Food Quality and Preference 134 (2025) 105671

Contents lists available at ScienceDirect

Food Quality and Preference

journal homepage: www.elsevier.com/locate/foodqual

Changes in chemosensory perception, food preferences and emotional responses to foods in cancer patients during the early stages of chemotherapy: an exploratory study

J. Di Meglio [a,*], C. Rorandelli [a], C. Dinnella [a], E. Monteleone [a], F.C. Stingo [b], L. Doni [c], L. Visani [d], A. Guarino [c], E. Gambale [c], R. De Sanctis [e,f,g], R. Gerosa [e,f], P. Tiberio [e,f], L. Antonuzzo [c,h,i], V. Scotti [d], I. Meattini [d,h], G. Roviello [c,i], S. Spinelli [a]

[a] SensoryLab, Department of Agriculture, Food, Environment & Forestry, University of Florence, Italy
[b] Department of Statistics, Informatics, Applications 'G. Parenti' University of Florence, Italy
[c] Clinical Oncology Unit, Careggi University Hospital, Florence, Italy
[d] Radiation Oncology Unit & Breast Unit - Oncology Department, Azienda Ospedaliero-Universitaria Careggi, Florence, Italy
[e] Medical Oncology and Hematology Unit, IRCCS Humanitas Research Hospital, Rozzano, MI, Italy
[f] Department of Biomedical Sciences, Humanitas University, Pieve Emanuele, MI, Italy.
[g] Medical Oncology Unit, ASST Papa Giovanni XXIII, Bergamo, Italy
[h] Department of Experimental and Clinical Biomedical Sciences "M. Serio", University of Florence, Florence, Italy
[i] Department of Health Sciences, Section of Clinical Pharmacology & Oncology, University of Florence, Italy

ARTICLE INFO

Keywords:
Taste alteration
Food preferences
Emotions
cancer treatment

ABSTRACT

The prevalence of chemosensory disorders among cancer patients is large and may affect preferences and patients' relationship with foods. The aim of this study is to explore the impact of chemotherapy on chemosensory perception and the impact of self-reported alterations on food experience, specifically on food preferences and emotions elicited by foods in cancer patients during the first cycles of chemotherapy. The data considered here are related to the observations before the start of therapy (T0), after the first (T1), the second (T2) and the fourth (T4) cycle of chemotherapy.

The study shows that chemotherapy induced a variety of chemosensory alterations and disturbances, from self-reported alterations such as phantogeusia and parageusia to decrease of sweet (at lower concentration) and salty (at lower and higher concentration) perception. Self-reported alterations were associated with an increase in negative emotions towards preferred foods after the first cycle of therapy. Self-reported decline in tastes was not associated with changes in preferences, while general taste alterations and parageusia were associated with a change in preference for sweet/bitter foods after the 2nd, and discomfort after the 4th cycle of therapy.

These findings suggest that chemosensory alterations begin early during chemotherapy and progressively worsen, with significant implications for patients' food choices and for their emotional wellbeing. Emotional responses to food may serve as early indicators of sensory-related distress, even before actual changes in preferences occur. This highlights the need for timely personalized supportive interventions to mitigate the impact of these side effects on patients' quality of life.

1. Introduction

The prevalence of taste and smell disorders among cancer patients may exceed 93 % (Larsen et al., 2021) with relevant impact on quality of life by reducing food enjoyment, appetite, and potentially leading to malnutrition (Boltong & Keast, 2012). These symptoms are especially common in patients receiving platinum- or taxane-based chemotherapy (Bernhardson, Tishelman, & Rutqvist, 2008; Gamper et al., 2012; Steinbach et al., 2009), however, they are considered "orphan symptoms" (Santini et al., 2020) because they are often neglected in clinical setting (Sevryugin, Kasvis, Vigano, & Vigano, 2021) and are sometimes not immediately reported by patients (Battle et al., 2020) probably

* Corresponding author at: via Gaetano Donizetti 6, 50127 Firenze, Italy.
E-mail address: jaclyn.dimeglio@unifi.it (J. Di Meglio).

https://doi.org/10.1016/j.foodqual.2025.105671
Received 22 May 2025; Received in revised form 15 July 2025; Accepted 11 August 2025
Available online 12 August 2025
0950-3293/© 2025 The Authors. Published by Elsevier Ltd. This is an open access article under the CC BY license (http://creativecommons.org/licenses/by/4.0/).

because they consider them as part of the treatment, and even as a sign of treatment effectiveness (Prieto-Callejero et al., 2020).

Despite patients receiving chemotherapy often experiencing chemosensory changes, accurately determining the frequency of these problems is difficult due to the variety of assessment methods and different types of alterations. In sensory research, several methodologies are used to assess chemosensory perception, but their application in oncology is limited (Nolden, Hwang, Boltong, & Reed, 2019). This limitation has made it difficult to compare results and has led to variable reports on the frequency and severity of these disorders among cancer patients (Galaniha & Nolden, 2023). Furthermore, methods used in studies which involve the evaluation of taste thresholds using electrical stimulation, filter paper strips or aqueous solutions are effective in the evaluation of disorders as hypogeusia and ageusia, but they typically focus on the lowest detectable concentration of tastants, which does not reflect the intensity level at which taste is normally perceived during real-life food consumption (Bartoshuk, 2000), as instead happens using suprathreshold methods. In addition, these methods fail to assess other symptoms commonly reported by patients, including phantogeusia, parageusia and cacogeusia (Kano & Kanda, 2013).

However, as highlighted by some studies (IJpma et al., 2017; de Vries et al., 2018; de Vries et al., 2019; Postma, Kok, de Graaf, Kampman, & Boesveldt, 2020) self-reported chemosensory changes often do not align with psychophysical assessments of taste and smell functions, as patients may struggle to differentiate between taste and smell, evaluating the overall flavor perception (de Vries, Winkels, et al., 2018). This divergence between methods, rather than representing a limitation, highlights the need to use both approaches in a complementary manner. Using a single method may lead to incomplete information. Therefore, an integrated methodological approach that combines sensory suprathreshold tests with self-reported measures is needed, allowing for a more accurate and broad understanding of chemosensory changes during chemotherapy.

It has long been known that taste and smell are important drivers for individuals' food preferences (Drewnowski, 1997), therefore their alterations during an anticancer treatment might reduce food palatability, limiting food choices and reducing the variety of the diet (Kim et al., 2020; Kourouniotis et al., 2016). However, it is still unclear when this condition occurs and how long it persists. Existing studies use different methods to assess cancer patients' food preferences and affective responses to foods; these include frequency of consumption, qualitative interviews, questionnaires such as the Macronutrient and Taste Preference Ranking Task, and measure of liking using the 9-point hedonic scale (Coa et al., 2015; de Vries, Winkels, et al., 2018; Kim et al., 2020; Nielsen, Theologides, & Vickers, 1980; Pedersini et al., 2021; Postma et al., 2020). The studies indicate a general trend of decreased liking of foods after chemotherapy treatment commencement, and in some cases food aversions have been reported for foods consumed immediately prior to the chemotherapy infusion (Boltong & Keast, 2012). However, as highlighted in a recent scoping review (Nolden et al., 2019) mixed results are often obtained, and a consistent effect was found only for sweetness with a reduced sweet taste function (decreased sensitivity) that was found to be associated with a reduced intake of a variety of different macro and micronutrients, reduced appetite, and overall lower energy intake. Instead, only limited evidence was found to be related to bitter alterations. Indeed, very few studies integrate psychophysical tests and assessment of food enjoyment and eating behaviors which limits the ability to capture the full impact of chemosensory changes on food-related experiences. Furthermore, studies rarely take into account sensory characteristics related to food preferences such as flavor, texture, smell, presence of herbs and spices, sourness, and bitterness, but focus more on their nutritional composition (de Bruijn, de Vries, de Graaf, Boesveldt, & Jager, 2017; Griffioen-Roose, Finlayson, Mars, Blundell, & de Graaf, 2010; Griffioen-Roose, Mars, Finlayson, Blundell, & De Graaf, 2011).

Food acceptance is frequently assessed through measures of hedonic liking, which primarily capture sensory pleasure that has been widely used to predict food choices and intake. Products that receive higher liking scores are typically selected more frequently than those with lower scores, and products disliked are not consumed (De Graaf et al., 2005; Keller, Shehan, Cravener, Schlechter, & Hayes, 2022). However, food choice is influenced by more than just liking; a variety of factors contribute to why a product is selected. Emotions elicited by food, for instance, can strongly influence the decision-making process (Jiang, King, & Prinyawiwatkul, 2014), suggesting that both sensory and emotional factors need to be considered to fully understand food preferences in cancer patients (Meiselman, 2021). This because food is more than just a source of nutrients (Prinyawiwatkul, 2023). Indeed, King (2016) claimed that food "*nourishes the body and soul*". Therefore, while food delivers nutrients to body, there are other elements, such as enjoyment and pleasure, associated with food. Macht (2008) uncovered a relationship between eating and emotions, suggesting, as an example, that emotions regulate eating, and eating regulates emotions. The emotions elicited by foods play a key role in food liking and choices (Cardello et al., 2012; Jaeger, Chheang, Roigard, & Cardello, 2022; Ng, Chaya, & Hort, 2013; Spinelli, 2021). Although previous studies (Boltong, Keast, & Aranda, 2012; de Vries et al., 2018; de Vries, Winkels, et al., 2018; Kim et al., 2020; Ponticelli et al., 2017; Postma et al., 2020; Speck et al., 2013) have explored the potential causes of chemosensory alterations and their impact on preferences, nutritional status, and quality of life in cancer patients, the emotions elicited by food remain largely unexplored. While emotions associated with food have been studied in vulnerable people such as children, (Aguiar-Bloemer & Diez-Garcia, 2018; Gallo, Swaney-Stueve, & Chambers, 2017; Sick, Monteleone, Pierguidi, Ares, & Spinelli, 2020) they have yet to be investigated in cancer patients. This gap leaves a critical area of understanding unaddressed, particularly in how emotional responses to food might influence eating behavior and preferences in cancer patients.

Oncologic treatment effects may differentially affect food preferences as taste changes have been shown to be individual (Brisbois, De Kock, Watanabe, Baracos, & Wismer, 2011). During chemotherapy, while some individuals demonstrated acceptance or even indifference towards their chemosensory disorders, others experienced profound frustration, disappointment, and guilt (Boltong et al., 2012). While some studies (Coa et al., 2015; Crowder et al., 2019; de Vries, Winkels, et al., 2018; Kim et al., 2020; Nielsen et al., 1980; Postma et al., 2020) have attempted to shed light on the impact that such disturbances may have on food preferences, to date, to our knowledge, no study has ever investigated in detail whether certain categories of foods may be associated with greater emotional deterioration. Chemosensory changes are sometimes unpredictable and could lead to emotional consequences which indirectly affect daily life especially in relation to cooking and social rituals of eating (Bernhardson, Tishelman, & Rutqvist, 2007, 2009). This altered relationship with foods and eating in general, which occurs during the treatment, may cause many psychological problems that lead to alienation from social life and significantly affect compliance with the treatment. These situations trigger loneliness and psychological bad feelings in patients over time negatively affecting the quality of life (Ejder & Sanlier, 2023).

The underestimation and consequent non-treatment of the occurrence of chemosensory alterations lead cancer patients to develop coping strategies and make dietary choices that may not always be suitable. As a result, they may face two opposite situations: firstly, they may experience a loss of appetite, have difficulty meeting nutritional requirements (Nielsen et al., 1980) and lose weight (Ryan, Prado, Sullivan, Power, & Daly, 2019; Tueros & Uriarte, 2018); alternatively, they may honor specific food cravings, exhibit irregular eating behaviors with increased caloric intake, leading to subsequent weight gain (Bernhardson et al., 2009; Speck et al., 2013). Both situations increase the risk of malnutrition for patients (Bernhardson et al., 2007; Boltong & Keast, 2012), resulting in reduced compliance in treatment regimen (Doty, Shah, & Bromley, 2008), increased treatment-related

complications, and in severe cases, higher co-morbidity and mortality rates (Ravasco, 2005).

