

[1]Department of Physical Sciences, SIMATS Engineering, Saveetha University, Chennai - 602105, Tamil Nadu, India

[2] Department of Medical Physics, Sir C V Raman Science Block, Anna University, Sardar Patel Road, Guindy, Chennai - 600025, Tamil Nadu, India; selvigjb@gmail.com

[3]Department of Physics, Women's Christian College, Chennai - 600006, Tamil Nadu, India

## Abstract

In today's world, every product has become artificial and instantaneous due to rapid technological development. Consumers are shifting to healthier diets, and packaged food companies are introducing more functional food items with immunity claims and incorporating more nutritious ingredients into their products. Due to the increased production, the products that ordinary people receive have many flaws and defects. Spectroscopic approaches are unique probing techniques to characterize various compounds in a product and find and rectify molecular-level flaws and defects. Fourier Transform Infrared Spectroscopy is considered to be the most effective and simpler technique to identify unknown materials, verify the quality of materials, de-formulate polymers, rubbers, and other materials through the identification of pollutants, examine thin films and coatings, monitor vehicle and smokestack emissions, and conduct failure analysis through Thermos-Gravimetric Infrared (TGA-IR) and other methods. The present study mainly addresses the authentication analysis of children's health nutrition powders using the ATR-FTIR technique to identify the elemental compounds and assess their benefits and drawbacks to human health.

**Keywords:** ATR-FTIR, Authentication Analysis, Health Powder, Nutrition Powder, Spectroscopic Analysis

## 1. Introduction

Nutrition and amusement have taken a backseat in today's frantic world for adults and children. They overlook adequate nutrition, such as that found in a well-balanced diet, resulting in poor performance in all activities. Soft drinks, on the other hand, have become a habit among children due to their accessibility[1]. On the other hand, the need for healthy beverages has been a hot topic in recent years. Various companies say these health beverages would compensate for the lost nutrients and help your children grow stronger and sharper. Children should drink healthy beverages even if they get all the nutrients they need to stay healthy[2]. Milk is a natural source of nourishment and the highest source of protein, and it can be consumed alone. If a child is a picky eater or dislikes milk, health drinks can be used to mask the taste while maintaining the same nutritional value. In addition to protein and calcium, health beverages contain iron, pantothenic acid, antioxidants, vitamin E, and other ingredients that promise to prevent anaemia, release energy, and support the immune system[2]. However, not all brands have the same nutrient measure to meet a child's nutritional needs, so selecting the best healthy drink is critical.

While pediatric dieticians believe that healthy drinks are an excellent alternative if a child struggles in school, athletics, or other activities, they are not required. Other times, health drinks are merely a way to flavour milk. Although the claims made by firms differ on many levels, they all rely on including DHA, which is essential for a child's cerebral development[3]. While limiting the amount of formula consumed to twice daily may be beneficial,

*Author for correspondence

excessive drinking of such drinks may harm one's health. Even though these beverages are pretty popular among children, they also have several drawbacks[4].

Health drinks have modest amounts of caffeine and a high sugar content to develop taste, in addition to some carbohydrates and proteins. These compounds have an early impact on children's health and cause cavities. Furthermore, precise nutritional information may not be provided to enhance the sale of a drink. They can potentially induce significant weight gain if used too frequently, and there is no assurance of satisfaction[4]. Although healthy drinks should be consumed no more than twice a day, they are not a substitute for a balanced diet. Instead, considerably healthier and natural alternatives such as kanji with ragi or jowar mixed with jaggery and milk might be substituted; these options are high in fibre, rich in minerals and proteins, and have no adverse effects[5]. Homemade smoothies, milkshakes, and juices are inexpensive and nutritious sources of extra nutrients. The parent and pediatrician should decide whether or not healthy drinks are beneficial to the child.

FT-IR spectroscopy has had a significant positive impact on the identification and characterization of materials. The invention of infrared spectroscopy as an analytical tool can be credited to Sir William Herschel's pioneering work in 1800. Since that time, FT-IR spectroscopy has experienced three different phases. The late 1950's introduction of the first-generation instruments featured a NaCl prism as a light scattering component. Due to severe restrictions, the first generation was short-lived. The second generation, underway in the 1960's, switched out the prism for a grating. Despite significant improvements, the second generation of devices had a short lifespan because of flaws like slow speed, poor sensitivity, and inconsistent wavelength repeatability. The third generation emerged around the time the first-generation instruments started to gain popularity. The Michelson interferometer, developed in 1881, did away with the need for single-wavelength band isolation because it could scan all wavelengths simultaneously. Peter Fellgett captured the first FT-IR spectrum in 1949. After that, it took several years for compelling and expensive computer systems to transform the interferometer into a usable spectrum. The Cooley-Tukey method was first applied to quick Fourier transforms in 1966. FT-IR spectroscopy was used to gather the necessary data, and it quickly outperformed dispersive IR technology in this application. In the beginning, FT-IR equipment was both expensive and large. In the following years, technical developments reduced the cost of FT-IR spectrometers while enhancing their performance. Today, various disciplines use FT-IR spectroscopy, including forensic investigations, surface coating analysis, lubricants and fuel additives, pharmaceutical and food research, polymer characterization, and biological studies.