The aim of this study is to investigate the impact of chemotherapy on chemosensory perception using a combined approach that includes both suprathreshold psychophysical tests and validated self-assessment measures. Furthermore, the study aims to explore the consequences of chemosensory alterations on the eating experience, assessing changes in food preferences and emotions elicited by foods differing in key sensory properties (e.g. quality and intensity of taste, texture, …) in cancer patients during the first cycles of chemotherapy.

2. Materials and methods

2.1. Overview and management of the study

The present data were collected as part of the larger ongoing ALTERTASTE project (Spinelli, Mini, Monteleone, Angiolini, & Roviello, 2021, Clinical trial CEAVC n. 20,839), a longitudinal prospective study started in 2022 and currently in progress (March 2025) at Careggi University Hospital (Florence, Italy) and IRCCS Humanitas Research Hospital (Rozzano, Milan, Italy). Study procedures were approved by the Ethics Committee for Clinical Trials in Tuscany Region – Large Central Area section (Rif. CEAVC n. 20839), Careggi University Hospital, Florence (CEAVC Em. 2022–418 ID 20839), and by the Independent Ethics Committee of the Humanitas Clinical Institute (3531/ID. 20839) and adhered to the principles of the Declaration of Helsinki. Written informed consent was obtained from all participants enrolled in the study in line with the GDPR (General Data Protection Regulation) 2016/679.

This article reports preliminary results from an ongoing prospective study examining the impact of chemotherapy-induced taste alterations on nutritional outcomes in cancer patients. These early findings are shared to underscore emerging patterns that warrant timely discussion, particularly in the context of symptom management in oncology. While data collection is still in progress, the current results provide valuable insights and lay the groundwork for more robust analyses upon study completion.

2.2. Patients: Recruitment, inclusion criteria, and description of study population

Patients must meet all of the following inclusion criteria to be eligible for enrollment into the study: a histologically confirmed diagnosis of breast cancer, gastrointestinal cancer, prostate cancer, testicular cancer, or bladder cancer; an Eastern Cooperative Oncology Group performance status ≤ 1; a treatment plan with taxane-based or platinum-based chemotherapy (in the neoadjuvant or adjuvant setting); an adequate hematological, hepatic, renal and cardiac function; an age $\geq$ 18 years; a written informed consent dated and signed by both patient and investigators.

The exclusion criteria were a major surgery within 2 weeks of study enrollment; brain metastases or leptomeningeal disease; severe and/or uncontrolled medical conditions or other conditions that could affect their participation in the study, such as severe malnutrition.

2.3. Overview of data collection

Patients were recruited during the oncological visit in which general information about the study was given. They were invited to attend a maximum of 7 sessions depending on the treatment: before therapy, after 1 cycle, after 2 cycles, after 4 cycles, after 6 cycles, after 8 cycles and 3 months after the conclusion of the treatment plan. The data considered here are related to the observations before the start of therapy (T0), after the first (T1), after the second (T2) and after the fourth (T4) cycle of chemotherapy.

The data collection happened always right before the next cycle (e.g. "after 2 cycles" refers to a data collection right before the 3rd cycle). Observation times varied based on the type of therapeutic plan as shown in Table 1. At T0, before the beginning of treatment, patients were introduced to the general organization of the session (Fig. 1). After the welcome, only at T0, patients were asked to fill out the 8-item short form Sensitivity to Disgust Scale (Haidt, Mccauley, & Rozin, 1994.; Inbar, Pizarro, & Bloom, 2009; Spinelli et al., 2018) and the Italian Child Food Neophobia Scale (Laureati, Bergamaschi, & Pagliarini, 2015; Pliner & Hobden, 1992). This latter scale was selected because it was simpler to understand, and we expected older patients having more problems in using the Food Neophobia Scale for adults (Pliner & Hobden, 1992) as it includes items related to exotic restaurants that may be unfamiliar to them.

The following procedures were carried out at each session. Weight and height were measured using a stadiometer. BMI was calculated as the weight (kg)/height (m^2). Body composition (fat mass and free fat mass) was determined by a bioelectrical impedance analysis device (TANITA, model BC-613). Quality of life was assessed using European Organization for Research and Treatment of Cancer Quality of Life questionnaire (EORTC-QLQ 30) (Aaronson et al., 1993); self-reported taste/odor responses, changes in hedonic responses to basic tastes and changes in eating habits, such as use of condiments, during treatment were collected using an adapted version of a questionnaire set up to measure chemosensory changes due to COVID-19 (Global Consortium of Chemosensory Research questionnaire, GCCR questionnaire) (Parma et al., 2020); self-reported taste alterations and related side effects were collected using an adapted version of the Italian Chemotherapy-induced Taste Alteration Scale (CiTAS) (Campagna et al., 2016; Kano & Kanda, 2013). Then, patients were asked to identify and rate the intensity of a series of five samples of aqueous solutions at low/moderate concentration ("lower concentration"). Then, they had a break and were asked to fill out the Food Preferences and Emotions Questionnaire developed specifically for this study and the subscale "Preparation and eating" of the Food Involvement Scale (Bell & Marshall, 2003). After the break patients had to identify and rate the intensity of other five samples of aqueous solutions at moderate/high concentration ("higher concentration"). During another break qualitative semi-structured interviews were conducted. Finally, an index of oral responsiveness was measured through a PROP test with filter paper disks (Rorandelli et al., 2024; Zhao, Kirkmeyer, & Tepper, 2003). Each session lasted approximately 1 h.

2.4. Procedure

2.4.1. Socio-demographics data, clinical and health status

Socio-demographic, clinical and health status data were collected and shown in Table 2. The questionnaire used to collect this information included forced-choice questions and open-ended questions.

The clinical data were obtained through the consultation of medical records.

2.4.2. Measuring taste responsiveness and self-reported alterations

2.4.2.1. Sensory tests with aqueous solutions. Before the test with water solutions, patients were trained to the use of the general Labeled Magnitude Scale (gLMS) (0: no sensation – 100: the strongest imaginable sensation of any kind) consistently with published standard procedure (Bartoshuk, 2000; Green et al., 1996; Green, Shaffer, & Gilmore, 1993). The gLMS consists of a 100-unit vertical line with labels placed at "no sensation" (0); "barely detectable" (1.4); "weak" (6); "moderate" (17); "strong" (34.7); "very strong" (52.5); and "strongest imaginable sensation of any kind" (100). Numerical labels were not reported on the scale. Patients were instructed to treat the "strongest imaginable sensation" as the most intense sensation they can imagine that involves remembered/imagined sensations in any sensory modality. This included the

Table 1
Planning of observation times for each site of cancer and related treatment regimen.

Type of cancer and treatment plan	T0	T1	T2	T3	T4	T6	T8	TF
Bladder – a total of 4 cycles of 21 days (carboplatin + gemcitabine) (cisplatin + gemcitabine)	**Before treatment** ***N* = 5**	**After the 1st cycle** ***(3 weeks)***	**After the 2nd cycle** ***(6 weeks)***	After the 3rd cycle *(9 weeks)*	**After the treatment (after the 4th cycle)** ***(12 weeks)***			3 months after the end of the treatment
Gastrointestinal – a total of 12 cycles of 15 days (5-fluorouracil + oxaliplatin + folinic acid)	**Before treatment** **N = 1**		**After the 2nd cycle** ***(4 weeks)***		**After the 4th cycle** ***(8 weeks)***	After the 6th cycle *(12 weeks)*	After the 8th cycle *(16 weeks)*	3 months after the end of the treatment
Testicle – a total of 1–3 cycles of 21 days (cisplatin + etoposide + bleomycin)	**Before treatment** **N = 5**	**After the 1st cycle** ***(3 weeks)*** (the test was conducted also after *7 days**)	**After the 2nd cycle** ***(6 weeks)***	After the treatment (after the 3rd cycle) *(9 weeks)*				3 months after the end of the treatment
Prostate – a total of 6 cycles of 21 days (docetaxel) (cabazitaxel)	**Before treatment** **N = 4**	**After the 1st cycle** ***(3 weeks)***	**After the 2nd cycle** ***(6 weeks)***	After the 3rd cycle *(9 weeks)*	**After the 4th cycle** ***(12 weeks)***	After the treatment (after the 6th cycle) *(18 weeks)*		3 months after the end of the treatment
a) Breast*** – a total of 8 cycles (4 cycles of 21 days of epirubicine and cyclophosphamide +4 cycles of 21 days of docetaxel (or 12 weekly paclitaxel**) and carboplatin)	**Before treatment** ***N* = 22**	**After the 1st cycle** ***(3 weeks)***	**After the 2nd cycle** ***(6 weeks)***		**After the 4th cycle** ***(12 weeks)***	After the 6th cycle *(18 weeks)*	After the treatment (after the 8th cycle) *(24 weeks)*	3 months after the end of the treatment
b) Breast*** – a total of 8 cycles (dose dense 4 cycles of 4 days of epirubicine and cyclophosphamide +4 cycles of 21 days of docetaxel)	**Before treatment** ***N* = 11**	**After the 1st cycle** ***(2 weeks)***	**After the 2nd cycle** ***(4 weeks)***		**After the 4th cycle** ***(8 weeks)***	After the 6th cycle *(14 weeks)*	After the treatment (after the 8th cycle) *(20 weeks)*	3 months after the end of the treatment
c) Breast*** –a total of 4 cycles (4 cycles of 21 days of docetaxel and cyclophosphamide) or (12 weekly cycles** of paclitaxel,)	**Before treatment** ***N* = 7**	**After the 1st cycle** ***(3 weeks)***	**After the 2nd cycle** ***(6 weeks)***	After the 3rd cycle *(9 weeks)*	**After the treatment (after the 4th cycle)** ***(12 weeks)***			3 months after the end of the treatment

Observations **emboldened** were considered in this paper. *To explore the platinum influence (IJpma et al., 2017). **For weekly treatment, 1 cycle was considered as a group of three (total of 21 days). *** For the breast cancer, in relation to the stage of the disease (metastatic or adjuvant) and biological parameters, chemotherapy treatment was associated with targeted therapy with trastuzumab or immunotherapy with pembrolizumab.

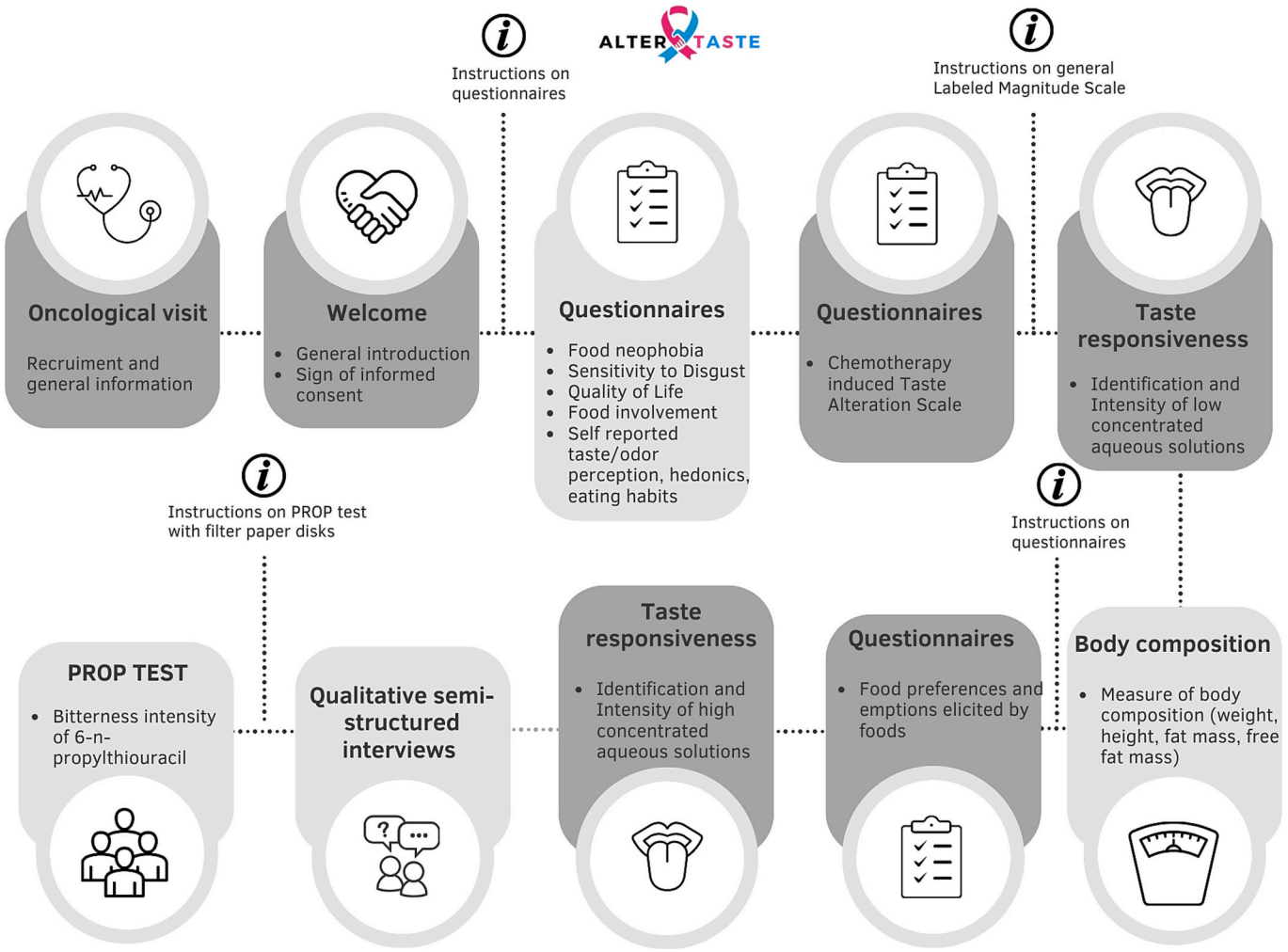

Fig. 1. Overview of data collection (dark grey boxes indicate the variables analyzed in this paper).

Table 2
Demographic, clinical and nutritional data of study population.

Variable	All patients (n = 55)
Age, yr (mean ± SD) min 23; max 82	50.7 ± 13.2
Sex (%)	F (74.5) M (25.5)
Smoking habits (%)	Never tried (45.4) Have tried, quit (38.2) Occasionally (5.5) Regularly (10.9)
Educational level (%)	None (0.0) Primary (1.8) Lower secondary (21.8) Upper secondary (41.8) Degree (34.6) Post degree (0.0)
Site of cancer (%)	Breast (72.7) Bladder (9.1) Testicle (9.1) Prostate (7.3) Colorectal (1.8)
BMI ranges at T0 (%)	Underweight <18.5 kg/m^2 (0) Normal weight 18.5–24.9 kg/m^2 (52.7) Overweight 25.0–29.9 kg/m^2 (38.2) Obesity >30 kg/m^2 (9.1)

deafening noise of a plane that is flying low, and the strong pain felt when shutting a finger in a door.

Then, patients were presented with a first series of five water solutions at lower concentration corresponding to the weak/moderate intensity on the gLMS. The aqueous solutions correspond to four basic tastes (sweet with 67 g/L of sucrose Sigma Aldrich, Milan, Italy; sour with 1.3 g/L of citric acid Sigma Aldrich, Milan, Italy; salty with 5 g/L of sodium chloride Sigma Aldrich, Milan, Italy; bitter with 0.75 g/L of caffeine Sigma Aldrich, Milan, Italy) and one somatosensory sensation (pungent with 0.00055 g/L of capsaicin Sigma Aldrich, Milan, Italy). Each sample (10 mL) was presented in a plastic cup, identified by a three-digit code. The presentation order of samples was randomized for the basic tastes while the pungent solution was always evaluated as the last sample to avoid perceptual interference between samples due to the carry-over effect of capsaicin. Patients had to hold the sample in their mouth for a total of 3 s, then spit and expectorate, wait 3 s (or 5 s for bitter and pungent solutions), identify one or more perceived sensations with a Check-All-That-Apply (CATA) format from a predefined list including sweet, sour, salty, bitter, astringent, pungent, tasteless, other (open-ended), and evaluate the overall intensity of each solution on the gLMS. Between the samples, there was a break of 60 s in which patients had to rinse their mouth with still water, had a cracker (optional) and rinsed again before the following solution.

Afterwards, patients were again presented with a second series of five higher concentration water solutions (sweet with 200 g/L of sucrose Sigma Aldrich, Milan, Italy; sour with 4 g/L of citric acid Sigma Aldrich,

Milan, Italy; salty with 15 g/L of sodium chloride Sigma Aldrich, Milan, Italy; bitter with 3 g/L of caffeine Sigma Aldrich, Milan, Italy; and pungent with 0.0015 g/L of capsaicin Sigma Aldrich, Milan, Italy). The procedure was the same as just described.

Both lower and higher concentrations were selected to cover a range of intensity ratings from weak/moderate to moderate/strong on the gLMS based on preliminary studies and on the literature (Feeney & Hayes, 2014; Hayes, Sullivan, & Duffy, 2010; Masi, Dinnella, Monteleone, & Prescott, 2015; Monteleone et al., 2017; Nolden & Hayes, 2017; Pierguidi et al., 2023; Spinelli et al., 2023; Webb, Bolhuis, Cicerale, Hayes, & Keast, 2015; Yeomans, Tepper, Rietzschel, & Prescott, 2007).

2.4.2.2. Self-reported responses about taste and smell perception. At each session patients completed CiTAS to assess self-responses. The original Italian Version of Chemotherapy-induced Taste Alteration Scale (Campagna et al., 2016) is a 18-item questionnaire which evaluates the 4 dimensions of some conditions related to taste and smell alterations using a Likert scale of 1–5 (where 1 = no difficulty or absence of the disorder and 5 = maximum difficulty or very much discomfort): decline in basic tastes (quantitative disturbances in the perception of sweet, bitter, sour, salty, umami tastes), discomfort (reduced appetite, difficulty in eating certain types of food, nausea), phantogeusia (taste perception in mouth without external stimuli), general taste alterations and parageusia (distorted/bitter/bad taste of food). Specifically for the study, the questionnaire was adapted by adding five items: "metallic taste in mouth" and "sour taste in mouth" and "increase in taste perception" added to the phantogeusia dimension, "dry mouth" and "mucositis/inflammation/pain/ulcerations in the mouth" added to the discomfort dimension. These additions were based on the literature (Corremans, Geurden, Luyten, & Mortelmans, 2021.; IJpma, Renken, ter Horst, & Reyners, 2015; Mahmoud, Aktas, Walsh, & Hullihen, 2011; McGettigan et al., 2019; O'Donoghue et al., 2023; Silva et al., 2021), and on preliminary interviews with cancer patients. The items "have difficulty tasting food", "unable to perceive the smell or flavor of food" and "have difficulty eating meat" were removed. The first because it was considered too generic and difficult to understand by patients. The second because it combines distinct sensory experiences such as smell and flavor, which can lead to ambiguity and reduce the clarity of data collected. Although smell contributes significantly to the perception of flavor, it may not always be the cause of its alteration (Belqaid et al., 2016; Spence, 2015). The item "have difficulty eating meat" was removed because it can have multiple meanings, not necessarily related to sensory discomfort. For example, the difficulty could arise from psychological factors, such as sarcophobia (fear or aversion to meat), or from a common inclination to change eating habits towards a healthier direction in order to potentially improve treatment efficacy (Pedersini et al., 2021; Salminen, Bishop, Poussa, Drummond, & Salminen, 2004). Furthermore, the item "I have difficulty perceiving umami tastes" was modified by replacing the word "umami" with "savory", as we believed that the concept of umami might be difficult for patients to understand due to its unfamiliarity within the European culture. The adapted version of CiTAS used for the study was thus composed by 20 items grouped in 4 dimensions: decline in basic tastes (5), general taste alterations and parageusia (3), phantogeusia and increase in taste perception (5), discomfort (7). The labels of the 5-point Likert scale were uniformed across the different subscales as follows: 1= "not at all", 2 = "slightly", 3 = "quite", 4 = "very", 5 = "very much".

2.4.3. Assessment of food preferences and emotions

The Food Preferences & Emotions Questionnaire (FP&EQ) was developed in order to track any changes in preferences and emotions elicited by foods differing in key sensory properties during the whole treatment period. The questionnaire (Tables 3a) is composed by 6 different dimensions (flavor, texture, herbs and spices, sweet/bitter, sweet/sour, odor) each containing 5 food/drink/odor pairs (for a total of 30 pairs of items), designed and tested to recall the different levels of target sensations. Some of the items were selected from the IT-Food Choice Questionnaire (Monteleone et al., 2017), with sensory differences between pairs validated in previous studies (De Toffoli et al., 2019; Pagliarini et al., 2021). The remaining items were developed exclusively for the study based on scientific literature on sensory differences between products. The new items were subjected to a preliminary validation involving 36 to 117 consumers recruited to perform a pairwise comparison test. Participants were asked to indicate in each pair which product was more "intense in flavor/creamier/sweeter/intense in odor". The results were analyzed through a unilateral test based on which it was possible to conclude whether there was a perceptible difference between the two products through a minimum number of correct answers (*Supplementary materials 1*).

In the questionnaire, patients were presented with pairs of foods, beverages, and odors. They did not taste or smell the products but were

Table 3a
Pairs of products of the Food Preference and Emotion Questionnaire (FP&EQ).

Dimension	Pairs of products
Flavor (less/more intense)	Fresh pecorino/Aged pecorino
	Cow mozzarella/Buffalo mozzarella
	Cooked ham/Dry cured ham
	Smashed potato/Baked potato
	Valerian and lettuce/Radicchio and rocket
Texture (crunchy-consistent/creamy)	Vegetable soup/Vegetable cream
	Toasted bread/White bread
	Couscous/Semolina
	Julienned carrots/Cooked carrots
	Chocolate bar/Chocolate pudding
Herbs and spices (with/without herbs and spices)	Vegetables with chili/Vegetables without chili
	Tomato sauce with basil/Tomato sauce
	Herbal tea/Water
	Grilled chicken with thyme/Grilled chicken
	Zucchinis cream with mint/Zucchinis cream
Sweet vs. bitter	Panna cotta/Dark chocolate pudding
	Tea with sugar/Tea without sugar
	Milk chocolate/Dark chocolate
	Coffee with sugar/Coffee without sugar
	Pumpkin risotto/Radicchio risotto
Sweet vs. sour	Sweetened yogurt/Natural yogurt
	ACE juice/Orange juice
	Strawberry sorbet/Lemon sorbet
	Apricot jam/Raspberry jam
	Apple smoothie/Apple and lemon smoothie
Odor (more/less intense odor)	Bean soup/Vegetable soup*
	Bolognese sauce/Tomato sauce
	Fried cutlet/Grilled meat
	Meat broth/Vegetable broth
	Cooked tomato/Boiled rice

* Note: This pair was excluded based on the validation through the unilateral test (Supplementary Material 1).

Table 3b
List of emotions of the Food Preference and Emotion Questionnaire (FP&EQ).

Emotions	Valence	Arousal
Joy	Positive	High
Curiosity	Positive	High
Happiness	Positive	Low
Relax	Positive	Low
Annoyance	Negative	High
Disgust	Negative	High
Boredom	Negative	Low
Indifference	Negative	Low
Sadness	Negative	Low

asked to express their preferences for each pair based on their daily experiences or expectations in a specific eating context (e.g. "Between 'dark chocolate' and 'milk chocolate', indicate which food/drink you would prefer to eat as a snack. If you like both or neither of them, choose the one you are more inclined to eat"): main meals (either lunch or dinner, 18 pairs), snacks (9 pairs), all-day consumption (3 pairs). For odor pairs, participants specified which option they would rather avoid in each given context (e.g. You are in a room where someone has just finished eating/cooking and you can smell food. Indicate the option you would least like to smell between 'boiled rice' and 'cooked tomato').

The presentation order of the items within each pair, and of the pairs within the questionnaire, was randomized across patients. After the forced choice between products, patients were asked: "How does it make you feel?" (Spinelli, Masi, Dinnella, Zoboli, & Monteleone, 2014) and they should indicate at least one (or more) emotions (Table 3b) elicited by each item (both the chosen and the unchosen one) using a Check-All-That-Apply (CATA) format.