FTIR analysis was employed effectively in determining the quality and safety of food substances[6-9]. Mojica *et al.* have reported examining the presence of carbohydrates in the form of sucrose, and fructose is determined from Maple syrup with FTIR spectral data. Carbohydrates are an essential food content that provides various nutrients to the body[6]. Another research work reported the presence of adulteration in paprika powder in the form of Sudan dye by employing FTIR spectroscopic technique[7]. Recently, Valand *et al.* have consolidated the review report on the significant usage of the FTIR technique in checking the quality of food and authenticity of the same[8]. Sucrose, fructose and saccharides play a vital role in food. Indrayanto and Rohman have reported on the spectral analysis of FTIR in the quality, composition, adulteration, and contamination of honey samples, flour, chicken meat, and paprika powders[9]. The classification and compositional analysis were carried out with chemometrics software utilizing the principal component and multivariate analysis, respectively. In this work, we carried out the green authentication analysis of children's health nutrition powders using ATR-FTIR spectroscopic technique.

## 2. Materials and Methods

### 2.1 Materials

Isopropanol (AR grade from Merck) and distilled water were used to clean the FTIR spectrometer's sample compartment. Five different health powders (Sample 1 to Sample 5) of children were collected from the supermarkets in Chennai, India. These health powders were considered samples, and FTIR analysis was performed to determine the sample's composition. Further, to identify the nutritional elements in the sample and their role in the development of children's health.

### 2.2 Sample Preparation, Instrumentation and Data Analysis

Health powder samples were kept in air-tight sachets without any external contaminations. The spatula and the sample compartment made of diamond were cleaned with

isopropanol. Then, the JASCO FTIR-6600 spectrometer (Japan) equipped with ATR single reflection diamond was switched on along with its software in a connected PC. The background or reference transmittance spectrum for diamond crystal was obtained before starting the sample spectrum collection. This spectrum will be used as a background for sample correction and subtracted from each raw spectrum[10]. The experimental setup was kept the same throughout the entire process.

Following these preliminary arrangements, the powdered sample was put inside the compartment and sealed so that the infrared radiation could interact with the sample's particles. With a resolution of 4 $cm^{-1}$, the spectrum was collected for both finger and high wavenumber regions with a range of 500-4000 cm. The reference transmittance spectrum was collected from the diamond crystal as a back group under identical experimental conditions for every sample. The FTIR spectrum is obtained by smoothening, noise cancellation and baseline correction[10]. For each sample, at least two sets of data were collected, and average spectra were used for the analysis. A graph was drawn between the wavenumber and the transmittance and spotted the elemental composition by taking "SPECTRA" as a reference.

## 3. Results and Discussion

Previous reports exist on the utilization FTIR spectroscopy as an authenticated analysis for food adulteration[7,8]. Figures 1-5 shows the ATR-FTIR spectrum of health nutritional powder (Sample 1-Sample 5) for the wavenumber region 500-4000 $cm^{-1}$. Table 1 shows the tentative assignments for the major peaks observed from ATR-FTIR spectra of five health powder samples[11-23]. ATR-FTIR spectrum of sample 1 shows the major bands at 590, 905, 968, 1067, 1157, 1388, 1472, 1656, 1740, 2932, and 2990 $cm^{-1}$ which corresponds to the nutritions chloride, transfat, saccharose, lactose, vitamin B2, protein (amide II and III), folic acid, biotin, carbohydrates and carboxylic acid respectively. Amidst these nutritional elements of health powder, sugar elements were observed with prominent bands such as saccharose, carbohydrates and lactose. The presence of carboxylic acid confirms the presence of preservatives in the health nutritional powder. FTIR band at ~1740 $cm^{-1}$ proves the presence of colouring agents such as bixin and norbixin[24]. Amide (II and III) bands, which are building blocks of proteins, vitamins and folic acid, are essential for children's physical and mental