The emotions were selected based on previous studies on food products (Spinelli, 2021; Spinelli et al., 2014; Spinelli & Jaeger, 2019) and on the *circumplex model of affect* (Russell, Clement, Jiwani, Ridgeway, & Schroeder, 1980), that describe emotions based on valence (positive/pleasure vs. negative/displeasure) and arousal (high/activation vs. low/deactivation). Five negative emotions and four positive emotions were chosen for the questionnaire.

2.5. Data analysis of selected variables

First, descriptive statistics were calculated on CATA responses to assess the percentage of correct identification of each stimulus (sweet, salty, sour, bitter, pungent) at each time point (T0, T1, T2, T4). A response was considered correct if the target sensation was selected from the list (e.g., "salty" for the salty solution), even when chosen in combination with another sensation (e.g., "salty" and "sour" for the salty sample). In cases where the correct target was not selected, further descriptive analyses were conducted to determine which alternative sensations participants had selected, expressed as a percentage for each time point. This allowed for a better understanding of the most common misclassifications. A two-sample proportion test was applied to test significant differences between percentages of identification at different time points. To examine potential changes in chemosensory perception during the first four cycles of chemotherapy, perceived intensity ratings were first assessed for normality with the Shapiro-Wilk test and examining the Q-Q plots. As the data deviated from a normal distribution ($p < .0001$), non-parametric methods were employed.

First, a Kruskal-Wallis test was applied to test the differences between time-points (T0, T1, T2, T4) considering all five chemosensory stimuli together (sweet, salty, sour, bitter, pungent) separately for lower and higher concentration solutions, to provide a general overview of intensity variation over time. Subsequently, additional Kruskal-Wallis tests were conducted for each stimulus individually testing the differences between time points, at lower or higher concentrations separately, to detect specific trends over time for each taste or sensation. When significant effects were found, Dunn's post hoc tests with Bonferroni correction were applied to identify which time points differed significantly.

To evaluate the dimensional structure of the adapted version of CiTAS questionnaire, a Factor Analysis was run on responses collected after the first cycle (T1) ($n = 41$), after the second cycle (T2) ($n = 47$) and after the fourth cycle (T4) ($n = 34$) (*Supplementary materials 2*). The internal consistency of the questionnaire was assessed through Cronbach's alpha. The adequacy of the data for Factor Analysis was assessed using the Kaiser-Meyer-Olkin measure of sampling adequacy and Bartlett's test of sphericity (Tabachnick & Fidell, 2001). Exploratory Factor Analysis (EFA) on Spearman correlation matrix was conducted using Principal Factor Analysis as a criterion for factor extraction. A four-factor structure was examined to align with the factor structure previously identified for the original questionnaires (Campagna et al., 2016; Kano & Kanda, 2013), using Varimax orthogonal rotation with Kaiser normalization. The level for retaining an item was set at a factor loading higher than 0.3 (Tabachnick & Fidell, 2001). To show a general overview of self-reported changes of chemosensory perception measured through the CiTAS during the first four cycles of chemotherapy, the mean scores of each dimension were first assessed for normality with the Shapiro-Wilk test. As the data deviated from a normal distribution ($p < .0001$), non-parametric methods were employed. Specifically, Kruskal–Wallis tests were conducted separately for each dimension of the questionnaire to assess differences across the four time points. When significant effects were found, Dunn's post hoc tests with Bonferroni correction were applied to identify which time points differed significantly.

Patients were classified with self-reported alterations through the CiTAS first by calculating the average score for each dimension per patient, then by identifying as "patients with alterations" those for whom the score was different from 1 (= "not at all") for each dimension.

Preferences expressed for each food/beverage/odor pair within every dimension (flavor, texture, odor, herbs and spices, sweet vs bitter, and sweet vs sour), and for each time point were indicated using binary data based on whether the patient selected the less intense/creamy/sweet/mild (0) or the more intense/grainy/crunchy/sour/bitter/seasoned option (1). The significance of the changes in preference for treatments T1, T2 and T4 compared to T0 for each dimension of the questionnaire between subjects with and without alteration segmented on the basis of self-reported responses of the CiTAS was tested through a Chi square analysis ($a = 0.05$). For this purpose, for the T0vsT1, T0vsT2 and T0vsT4 comparisons, a 2 × 2 contingency table was prepared with the presence of alterations on the rows (Yes; No) and the preference changes in the columns (Yes Change; No Change). Fisher exact test was run to test the significance by cell with significance level set at $a = 0.05$.

In order to understand if based on the specific self-reported alteration there was a specific direction of changes in preferences, a McNemar test

Table 4
Example of a 2 × 2 contingency table for the McNemar test – Analysis of change directions.

		T1 or T2 or T4	
		Sweet	Bitter
T0	Sweet	n (choice of sweet options in both observation)	n (choice of sweet options before treatment, which are replaced by the bitter options)
	Bitter	n (choice of bitter options before treatment, which are replaced by the sweet options)	n (choice of bitter options in both observation)

Table 5
Example of a 2 × 2 contingency table for the McNemar test – Analysis of changes in emotional valence of chosen options.

		T1or T2 or T4	
		Positive	Negative
T0	Positive	n (positive valence for chosen options in both observation)	n (positive valence of emotions for chosen options before treatment, which are replaced by the negative valence)
	Negative	n (negative valence of emotions for chosen options before treatment, which are replaced by the positive valence)	n (negative valence for chosen options in both observation)

Table 6
Percentage of identification of lower concentration samples at baseline (T0), the first (T1), the second (T2), and the fourth (T4) cycles of chemotherapy.

	T0 Correct identification (%)	T1 Correct identification (%)	T2 correct identification (%)	T4 correct identification (%)
Lower concentrated aqueous solutions				
Sweet (sucrose 67 g/l)	100	97.1	100	100
Sour (citric acid 1.3 g/l)	87.3	88.6	79.1	78.6
Salty (NaCl 5 g/l)	87.3	77.1	79.1	78.6
Bitter (caffeine 0.75 g/l)	52.7	60	62.8	67.9
Pungent (capsaicin 0.00055 g/l)	94.5	85.7	95.2	85.7
Higher concentrated aqueous solutions				
Sweet (sucrose 200 g/l)	100	100	100	100
Sour (citric acid 4 g/l)	92.7	97.1	90	88.9
Salty (NaCl 15 g/l)	94.5	91.4	87.5	88.9
Bitter (caffeine 3 g/l)	90.9	82.9	82.5	85.2
Pungent (capsaicin 0.0015 g/l)	100	94.3	95	92.6

was computed. The analysis tests differences in dichotomous data (e.g. bitter/sweet) before and after a certain treatment and it is necessary to set up a 2 × 2 contingency table which considers in the rows the choice at T0 (e.g. sweet/bitter) and in the columns the choice at the subsequent observation (T1; T2; T4) as explained in Table 4.

In order to understand if based on the specific alterations there was a change in valence of emotions elicited by the chosen options of the preferences questionnaire, a McNemar test was computed. The McNemar test was used to analyze changes within the same group of patients over time and therefore to study differences in dichotomous data before and after a certain treatment. A 2 × 2 contingency table was prepared for each comparison (T0 with T1; T0 with T2; T0 with T4) which has in the rows the valence (positive/negative) at T0 and in the columns the valence (positive/negative) at the subsequent observation individually (T1 or T2 or T4), as reported in Table 5.

A *p*-value of 0.05 was considered as threshold for statistical significance in all analyses.

Data were collected through the software Compusense v. 23.0.46 (Compusense Inc. Guelph, Ontario, Canada). Statistical analyses were performed using XLSTAT Statistical and Data Analysis Solution 2023.2.1414 (Lumivero 2023, Paris, France). Data were expressed as mean ± standard deviation (SD) or percentage, as appropriate.

3. Results

3.1. Demographic characteristics

All patients considered in the present paper completed between 1 and 4 cycles of chemotherapy. Demographic and clinical characteristics of the study population are presented in Table 2. Of 55 patients (mean age 50.7 ± 13.2 years) most were females (74.5 %), no-smokers (45.4 % never tried; 38.2 % have tried, quit), and with breast cancer (72.7 %). Before the start of the treatment, according to the body mass index (BMI) classification none of the patients (0 %) were in a condition of underweight, 52.7 % were of normal weight, 38.2 % were overweight, and 9.1 % were obese. The data were collected depending on the availability and conditions of the patients on 55 patients at T0, 41 patients at T1, 47 patients at T2, 34 patients at T4.

3.2. Overview of chemosensory perception: Identification and perceived intensity of aqueous solutions

The percentages of identification for the five stimuli across the four time points are shown in Table 6. Recognition was consistently high for sweetness (around 100 %), sourness, saltiness, and pungency, particularly at higher concentrations, where identification percentages mostly remained above 85 %. The bitter solution at lower concentration was the least accurately identified, although its recognition progressively improved from 52.7 % at T0 to 67.9 % at T4. When not correctly identified as bitter, participants most frequently misclassified the solution as tasteless (T0: 27.3 %; T1: 17.1 %; T2: 14.0 %; T4: 3.6 %), sour (T0: 10.9 %; T1: 5.7 %; T2: 11.6 %; T4: 14.3 %), or astringent (T0: 10.9 %; T1: 5.7 %; T2: 11.6 %; T4: 7.1 %).

While most stimuli were reliably recognized over time, a slight decline in identification rates was observed for some lower concentration solutions, such as salty and sour, particularly from T0 to T4. Despite

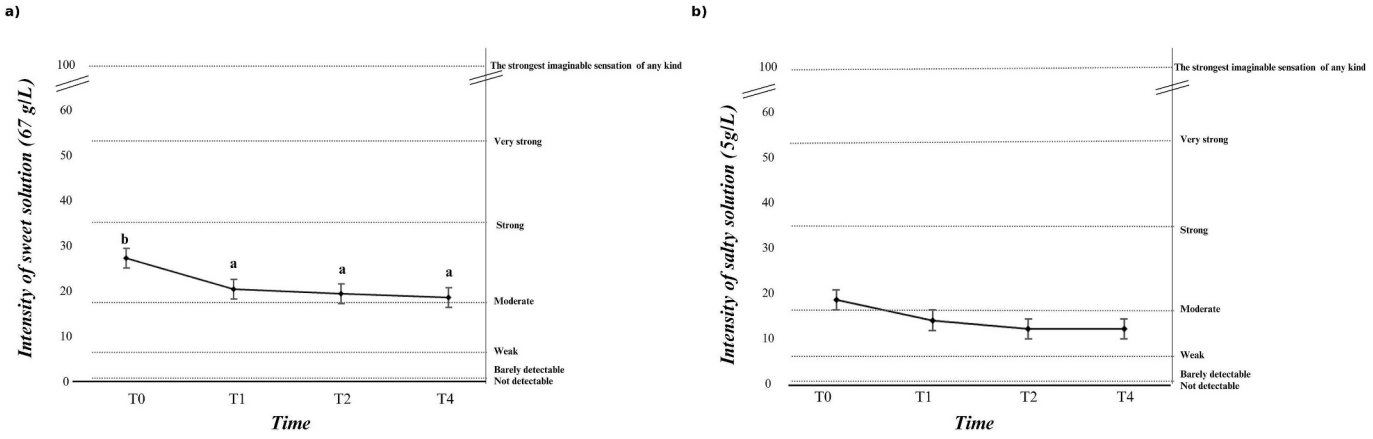

Fig. 2. a. Mean intensity ratings of lower concentration sweet solution at baseline (T0), after the 1st cycle (T1), after the 2nd cycle (T2) and after the 4th cycle (T4). Total observations $N = 158$; T0 $n = 55$; T1 $n = 35$; T2 $n = 40$; T4 $n = 28$.
b. Mean intensity ratings of lower concentration salty solution at baseline (T0), after the 1st cycle (T1), after the 2nd cycle (T2) and after the 4th cycle (T4). Total observations N = 158; T0 n = 55; T1 n = 35; T2 n = 40; T4 n = 28.
Different letters indicate significantly different ratings according to Dunn's post hoc with Bonferroni correction.