**Table 1.** Major FTIR bands of health powders (Sample 1 to Sample 5) and its tentative assignments for nutritional element for the wavenumber region 500 – 4000 $cm^{-1}$[11-23]

| Wave Number ($cm^{-1}$) | Proposed Nutritional Element |
|---|---|
| **Sample 1** | |
| 590 | Chloride |
| 905 | Transfat |
| 968 | Saccharose |
| 1067 | Lactose |
| 1157 | Vitamin $B_2$ |
| 1388 | Protein (amide III) |
| 1472 | Protein (amide II) |
| 1656 | Folic acid |
| 1740 | Biotin |
| 2932 | Carbohydrates |
| 2990 | Carboxylic acid |
| **Sample 2** | |
| 583 | Amide V |
| 1015 | Glucose |
| 1141 | Vitamin E |
| 1750 | Acesulfame |
| 3352 | Carboxylic acid |
| **Sample 3** | |
| 952 | Potassium phosphate |
| 1157 | Riboflavin |
| 1461 | Protein |
| 1540 | Calcium citrate |
| 1750 | Sodium citrate |
| 2937 | Biotin |
| 2980 | Magnesium chloride |
| 2990 | Carboxylic acid |
| **Sample 4** | |
| 1015 | Cocoa powder |
| 1147 | Edible iodized salt |
| 1399 | Amide III protein |
| 1656 | Wheat gluten |
| 1745 | Vitamin $B_1$ |
| 2922 | Iodine |
| 3305 | Wheat extract |
| **Sample 5** | |
| 558 | Sucrose |
| 1015 | Cocoa powder |
| 1425 | Calcium |
| 1745 | Vitamin $B_1$ |
| 2922 | Iodine |
| 3305 | Caramel powder |

health. Folic acid plays a key role as one of the factors to produce nucleic acids and proteins through enzymes[25].

ATR-FTIR spectrum of Sample 2 shows the major bands at 583, 1015, 1141, 1750 and 3352 $cm^{-1}$ attributing towards the elements amide (V), glucose, vitamin E, acesulfame and carboxylic acid, respectively. As per the reports, glucose is an essential element which determines the quality of physical health. This element is responsible for weight management and energy intake by the body. Plethora of report has shown the importance of glucose kinetics for body weight, insulin sensitivity and body energy balance[26]. Another component, acesulfame K assigned to ~1750 $cm^{-1}$ band, was one of the non-nutritive sweetener (NNS) element. In recent times, the consumption of NNS among children got elevated. Especially the NNS are heterogeneous elements present in nutrition powder of children or adults. It acts as a zero or less calorie element which was found to be 200 times sweeter than sugar[27]. The research studies of acesulfame K or non-nutritive sweetener towards children's health was very less. This acesulfame K and other NNS components are potential candidates to cause adverse health effects in children by changing their bodies metabolism[27,28].

Figure 3 represents the ATR-FTIR spectrum of sample 3 for the region 500-4000 $cm^{-1}$. The major bands observed at 952, 1157, 1461, 1540, 1750, 2980, 2937 and 2990 $cm^{-1}$ were assigned to the elements potassium phosphate, riboflavin, protein, calcium citrate, sodium citrate, magnesium chloride, biotin and carboxylic acid, respectively. Among these nutritions- magnesium chloride, sodium citrate, and potassium phosphate provide a needed mineral supplement for children[29]. Calcium is a must to maintain healthy and strong bones. Also, it aids in blood clotting, muscle contraction, normal heart rhythms and neuron function. Calcium is given to the body in the form of supplements- calcium citrate, calcium gluconate and calcium carbonate to provide bone health[30]. It is free from added flavours and colouring agents. Calcium citrate malate in beverages or food supplements provides substantial nutrition to the consumer irrespective of their age[29,30]. Carboxylic acid is a bio-renewable substance that acts as a precursor to various chemical substances. The carboxylic acid inhibits the growth of microbes. Hence, it is utilized as a food preservative in health drink powders and other foodstuffs[31].

Another Figure 4 represents the elements such as cocoa powder, amide II, edible iodized salt, wheat gluten, vitamin B1 and iodine present at band positions- 1015, 1399, 1147, 1656, 1745, 2922 and 3305 $cm^{-1}$, respectively. From the nutritions listed out, wheat extract and cocoa powder have shown a great role in this nutrition powder sample and acts as a preservative. Wheat germ has excellent nutritional value as a food supplement. It's a great source of vegetable proteins, fibre, and healthy fats[32]. It's also a good source of magnesium, zinc, thiamin, folate, potassium, and phosphorus. Wheat gluten is high in protein content[32].