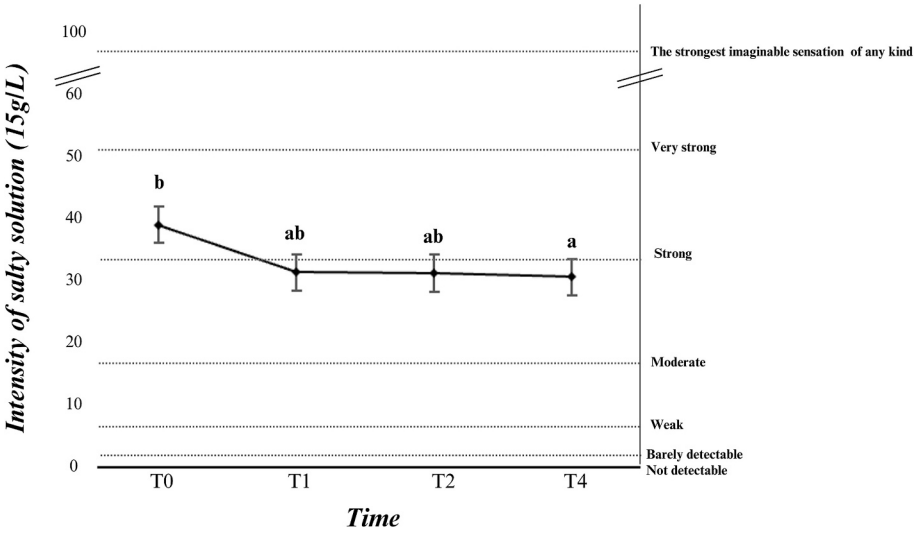

Fig. 3. Mean intensity ratings of higher concentration salty solution at baseline (T0), after the 1st cycle (T1), after the 2nd cycle (T2) and after the 4th cycle (T4). Total observations $N = 157$; T0 n = 55; T1 n = 35; T2 n = 40; T4 $n = 27$.
Different letters indicate significantly different ratings according to Dunn's post hoc with Bonferroni correction.

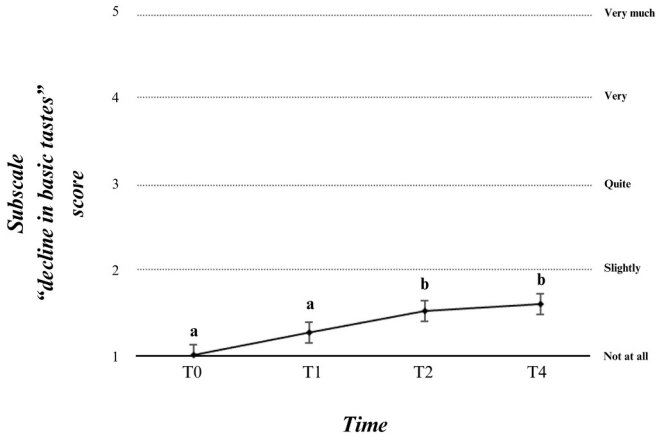

Fig. 4. Mean scores of "Decline in basic tastes" dimension at baseline (T0), after the 1st cycle (T1), after the 2nd cycle (T2) and after the 4th cycle (T4). Total observations $N = 177$; T0 n = 55; T1 $n = 41$; T2 $n = 47$; T4 $n = 34$.
Different letters indicate significantly different ratings according to Dunn's post hoc with Bonferroni correction. ($p < .05$).

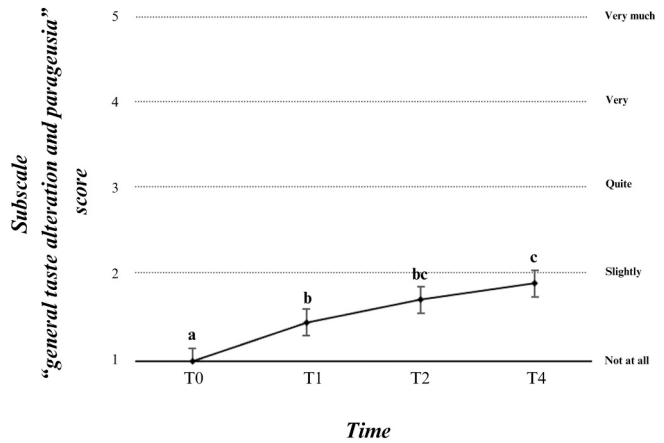

Fig. 5. Mean scores of "General taste alterations and parageusia" dimension at baseline (T0), after the 1st cycle (T1), after the 2nd cycle (T2) and after the 4th cycle (T4). Total observations N = 177; T0 n = 55; T1 n = 41; T2 n = 47; T4 n = 34.
Different letters indicate significantly different ratings according to Dunn's post hoc with Bonferroni correction. (p < .05).

this decline, rates remained relatively high, indicating that patients generally maintained the ability to correctly identify target sensations throughout treatment. Additionally, statistical analysis based on two-proportion tests did not reveal significant changes in identification rates across time points, suggesting that, overall, patients maintained a relatively stable ability to recognize basic chemosensory stimuli during chemotherapy.

Patients reported a significant decline in their response to the sweet solution at lower concentration already after the first cycle of treatment ($\chi^2(3) = 13.67$, $p = .003$), with intensity ratings decreasing from moderate/strong (27.55) at T0 to moderate at T1 (20.72) (Fig. 2a). For the salty solution, the Kruskal–Wallis test showed a significant overall difference in perceived intensity across the four time points ($\chi^2(3) = 8.54$, $p = .036$). Although Dunn's post hoc with Bonferroni correction test ($\alpha = 0.0083$) did not identify significant differences between specific time points, a decreasing trend in intensity was observed with a reduction from T0 to T2 close to significance ($p = .009$) (Fig. 2b). No statistically significant changes over time were observed for the sour ($\chi^2(3) = 3.305$, $p = .347$), bitter ($\chi^2(3) = 2.276$, $p = .517$) and pungent ($\chi^2(3) = 4.825$, $p = .185$) solutions at lower concentration (*Supplementary Materials 3a*).

Among the higher concentration solutions, a significant decline in perceived intensity after T4 was found only for the salty solution (Fig. 3; $\chi^2(3) = 9.64$, $p = .022$), decreasing from an intensity rated between 'strong' and 'very strong' (41.66) to an intensity described less than strong (33.45). No significant differences between time points were found in the case of the sweet ($\chi^2(3) = 3.971$, $p = .265$), sour ($\chi^2(3) = 3.698$, $p = .296$), bitter ($\chi^2(3) = 0.866$, $p = .834$) and pungent ($\chi^2(3) = 0.408$, $p = .939$) solutions at higher concentration (*Supplementary Materials 3b*).

3.3. Self-reported responses to Chemotherapy-induced Taste Alteration Scale

The adapted version of the Italian CiTAS showed a good internal consistency with a Cronbach's alpha coefficient of 0.911. A Kaiser-Meyer-Olkin (KMO) of 0.842 and a significant Bartlett's sphericity test ($p < .0001$) indicated that the data was adequate for Factor Analysis. A

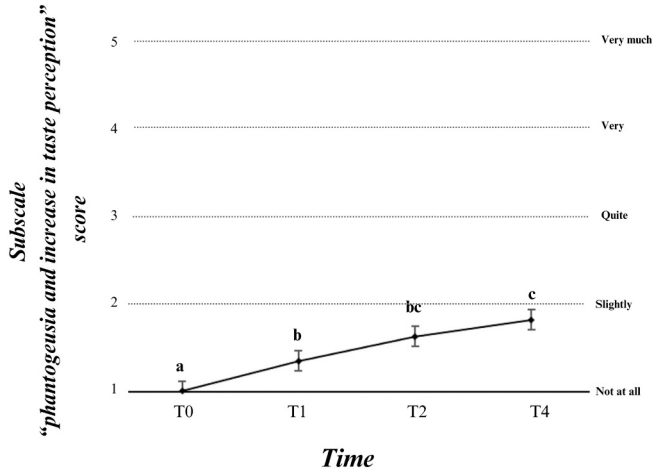

Fig. 6. Mean scores of "Phantogeusia and increase in taste perception" dimension at baseline (T0), after the 1st cycle (T1), after the 2nd cycle (T2) and after the 4th cycle (T4). Total observations N = 177; T0 n = 55; T1 n = 41; T2 n = 47; T4 n = 34.
Different letters indicate significantly different ratings according to Dunn's post hoc with Bonferroni correction. ($p < .05$).

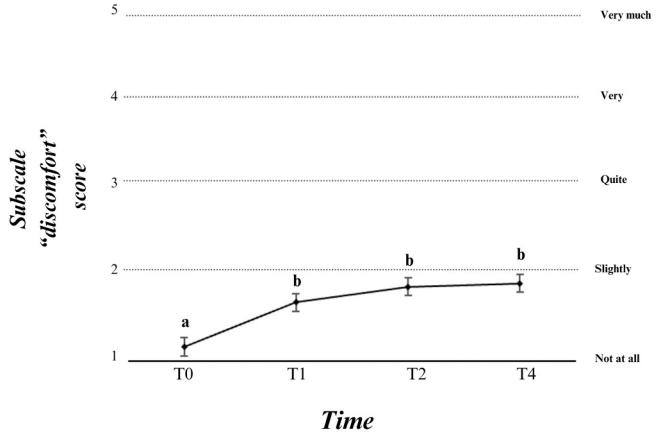

Fig. 7. Mean scores of "Discomfort" dimension at baseline (T0), after the 1st cycle (T1), after the 2nd cycle (T2) and after the 4th cycle (T4). Total observations N = 177; T0 n = 55; T1 n = 41; T2 n = 47; T4 n = 34.
Different letters indicate significantly different ratings according to Dunn's post hoc with Bonferroni correction. ($p < .05$).

Table 7
Percentage of patients who self-reported the different types of conditions represented by the CiTAS dimensions during the baseline (T0), the first (T1), the second (T2), and the fourth (T4) cycle of chemotherapy.

	% of patients who self-reported the condition			
CiTAS dimension	T0	T1	T2	T4
Decline in basic tastes	0.0 %	19.5 %	46.8 %	64.7 %
General taste alterations and parageusia	0.0 %	26.8 %	46.8 %	61.8 %
Phantogeusia and increase in taste perception	3.6 %	41.5 %	63.8 %	76.5 %
Discomfort	45.5 %	78.0 %	89.4 %	85.3 %

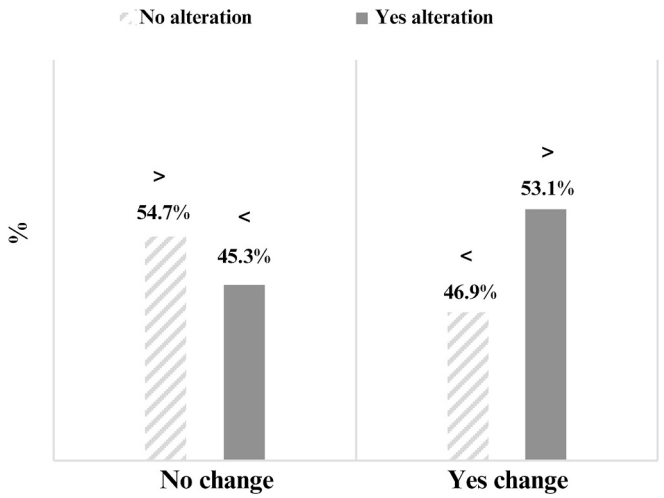

Fig. 8. Chi-Square analysis - Association between General taste alterations and parageusia and food preferences (all the dimensions of questionnaire) after the 2nd cycle of chemotherapy. < > indicate that the observed count was significantly greater or lower than its expected count (Fisher exact test).

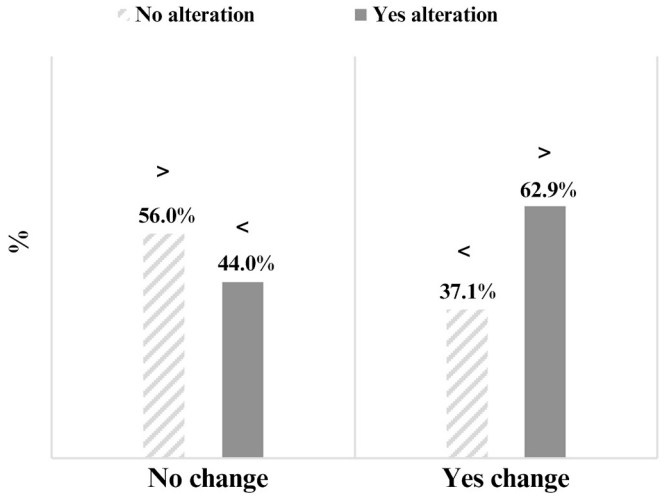

Fig. 9. Chi-Square analysis - Association between General taste alterations and parageusia and food preferences of "Sweet vs Bitter" dimension after the 2nd cycle of chemotherapy. < > indicate that the observed count was significantly greater or lower than its expected count (Fisher exact test).

four-factor structure was examined to align with the factor structure previously identified for the original questionnaire (Kano & Kanda, 2013) and for the Italian version (Campagna et al., 2016), using Varimax orthogonal rotation with Kaiser normalization. Once rotated the four-factor structure explained 55.93 % of the total variance. Factor loadings, explained variance, and Cronbach's alphas for the four-factor structure are reported in Supplementary materials 2.

To get a general overview of self-reported changes of chemosensory perception measured with the CiTAS during the first four cycles of chemotherapy, the scores of each dimension were analyzed through a Kruskal–Wallis test testing the effect of time points.

Starting from the 2nd cycle of chemotherapy the analyses showed a significant increase over time of the mean scores of "Decline in basic tastes" dimension ($\chi^2(3) = 47.43$, $p < .0001$, Fig. 4), and from the 1st cycle in "General taste alterations and parageusia" dimension ($\chi^2(3) = 43.50$, $p < .0001$, Fig. 5), in "Phantogeusia and increase in taste perception" dimension ($\chi^2(3) = 58.12$, $p < .0001$, Fig. 6) and in "Discomfort" dimension ($\chi^2(3) = 41.50$, $p < .0001$, Fig. 7).

Table 8
Comparison of the percentages of negative emotions elicited by selected options in the Food Preference and Emotion Questionnaire (FP&EQ) between baseline and the first cycle of chemotherapy in patients with self-reported alterations.

		% of negative emotions elicited by chosen options		
CiTAS dimension	FP&EQ dimension	T0	T1	p-value
Decline in basic tastes	Flavor	7.5 %	20.0 %	0.125
	Texture	15.0 %	25.0 %	0.344
	Herbs and spices	15.0 %	35.0 %	**0.039**
	Sweet vs bitter	10.0 %	27.5 %	0.092
	Sweet vs sour	17.5 %	20.0 %	1.000
	Odor	87.5 %	81.2 %	0.727
	Flavor	10.9 %	23.6 %	**0.039**
General taste alterations and parageusia	Texture	12.7 %	27.3 %	°0.057
	Herbs and spices	23.6 %	34.5 %	0.238
	Sweet vs bitter	14.5 %	29.1 %	0.096
	Sweet vs sour	23.6 %	18.9 %	0.581
	Odor	79.5 %	84.1 %	0.754
	Flavor	12.9 %	17.6 %	0.388
Phantogeusia and increase in taste perception	Texture	16.5 %	23.5 %	0.210
	Herbs and spices	25.8 %	25.8 %	1.000
	Sweet vs bitter	11.8 %	21.2 %	0.115
	Sweet vs sour	23.5 %	12.9 %	**0.022**
	Odor	82.3 %	76.5 %	0.454
	Flavor	11.9 %	20.6 %	**0.009**
Discomfort	Texture	14.4 %	23.1 %	**0.020**
	Herbs and spices	20.6 %	26.9 %	0.132
	Sweet vs bitter	11.9 %	21.3 %	**0.024**
	Sweet vs sour	20.0 %	17.5 %	0.585
	Odor	78.9 %	72.5 %	0.185

Emboldened p-value<.05 indicates a significant increase. ° sign on p-value indicates a value close to significance.

Table 7 shows the percentage of patients who self-reported the different types of conditions (mean scores >1) represented by the CiTAS dimensions before the start and during the treatment. Based on this classification, the impact of these conditions on food preferences and on emotional responses to foods has been explored and described in the following paragraphs.

3.4. Changes in food preferences in patients with self-reported alterations

After the first cycle of therapy, no type of alteration recorded with the CiTAS had an impact on the patients' food preferences. Instead, after the second cycle, the presence of self-reported "General taste alterations and parageusia" was associated with greater changes in all food preferences ($p = .020$ $\chi^2 = 5.416$, significance by cell $p = .022$) (Fig. 8), suggesting that these alterations have a significant impact on preferences over time.

In particular, the presence of this type of alteration was significantly associated with greater changes in preferences of "Sweet *vs.* Bitter" foods. From the Chi-Square analysis ($p = .039$ $\chi^2 = 4.254$) it emerged that the observed frequencies of patients with "General taste alterations and parageusia" who changed preference were significantly higher than the theoretical frequencies (significance by cell $p = .044$) (Fig. 9).

However, during the second cycle, other conditions such as "Phantogeusia and increase in taste perception", "Decline in basic tastes", and "Discomfort" were not associated with changes in preferences, as indicated by the Chi-Square analysis.

After the 4th cycle of therapy, in patients who self-reported "Discomfort" and therefore a condition that includes symptoms such as nausea, mucositis and discomfort with odors, a significant association with preference changes was observed ($p = .004$ $\chi^2 = 8.188$) and a tendency to change for specific odors was recorded ($p = .063$ $\chi^2 = 3.465$; significance by cell $p = .074$). Conversely, no significant preference changes were observed in the presence of other conditions.

McNemar tests computed to understand whether the observed preference changes had a specific direction were not significant.

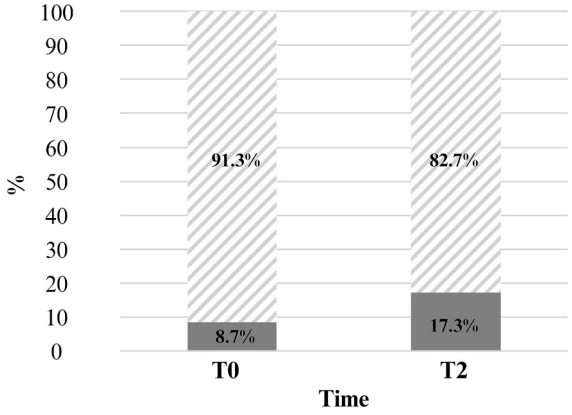

Fig. 10. Increase in percentage of negative emotions (dark grey) elicited by selected options of Sweet bitter dimension, from baseline (T0) to the second cycle of chemotherapy (T2) in patients who self-reported "Phantogeusia and increase in taste perception". Results from McNemar test ($p = .039$).

3.5. Changes in emotional responses to foods in patients with self-reported alterations

After T1 (Table 8) a significant increase in negative emotions elicited by the chosen options of the Food Preference and Emotion Questionnaire was observed in patients who self-reported "Decline in basic tastes" for the products of the "Herbs and Spices" dimension ($p = .039$), in patients who self-reported "General taste alterations and parageusia" for the products of the "Flavor" ($p = .039$) and, close to significance, "Texture" dimension ($p = .057$), and in patients with "Discomfort" for "Flavor" ($p = .009$), "Texture" (p = .020) and "Sweet *vs.* Bitter" ($p = .024$) dimensions. In contrast, patients who self-reported "Phantogeusia and increase in taste perception" showed a significant decrease in negative emotions elicited by the chosen options of the "Sweet *vs.* Sour" dimension ($p = .022$).

After T2, in patients who self-reported "Phantogeusia and increase in taste perception" a significant increase ($p = .024$) in negative emotions elicited by the chosen options was recorded for the "Sweet *vs.* Bitter" dimension from 8.7 % at T0 to 17.3 % at T2 (Fig. 10).

The McNemar test showed that after T4 no changes in emotional responses to the chosen foods were observed in the presence of self-reported conditions.

4. Discussion

The study shows that patients receiving chemotherapy encounter a variety of chemosensory alterations and disturbances, from decline of tastes, with a decrease of sweet (at lower concentration) and salty (at lower and higher concentration) taste perception, to phantogeusia and parageusia. Self-reported alterations were associated in many cases with an increase in negative emotions towards the preferred foods, already after the first cycle of therapy. We observed also that self-reported decline in tastes was not associated with changes in preferences, while general taste alterations and parageusia were associated with a change in preference for sweet/bitter foods after the 2nd cycle of therapy, and discomfort after the 4th cycle of therapy.

Patients were generally able to correctly identify the stimuli in aqueous solutions, particularly at higher concentration. Sweetness (induced by sucrose) was the most accurately identified tastant, while bitterness (induced by caffeine) at lower concentration was the least accurately recognized (even at baseline), in line with previous findings (Boltong et al., 2014). Generally, our results on identification suggest that, despite self-reported or measured decreases in perceived intensity, taste recognition remained largely preserved. Bitter taste at lower concentration was not well identified and was frequently misidentified as tasteless or sour, even at baseline. This finding aligns with previous studies reporting that healthy individuals often confuse bitter and sour stimuli (Gregson & Baker, 1973; McAuliffe & Meiselman, 1974; Meiselman & Dzendolet, 1967; O'Mahony, Goldenberg, Stedmon, & Alford, 1979; Pangborn, 1961; Robinson, 1970).

Our results of sensory measures have shown a significant decrease in perception after one cycle for sweet taste and a general trend of decrease for salty taste presented in aqueous solutions at lower concentration (when the reported intensity is around moderate). Instead, for solutions at higher concentration the decline reported is smaller and was found only for the salty taste after the fourth cycle. Our results further expand previous results that were mainly found on threshold measurements. The decrease of saltiness perception found both in lower (NaCl: 5 g/L) and higher (NaCl: 15 g/L) concentrated aqueous solutions is consistent with several studies in which such phenomenon was frequently observed through quantitative methods using threshold concentrations, qualitative methods, or a combination of both (Boltong et al., 2014; Epstein et al., 2019; Kaizu et al., 2021; Obayashi et al., 2023; Pedersini et al., 2022; Steinbach et al., 2009). Even the perceived intensity of lower concentrated sweet solution (67 g/L) significantly decreased after the first cycle of treatment, coherently with an increase in the sweet threshold reported in other studies (de Vries, Boesveldt, et al., 2018; Dewys & Walters, 1975; Sánchez-Lara et al., 2010; Schalk et al., 2018; Steinbach et al., 2009). However, this increase in threshold may not be sufficient to compromise the perception of the sweet stimulus at higher intensity, as demonstrated by the absence of significant changes in ratings of the most concentrated sweet solution (200 g/L), which remained stable over time. Our results were not consistent with previous study using suprathreshold concentrations, as Mulder et al. (1983) reported an increase in perceived salty and sweet intensity after each chemotherapy cycle. The reason behind the difference observed can be due to the different types of chemotherapy principles (that were bleomycin, actinomycin D, vindesine and DTIC in Mulder et al., 1983) and furthermore the sample size is not reported.

In contrast, as previously anticipated, intensity ratings of sour, bitter, and pungent stimuli presented at both concentrations showed no significant changes over time, confirming previous studies that did not showed effect at a threshold level for sour and bitter (de Vries, Winkels, et al., 2018; IJpma et al., 2017; Kim et al., 2020; Schalk et al., 2018). This suggests that chemosensory alterations during chemotherapy do not uniformly affect all basic tastes. A possible explanation for the absence of variation in bitter and sour perception lies in their functional role: sour and bitter are considered warning sensations in foods (e.g., they indicate the presence of toxic substances, fermentation). Therefore, the perception of bitter and sour could be more resistant to changes induced by chemotherapy, due to attentional and functional mechanisms. Furthermore, patients receiving chemotherapy often experience that foods normally consumed suddenly taste bitter/sour/bad, thus exacerbating the perception of these sensations. However, this remains a hypothesis that requires further targeted investigation.