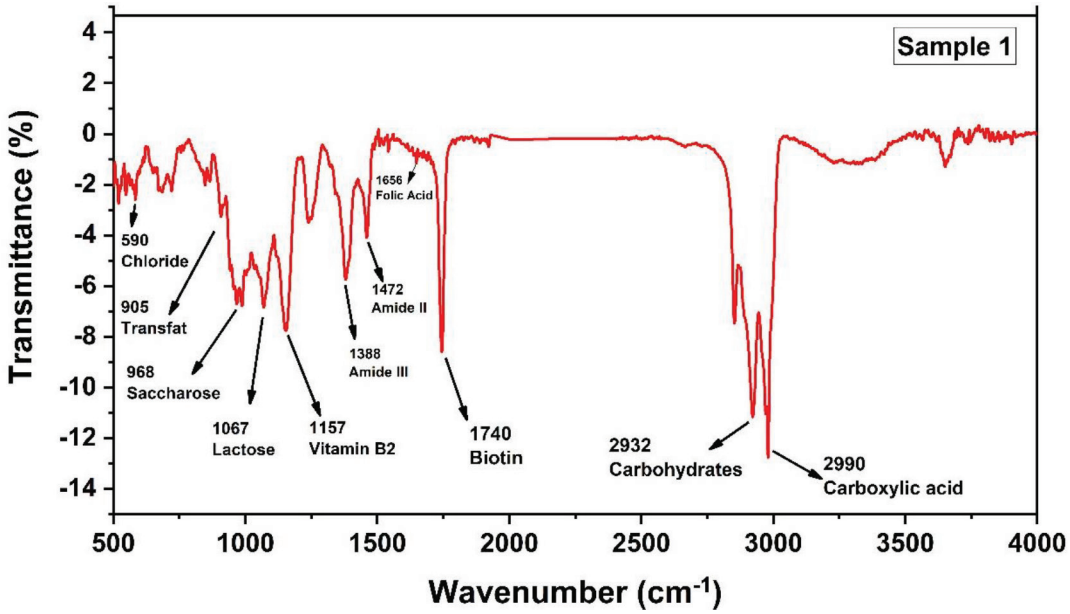



**Figure 1.** ATR-FTIR spectrum of the sample 1 for the wavenumber region (500-4000 $cm^{-1}$).

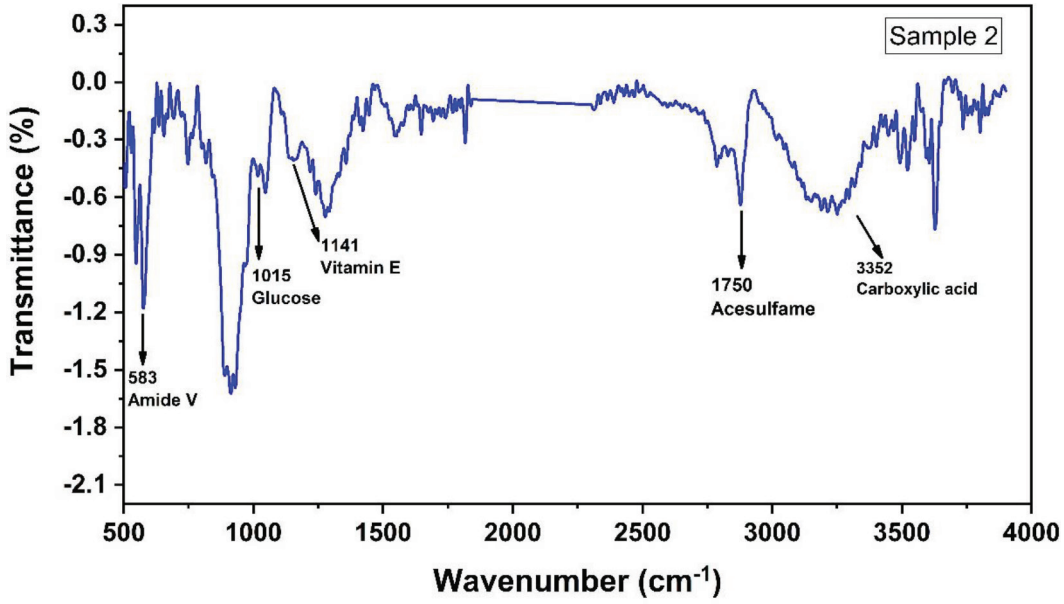



**Figure 2.** ATR-FTIR spectrum of the sample 2 for the wavenumber region (500-4000 $cm^{-1}$).

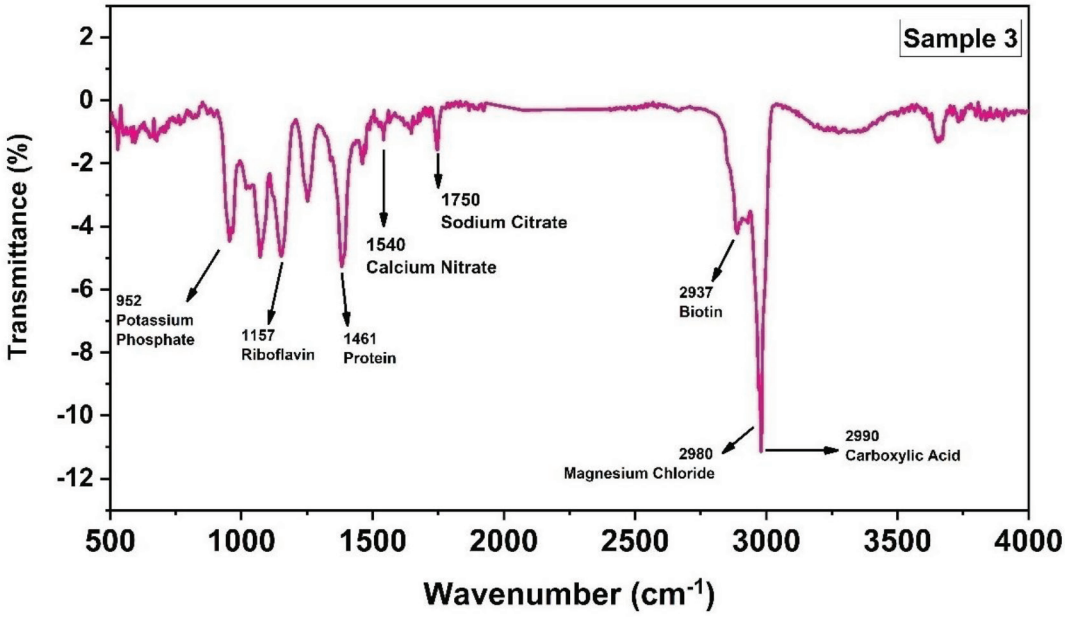



**Figure 3.** ATR-FTIR spectrum of the sample 3 for the wavenumber region (500-4000 $cm^{-1}$).

Figure 5 shows the important band of polyphenols from cocoa and caramel at 1015 and 3305 $cm^{-1}$, respectively. Cocoa is observed to be high in flavanols, which have anti-inflammatory and antioxidant properties. When sucrose is metabolized, it splits into fructose and glucose, which go their own ways throughout the body. This process elevates blood sugar levels, and too much of it can cause blood vessels to break, resulting in cavities and gum disease. Caramel powder has a little bitter, burnt-sugar flavour that won't overpower your desserts or drinks. Sauces, gravies, homemade soft drinks, liqueurs, sweets, and vinegars are just a few of the dishes that can be benefited from it. The other bands include the substances such as sucrose, calcium, vitamin B1, and iodine at 558, 1425, 1745, and 2922, respectively. As said, sucrose, calcium, vitamin and iodine are essential for the body's growth and maintaining health. Thus, the section shows that