Even for the pungent solution at both concentrations no significant changes were observed during the treatment, in contrast with limited evidence that reported a reduction in pungency perception in head-and-neck cancer patients (Epstein, Villines, Epstein, & Smutzer, 2020; Riantiningtyas et al., 2023). These discrepancies may reflect interindividual variability, as well as the influence of concomitant conditions such as mucositis or xerostomia, which may increase sensitivity or reduce reactivity due to tissue damage or changes in salivary flow (Thorne, Olson, & Wismer, 2015). Additionally, medical guidelines often recommend avoiding spicy foods to reduce oral discomfort during treatment (Singh & Singh, 2020), which may result in reduced exposure and induce sensitization (Prescott, 1999). Furthermore, in our study, the maximum dose of capsaicin used (0.0015 g/L) may not have been sufficient to detect small changes in sensitivity, particularly in the absence of severe mucosal symptoms.

Alterations may affect not only the perceived intensity, but may occur in the form of a distorted, bitter or bad perception of food often linked to changes in smell perception, as both taste and smell work together to create the full experience of flavor (Amézaga et al., 2018). Patients frequently describe the taste of food as "different than usual" but the information about the timing of the occurrence remains unclear. In our study these alterations were reported by the patients filling out the CiTAS, particularly the "General taste alterations and parageusia" dimension which consider perception of food as bad/bitter/unusual. The percentage of affected patients increased from 26.8 % at T1 to 46.8 % at T2 and 61.8 % at T4, with average scores rising significantly already after the first cycle of therapy. These results align with several studies (Amézaga et al., 2018; Bernhardson et al., 2007) in which patients describe the new taste sensation as "not recognizable" and similar to "paper", "sawdust", "metal", and therefore like a bad taste different from the usual; they also describe the taste of water as "musty", "stale", "sweet" or like "iron", and the taste of coffee as unusually burnt or bitter.

Chemotherapy-treated cancer patients often report sensations, such as a "metallic taste", "chemical taste", "drug taste", "blood taste" and "bitter taste" in the mouth in absence of an external stimulus (Epstein & Barasch, 2010; Jensen et al., 2008). Among these sensations, metallic taste is one of the most frequently reported complaints (Boltong et al., 2012), likely due to chemotherapy drugs being secreted into saliva and directly interacting with taste receptors (Amézaga et al., 2018). In our study the percentage of patients self-reporting phantogeusia and heightened taste perception increased after the first (41.5 %), the second (63.8 %) and the fourth cycle (76.5 %). The significant rise in average scores for this dimension after the first cycle suggests that even these alterations appear early in the treatment and worsen over time.

A variety of antineoplastic side effects are associated with chemosensory alterations, including nausea, vomiting, dry mouth, sore mouth and throat, excessive thirst, swallowing difficulty, appetite changes, weight loss, dizziness, lack of energy, disturbed sleep, anxiety, and difficulty concentrating (Al-Amouri & Badrasawi, 2024; Martini et al., 2019). Some of these conditions are included in the dimension of "Discomfort" where mean CiTAS scores significantly increased after the first chemotherapy cycle. Notably, baseline scores were already above the minimum (>1), suggesting that discomfort is primarily derived from the disease itself. It is further exacerbated by chemotherapy, as evidenced by 78 % of patients reporting discomfort after already one cycle.

Preliminary results on CiTAS responses show that the percentage of patients reporting qualitative alterations, as general taste alterations and parageusia or phantogeusia, or discomfort, increases as the treatment progresses, suggesting a cumulative drug effect of the treatment. However, this trend of cumulative effect was not consistently reflected

in ratings of perceived intensity of aqueous solutions. This discrepancy may be due to the specific nature of the alterations. In fact, also when measured with the CiTAS the cumulative effect is limited to some types of alterations; in the case of "taste decline" once the decline happens, it seems to remain stable. Instead, other types of alterations such as parageusia, phantageusia, or discomfort report an ongoing increase up to the 4th cycle, supporting the hypothesis of a cumulative effect of the chemotherapy. Furthermore, this discrepancy may reflect differences in the assessment methods and timing of measurements between solutions and self-report measures. Recent research has shown that taste alterations may peak early in the chemotherapy cycle, in the first 4–6 days after the infusion (Boltong et al., 2014; IJpma et al., 2016), whereas our study assessed chemosensory function later in the cycle, close to the next infusion, when supposedly the effect is lower and intracycle recovery has happened. While the gLMS captures the perceived intensity of isolated chemosensory stimuli under controlled conditions at a specific time point (the time when the test was run), the CiTAS reflects the everyday taste experience during food consumption in the last period. In daily eating experience, multiple sensory inputs, such as texture, and temperature, combine to shape the overall flavor, potentially revealing alterations that are not detected through tests that focus on a single stimulus.

In addition to the variety of sensory changes and their associated adverse effects, there is considerable variability in how patients respond to these changes. Our results suggest that in the presence of specific conditions, the relationship with foods belonging to specific categories may worsen, inducing more negative emotions, and that such conditions may, in some cases, lead to a change in food preferences. After the first cycle of therapy, the presence of chemosensory alterations does not seem to have an effect such as to cause the modification of food preferences, but even though patients did not change preference compared to baseline, the relationship with the preferred foods appears to change. The "Sweet *vs.* Bitter" dimension showed the largest number of significant changes in emotional responses to foods during the first cycle of chemotherapy in relation to different types of alterations. Patients classified by different self-reported chemosensory alterations, decline in basic tastes, phantogeusia and increased taste perception, and discomfort, experienced a worsening of their emotional relationship with foods in this category, despite no significant changes in food preferences. We may hypothesize that the presence of chemosensory alterations may cause sweet or bitter foods to be perceived as excessively strong or insufficiently satisfying, leading to frustration, dissatisfaction, and indifference. Our data indicate a reduced sweet perception, while no change in bitterness perception is detected. This suggests that previously preferred bitter foods (e.g. coffee or tea) may now be perceived as less satisfying, and/or too bitter due to the reduced effect of suppression of sweetness, even if still preferred compared to an alternative option.

The presence of a phantom taste in the mouth and the increase in the perception of tastes in our patients were not associated with changes in preferences but nevertheless led to an altered emotional relationship with foods in the "Sweet *vs.* Bitter" dimension after the second cycle of therapy. The hypothesis, consistent with Trant, Serin, and Douglass (1982), is that the presence of a bitter or metallic taste in the mouth leads to a rejection of bitter foods and therefore to a worse relationship with them. In fact, symptoms such as phantogeusia may cause some patients to perceive sweet or bitter foods as excessively intense or unpleasant, even if the intensities of the sweetness and bitterness have not actually increased. This can turn the consumption of these foods into a monotonous and/or unpleasant experience. Boltong et al. (2014) reported a lower liking for sweet foods during treatment and therefore we can hypothesize that this decline may also worse positive emotions for normally preferred sweet foods.

Preference changes were observed after the second cycle of therapy in patients who report general taste alteration and parageusia, particularly in the dimension "Sweet *vs*. Bitter". This is consistent with a systematic review of Boltong and Keast (2012) which reports that the most commonly aversive foods and beverages during chemotherapy are bitter items as coffee and tea (Grindel, Cahill, & Walker, 1989; Jacobsen et al., 1993) and sweet/bitter items as chocolate and cola (Andrykowski & Otis, 1990; Mattes, Arnold, & Boraas, 1987; Steinbach et al., 2009). At the same time, patients may respond to these challenges in different ways, such as satisfying specific cravings (Nucci et al., 2022) for sweet foods as a form of emotional compensation or avoiding them altogether for health reasons, further complicating their emotional relationship with these foods during chemotherapy.

Furthermore, a trend of worsening of the emotions elicited by the foods chosen in the "Flavor" dimension of the FP&EQ was observed in patients with general taste alteration and parageusia. These types of disorder could lead to an altered relationship with foods with a more or less intense flavor. Our hypothesis is that an altered taste in food (parageusia) could be worsened by more intense flavors and cause emotions of annoyance and disgust. Discomfort as well is associated to an increase of negative emotions in the "Flavor", "Texture" and "Sweet *vs*. Bitter" dimensions. This maybe because the presence of nausea, inflammation in the mouth, reduction of appetite, and disturbance in smelling food could cause annoyance, frustration and increase in such disturbances in consuming those usual foods that have a specific flavor. Moreover, when nausea follows ingestion of a food, people tend to develop a dislike for the taste of that food (Pelchat & Rozin, 1982). Furthermore, food texture may influence satiety through differences in appetite sensations, gastrointestinal peptide release and food intake (Stribiţcaia, Evans, Gibbons, Blundell, & Sarkar, 2020) and specific types of food textures, such as pasty, are more likely to cause nausea (Tan et al., 2020).

Still focusing on the first cycle, we observed a trend of worsening of the emotional responses to food of the "Herbs and Spices" dimension by patients who self-report a decline in basic tastes in the absence of a change in preferences. In general, literature has reported that a reduced perception leads to choosing seasoned foods with enhancing agents such as salt, lemon juice, spices and garlic (Drareni et al., 2023; Speck et al., 2013), however our hypotheses are multiple. First, it is possible that these foods, being already preferred before the start of therapy, may still not bring the hoped-for relief, thus arousing negative emotions. The second hypothesis is that there is a tendency to avoid specific foods because they are perceived as too flavorful or, on the contrary, as tasteless. Interestingly the domain of odor has not been impacted, suggesting that probably this is a dimension affected for all patients independently from taste alterations (Ishinaga et al., 2018; Nielsen et al., 1980).

These results taken together suggest that provoking different taste and chemosensory alterations, chemotherapy is associated with an altered affective relationship with foods, with a general worsening of the experience. Even preferred foods become more associated with negative emotions. We may hypothesize that this impact that we observe on emotional responses does not affect preference in the short run. In fact, patients do not change their preferences even when they experience a worsening of the emotional experience of these foods. Probably this is due to the fact that the alternative option is not perceived as better, as already not appreciated (it was not preferred at baseline), or also to the fact that for changing preferences more time is needed. These results further expand findings of studies on liking that showed that emotions may discriminate beyond liking, suggesting that they can discriminate also beyond preference (Spinelli, 2021). For patients, it may take time to readjust the habits and develop strategies to cope with the new altered perception that they are experiencing. In fact, we observed changes in preferences but only after the 2nd cycle in people with general taste alterations and parageusia (particularly for the "Sweet *vs.* Bitter" dimension) and after the 4th cycle for people with discomfort. Furthermore, the fact that the results of the tests to identify the direction of the change of preference are not significant may be indicative of inter-individual differences in preferences at baseline. A larger sample is needed to observe these associations considering individual differences.

These results have implications for the supportive care of patients

undergoing chemotherapy as they suggest that the experience of foods should be more considered as it contributes to a worsening of patients' quality of life. Tailor-made recommendations should be developed to suggest to patients what they can do to improve their relationship with food based on the specific alterations that they are experiencing, avoiding the increase of negative emotions.

While the study is the first to show an impact of alterations on emotional responses to foods in cancer patients receiving chemotherapy, it is not without limitations. First of all, the sample size is relatively small and heterogeneous, which limits the generalizability of the results. This is partly due to the fact that the data were collected in a hospital setting, where recruitment depended on patient availability and willingness to participate, as well as the availability of places to conduct the test and of the oncologist to mediate the recruitment. Confounding variables such as age, gender and individual differences in preference may have influenced the results, such as the variety in the cancer type and treatment. However the vast majority of the sample is affected by breast cancer, with similar treatment plans. In addition, as the study is still ongoing the current lack of longitudinal data beyond the chemotherapy treatment period leaves unanswered questions about recovery and long-term impacts.

5. Conclusions

This study provides valuable insights into the chemosensory alterations experienced by patients receiving chemotherapy and their impact on food preferences and emotional responses. Our findings highlight the complexity and variability of these changes, emphasizing the importance of a multidimensional approach to understand and address the chemosensory side effects of anticancer treatment.