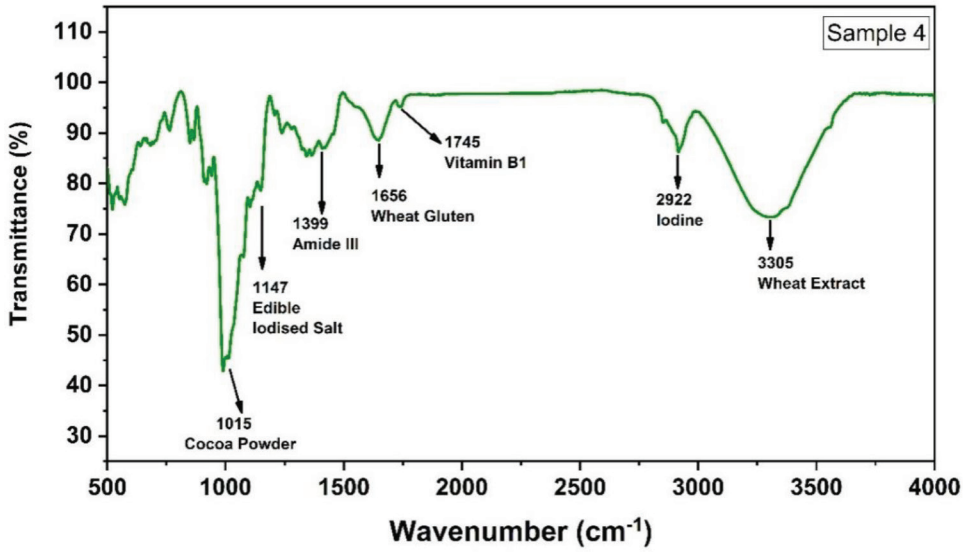



**Figure 4.** ATR-FTIR spectrum of the sample 4 for the wavenumber region (500-4000 $cm^{-1}$).

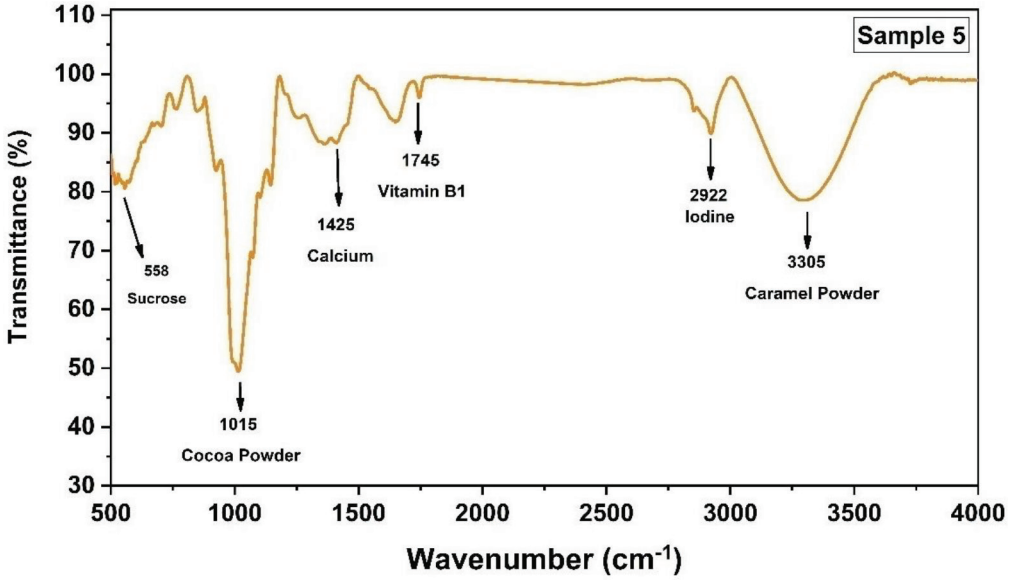



**Figure 5.** ATR-FTIR spectrum of the sample 5 for the wavenumber region (500-4000 $cm^{-1}$).

all five samples contain essential common nutrients, sweeteners, colouring agents and food preservatives.

## 4. Conclusion

ATR-FTIR spectral analysis of children's nutrition health powders successfully showed the presence of various elements. Among that, glucose, carbohydrates, calcium citrate, folic acid, amide Groups (II, III and V), vitamins, wheat extract and caramel are essential for physical body development and also provide mental health. Whereas on the other presence of acesulfame and more sugar components give rise to many health problems like obesity, loss of appetite *etc*., in the consumer. Further, all samples were found to possess preservatives (carboxylic acid) and colouring agents (bixin and norbixin). Consuming healthy nutritional powder drinks provides children with essential elements and keeps them no feeling of hunger for long hours. Make the children resist proper intake of regular foods at the appropriate time. Despite healthy nutrition, the health drink powders contain other compounds (preservatives and colouring

agents) that do not contribute to nutritional values. Prolonged consumption of health nutrition powders with preservatives and colouring agents might cause harm to the health of children in the future as well as harming the health of children. Hence, parents must know about children's nutrition supplements and their proper diet. In conclusion, this ATR-FTIR spectroscopic study helped to authenticate food quality and confirm the quality and safety of the food substances

## 5. Acknowledgements

The authors thanked the funding agency Department of Science and Technology under the FIST scheme for the ATR-FTIR set up utilized in this study.

## 6. References

1. Schneider S, Schilling L, Osenbrügge N. Determinants of soft drink consumption among children and adolescents in developed countries - a systematic review Central European. Journal of Public Health. 2021; 29:290-300. https://doi.org/10.21101/cejph.a6755 PMid:35026068
2. Ferruzzi MG, Tanprasertsuk J, Kris-Etherton P, Weaver CM, Johnson EJ. Perspective: The role of beverages as a source of nutrients and phytonutrients. Adv Nutr. 2020; 11:507-523. https://doi.org/10.1093/advances/nmz115 PMid:31755901 PMCid:PMC7231580
3. Guillot M, Synnes A, Pronovost E, Qureshi M, Daboval T, Caouette G, Olivier F, Bartholomew J, Mohamed I, Massé E, Afifi J. Pediatrics 150, association between early childhood exposure to ambient air pollution and subsequent asthma diagnosis in children; 2022. https://doi.org/10.1542/peds.2021-055819 PMid:35652296
4. Or F, Kim Y, Simms J, Austin SB. Taking stock of dietary supplements' harmful effects on children, adolescents, and young adults. J Adolesc Health. 2019; 65:455-461. https://doi.org/10.1016/j.jadohealth.2019.03.005 PMid:31176525
5. Shobana S, Krishnaswamy K, Sudha V, Malleshi NG, Anjana RM, Palaniappan L, Mohan V. Finger millet (Ragi, *Eleusine coracana* L.): A review of its nutritional properties, processing, and plausible health benefits. Adv Food Nutr Res. 2013; 69:1-39. https://doi.org/10.1016/B978-0-12-410540-9.00001-6 PMid:23522794
6. Mellado-Mojica E, Seeram NP, López MG. Phenolic profile and antioxidant capacity of different commercial varieties of pomegranate (*Punica granatum* L.) arils, juices and peels. J Food Compos. Anal. 2016; 1-8.
7. Lohumi S, Joshi R, Kandpal LM, Lee H, Kim MS, Cho H, Mo C, Seo YW, Rahman A, Cho BK. Quantitative analysis of Sudan dye adulteration in paprika powder using FTIR spectroscopy. Food Addit Contam- Part A. 2017; 34:678-686. https://doi.org/10.1080/19440049.2017.1290828 PMid:28277181
8. Valand R, Tanna S, Lawson G, Bengtström L. A review of the potential presence of mycotoxins in plant-based foods and their health implications. Food Addit Contam- Part A. 2020; 37:19-38. https://doi.org/10.1080/19440049.2019.1675909 PMid:31613710
9. Indrayanto G, Rohman A. The use of FTIR spectroscopy combined with multivariate analysis. Food Composition Analysis Spectroscopic Techniques & Artificial Intelligence for Food and Beverage Analysis. 2020; 25-51. https://doi.org/10.1007/978-981-15-6495-6_2
10. Pachaiappan R, Prakasaraoand A, Singaravelu G. In optical biopsy XV: Toward real-time spectroscopic imaging and diagnosis. SPIE Proceedings. 2017; 10060:151. https://doi.org/10.1117/12.2255605
11. Mahesar SA, Kandhro AA, Cerretani L, Bendini A, Sherazi ST, Bhanger MI. Determination of total trans fat content in Pakistani cereal based foods by SB-HATR FT-IR spectroscopy coupled with partial least square regression. Food Chem. 2010; 123:1289-1293. https://doi.org/10.1016/j.foodchem.2010.05.101
12. Černá M, Barros AS, Nunes A, Rocha SM, Delgadillo I, Čopíková J, Coimbra MA. Physicochemical characterization of polysaccharides from *Opuntia ficus-indica* cladodes. Carbohydr Polym. 2003; 51:383-389. https://doi.org/10.1016/S0144-8617(02)00259-X
13. Lei Y, Zhou Q, Zhang YL, Chen JB, Sun SQ, Noda I. Structural and vibrational studies of 1,3-dithiane and 1,3-dithiane-2-thione by FT-IR, FT-Raman and AB initio calculations. J Mol Struct. 2010; 974:88-93.
14. Çimen D, Denizli A. Recent advancements in nanomaterial based optical detection of food additives. Photonic Sens. 2020; 10:316-332. https://doi.org/10.1007/s13320-020-0578-1
15. Yang W, Wang M, Ma L, Li H, Huang L. Carbohydrate polymers 99. Carbohydr Polym. 2014; 720-727. https://doi.org/10.1016/j.carbpol.2013.09.013 PMid:24274563
16. Amir RM, Anjum FM, Khan MI, Khan MR, Pasha I, Nadeem M. Chemical composition, antioxidant activity and sensory evaluation of date (*Phoenix dactylifera* L.) varieties at various maturity stages. Journal of Food Science and Technology. 2013; 50:1018-1023.
17. Jiang X, Li S, Xiang G, Li Q, Fan L, He L, Gu K. Optimization of ultrasound-assisted extraction of polysaccharides from *Ganoderma lucidum* and their antioxidant activities. Food Chem. 2016; 212:585-589. https://doi.org/10.1016/j.foodchem.2016.06.035 PMid:27374571
18. Chilom CG, Bacalum M, Stanescu MM, Florescu M. Raman spectroscopic characterization of Romanian honey

samples. Spectrochimica Acta Part A: Molecular and Biomolecular. 2018; 204:648 -656. https://doi.org/10.1016/j.saa.2018.06.093 PMid:29982155

19. Assifaoui A, Loupiac C, Chambin O, Cayot P. Further studies on the composition and structure of a fucoidan preparation from the brown alga *Saccharina latissimi.* Carbohydr Res. 2010; 345:929-933. https://doi.org/10.1016/j.carres.2010.02.015 PMid:20303071
20. Anjos O, Campos MG, Ruiz PC, Antunes P. Optimization of ultrasound-assisted extraction of phenolic compounds from red wine grape pomace and evaluation of their antioxidant activity. Food Chem. 2015; 169:218-223.
21. Fathi M, Nasrabadi MN, Varshosaz J. Optimization of ultrasound-assisted extraction of phenolic compounds from red wine grape pomace and evaluation of their antioxidant activity. Int J Food Prop. 2017; 20:2665-2674. https://doi.org/10.1080/10942912.2016.1247365
22. Armenta S, Garrigues S, de la Guardia M. Determination of trace levels of polycyclic aromatic hydrocarbons in olive oil by liquid chromatography with fluorescence detection after solid-phase extraction. J Agric Food Chem. 2004; 52:7798-7803.
23. Monte-Filho SS, Andrade SI, Lima MB, Araujo MC. J Pharm Anal. 2019; 9:209-216. https://doi.org/10.1016/j.jpha.2019.02.003 PMid:31297299 PMCid:PMC6598167
24. Pérez-Monterroza EJ, Chaux-Gutiérrez AM, Franco CM, Nicoletti VR. Effect of high hydrostatic pressure on the physicochemical and functional properties of whey protein isolate. Food Biophysics. 2018; 13:343-352. https://doi.org/10.1007/s11483-018-9540-9
25. Flegr J, Sýkorová K. A novel approach to the analysis of volatile compounds in food using solid-phase microextraction coupled with gas chromatography-mass spectrometry. Sci Rep. 2019; 9:18138.
26. Pang MD, Goossens GH, Blaak EE. The role of nutrition in skeletal muscle health and function in older adults: A narrative review. Front Nutr. 2021; 7:598340.
27. Fagundes Grilo M, Sylvetsky A, Taillie LS. The widespread presence of non-nutritive sweeteners challenges adherence to beverage guidance for children. Front Public Health. 2023; 11:1221764. https://doi.org/10.3389/fpubh.2023.1221764 PMid:37663855 PMCid:PMC10472131
28. Sylvetsky AC, Jin Y, Clark EJ, Welsh JA, Rother KI, Talegawkar SA. Consumption of low-calorie sweeteners among children and adults in the United States. Journal of the Academy of Nutrition and Dietetics. 2017; 117:441-448. https://doi.org/10.1016/j.jand.2016.11.004 PMid:28087414 PMCid:PMC6176710
29. Reinwald S, Weaver CM, Kester JJ. The health benefits of calcium citrate malate: A review of the supporting science. Adv Food Nutr Res. 2008; 54:219-346. https://doi.org/10.1016/S1043-4526(07)00006-X PMid:18291308
30. France TC, Barone G, O'Regan J, Kelly AL, O'Mahony JA. Impact of colloidal stability on the rheological properties of oil-in-water emulsions stabilized by whey protein isolate and gum Arabic. Colloids Surf. B Biointerfaces. 2020; 194:111125.
31. Jarboe LR, Royce LA, Liu P. the role of the gut microbiota in the pathogenesis of inflammatory bowel disease: a review. Front Microbiol. 2013; 4:272.
32. Arshad MU, Anjum FM, Zahoor T. Nutritional assessment of cookies supplemented with defatted wheat germ. Food Chem. 2007; 102:123-128. https://doi.org/10.1016/j.foodchem.2006.04.040