The integration of both measurements, such as aqueous solution tests, and self-reported responses using CiTAS provided a better understanding of chemosensory alterations. Furthermore, the investigation of emotional responses to food allowed the identification of changes in the relationship with food, highlighting how these sensory changes can influence the daily eating experience and quality of life even when preferences remain stable. In particular, the early detection of significant changes in chemosensory perception and emotional responses already after the first cycle of therapy underscores the importance of timely interventions. Based on these exploratory results, future research should focus on developing tailored interventions that could help mitigate the impact of the changes on patients' daily lives. It is also needed to complete the study to investigate the persistence or recovery of chemosensory changes and their effects on eating habits and quality of life after treatment.

Ethical statement

The study obtained the approval from the Ethics Committee for Clinical Trials in Tuscany Region – Large Central Area section (Rif. CEAVC n. 20839), Careggi University Hospital, Florence (CEAVC Em. 2022–418 ID 20839), and the Independent Ethics Committee of the Humanitas Clinical Institute (3531/ID. 20839).

CRediT authorship contribution statement

J. Di Meglio: Writing – original draft, Visualization, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **C. Rorandelli:** Writing – review & editing, Methodology, Investigation. **C. Dinnella:** Writing – review & editing, Supervision, Methodology, Conceptualization. **E. Monteleone:** Writing – review & editing, Supervision, Methodology, Data curation, Conceptualization. **F.C. Stingo:** Writing – review & editing, Formal analysis. **L. Doni:** Writing – review & editing, Investigation. **L. Visani:** Writing – review & editing, Investigation. **A. Guarino:** Writing – review & editing, Investigation. **E. Gambale:** Writing – review & editing, Investigation. **R. De Sanctis:** Writing – review & editing, Investigation. **R. Gerosa:** Writing – review & editing, Investigation. **P. Tiberio:** Writing – review & editing, Investigation. **L. Antonuzzo:** Writing – review & editing, Investigation. **V. Scotti:** Writing – review & editing, Investigation. **I. Meattini:** Writing – review & editing, Supervision, Investigation. **G. Roviello:** Writing – review & editing, Supervision, Project administration, Methodology, Investigation. **S. Spinelli:** Writing – review & editing, Supervision, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgement

The authors thank all patients for their time to participate in the study.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.foodqual.2025.105671.

Data availability

Data will be made available on request.

References

Aaronson, N. K., Ahmedzai, S., Bergman, B., Bullinger, M., Cull, A., Duez, N. J., … Takeda, F. (1993). The European Organization for Research and Treatment of Cancer QLQ-C30: A Quality-of-Life Instrument for Use in International Clinical Trials in Oncology. *JNCI Journal of the National Cancer Institute, 85*(5), 365–376. https://doi.org/10.1093/jnci/85.5.365, 3 March 1993, Pages.

Aguiar-Bloemer, A. C., & Diez-Garcia, R. W. (2018). Influence of emotions evoked by life events on food choice. *Eating and Weight Disorders, 23*(1), 45–53. https://doi.org/10.1007/s40519-017-0468-8

Al-Amouri, F. M., & Badrasawi, M. (2024). Taste alteration and its relationship with nutritional status among cancer patients receiving chemotherapy, cross-sectional study. *PLoS One, 19*(5), Article e0302990. https://doi.org/10.1371/journal.pone.0302990

Amézaga, J., Alfaro, B., Ríos, Y., Larraioz, A., Ugartemendia, G., Urruticoechea, A., & Tueros, I. (2018). Assessing taste and smell alterations in cancer patients undergoing chemotherapy according to treatment. *Supportive Care in Cancer, 26*(12), 4077–4086. https://doi.org/10.1007/s00520-018-4277-z

Andrykowski, M. A., & Otis, M. L. (1990). Development of learned food aversions in humans: Investigation in a "natural laboratory" of cancer chemotherapy. *Appetite, 14*(2), 145–158. https://doi.org/10.1016/0195-6663(90)90016-2

Bartoshuk, L. M. (2000). Comparing sensory experiences across individuals: Recent psychophysical advances illuminate genetic variation in taste perception. *Chemical Senses, 25*(4), 447–460. https://doi.org/10.1093/chemse/25.4.447

Battle, D., Rathmell, W. K., Jonasch, E., Msaouel, P., Stern, A. P., Zhang, T., … Staehler, M. D. (2020). Patient-reported outcomes on treatment-related side effects in renal cell carcinoma. *Journal of Clinical Oncology, 38*(6_suppl), 654. https://doi.org/10.1200/jco.2020.38.6_suppl.654

Bell, R., & Marshall, D. W. (2003). The construct of food involvement in behavioral research: Scale development and validation. *Appetite, 40*(3), 235–244. https://doi.org/10.1016/s0195-6663(03)00009-6

Belqaid, K., Tishelman, C., McGreevy, J., Månsson-Brahme, E., Orrevall, Y., Wismer, W., & Bernhardson, B. M. (2016). A longitudinal study of changing characteristics of self-reported taste and smell alterations in patients treated for lung cancer. *European Journal of Oncology Nursing, 21*, 232–241. https://doi.org/10.1016/j.ejon.2015.10.009

Bernhardson, B. M., Tishelman, C., & Rutqvist, L. E. (2007). Chemosensory changes experienced by patients undergoing Cancer chemotherapy: A qualitative interview study. *Journal of Pain and Symptom Management, 34*(4), 403–412. https://doi.org/10.1016/j.jpainsymman.2006.12.010

Bernhardson, B. M., Tishelman, C., & Rutqvist, L. E. (2008). Self-reported taste and smell changes during cancer chemotherapy. *Supportive Care in Cancer, 16*(3), 275–283. https://doi.org/10.1007/s00520-007-0319-7

Bernhardson, B. M., Tishelman, C., & Rutqvist, L. E. (2009). Olfactory changes among patients receiving chemotherapy. *European Journal of Oncology Nursing, 13*(1), 9–15. https://doi.org/10.1016/j.ejon.2008.10.002

Boltong, A., Aranda, S., Keast, R., Wynne, R., Francis, P. A., Chirgwin, J., & Gough, K. (2014). A prospective cohort study of the effects of adjuvant breast cancer chemotherapy on taste function, food liking, appetite and associated nutritional outcomes. *PLoS One, 9*(7), Article e103512. https://doi.org/10.1371/journal.pone.0103512

Boltong, A., & Keast, R. (2012). The influence of chemotherapy on taste perception and food hedonics: A systematic review. *Cancer Treatment Reviews, 38*(2), 152–163. https://doi.org/10.1016/j.ctrv.2011.04.008

Boltong, A., Keast, R., & Aranda, S. (2012). Experiences and consequences of altered taste, flavour and food hedonics during chemotherapy treatment. *Supportive Care in Cancer, 20*(11), 2765–2774. https://doi.org/10.1007/s00520-012-1398-7

Brisbois, T. D., De Kock, I. H., Watanabe, S. M., Baracos, V. E., & Wismer, W. V. (2011). Characterization of chemosensory alterations in advanced cancer reveals specific chemosensory phenotypes impacting dietary intake and quality of life. *Journal of Pain and Symptom Management, 41*(4), 673–683. https://doi.org/10.1016/j.jpainsymman.2010.06.022

de Bruijn, S. E. M., de Vries, Y. C., de Graaf, C., Boesveldt, S., & Jager, G. (2017). The reliability and validity of the macronutrient and taste preference ranking task: A new method to measure food preferences. *Food Quality and Preference, 57*, 32–40. https://doi.org/10.1016/j.foodqual.2016.11.003

Campagna, S., Gonella, S., Stuardi, M., Sperlinga, R., Cerponi, M., Olivero, M., … Dimonte, V. (2016). Italian validation of the chemotherapy induced taste alteration scale. *Assistenza Infermieristica e Ricerca : AIR, 35*(1), 22–28. https://doi.org/10.1702/2228.24016

Cardello, A. V., Meiselman, H. L., Schutz, H. G., Craig, C., Given, Z., Lesher, L. L., & Eicher, S. (2012). Measuring emotional responses to foods and food names using questionnaires. *Food Quality and Preference, 24*(2), 243–250. https://doi.org/10.1016/j.foodqual.2011.12.002

Coa, K. I., Epstein, J. B., Ettinger, D., Jatoi, A., McManus, K., Platek, M. E., … Moskowitz, B. (2015). The impact of cancer treatment on the diets and food preferences of patients receiving outpatient treatment. *Nutrition and Cancer, 67*(2), 339–353. https://doi.org/10.1080/01635581.2015.990577

Corremans, M., Geurden, B., Luyten, S., & Mortelmans, D. (2021). *Validation of the Dutch version of the chemotherpy-induced taste alteration scale (CiTAS). [preprint]. Research Square*. https://doi.org/10.21203/rs.3.rs-543006/v1

Crowder, S. L., Douglas, K. G., Frugé, A. D., Carroll, W. R., Spencer, S. A., Locher, J. L., … Arthur, A. E. (2019). Head and neck cancer survivors' preferences for and evaluations of a post-treatment dietary intervention. *Nutrition Journal, 18*(1). https://doi.org/10.1186/s12937-019-0479-6

De Graaf, C., Kramer, F. M., Meiselman, H. L., Lesher, L. L., Baker-Fulco, C., Hirsch, E. S., & Warber, J. (2005). Food acceptability in field studies with US army men and women: Relationship with food intake and food choice after repeated exposures. *Appetite, 44*(1), 23–31. https://doi.org/10.1016/j.appet.2004.08.008

De Toffoli, A., Spinelli, S., Monteleone, E., Arena, E., Di Monaco, R., Endrizzi, I., … Dinnella, C. (2019). Influences of psychological traits and PROP taster status on familiarity with and choice of phenol-rich foods and beverages. *Nutrients, 11*(6), 1329. https://doi.org/10.3390/nu11061329

Dewys, W. D., & Walters, K. (1975). Abnormalities of taste sensation in cancer patients. *Cancer, 36*(5), 1888–1896. https://doi.org/10.1002/1097-0142(197511)36:5<1888::AID-CNCR2820360546>3.0.CO;2-Y

Doty, R. L., Shah, M., & Bromley, S. M. (2008). Drug-induced taste disorders. *Drug Safety, 31*(3), 199–215. https://doi.org/10.2165/00002018-200831030-00002

Drareni, K., Dougkas, A., Lusson, H., Vansteene, D., Giboreau, A., & Bensafi, M. (2023). Flavor enhancement as a strategy to improve food liking in cancer patients with taste and smell alterations. *Clinical Nutrition Open Science, 47*, 53–63. https://doi.org/10.1016/j.nutos.2022.11.009

Drewnowski, A. (1997). Taste preferences and food intake. *Annual Review of Nutrition, 17*, 237–253. https://doi.org/10.1146/annurev.nutr.17.1.237

Ejder, Z. B., & Sanlier, N. (2023). The relationship between loneliness, psychological resilience, quality of life and taste change in cancer patients receiving chemotherapy. *Supportive Care in Cancer, 31*(12). https://doi.org/10.1007/s00520-023-08156-w

Epstein, J. B., & Barasch, A. (2010). Taste disorders in cancer patients: Pathogenesis, and approach to assessment and management. *Oral Oncology, 46*(2), 77–81. https://doi.org/10.1016/j.oraloncology.2009.11.008

Epstein, J. B., M., d. A.e. S., .S., Epstein, G. L., Leal, J. H. S., Barasch, A., & Smutzer, G. (2019). Taste disorders following cancer treatment: Report of a case series. *Supportive Care in Cancer, 27*(12), 4587–4595. https://doi.org/10.1007/s00520-019-04758-5

Epstein, J. B., Villines, D., Epstein, G. L., & Smutzer, G. (2020). Oral examination findings, taste and smell testing during and following head and neck cancer therapy. *Supportive Care in Cancer, 28*(9), 4305–4311. https://doi.org/10.1007/s00520-019-05232-y

Feeney, E. L., & Hayes, J. E. (2014). Regional differences in suprathreshold intensity for bitter and umami stimuli. *Chemosensory Perception, 7*(3–4), 147–157. https://doi.org/10.1007/s12078-014-9166-3

Galaniha, L. T., & Nolden, A. A. (2023). Taste loss in cancer patients: Clinicians' perceptions of educational materials and diagnostic tools. *Supportive Care in Cancer, 31*(6). https://doi.org/10.1007/s00520-023-07794-4

Gallo, K. E., Swaney-Stueve, M., & Chambers, D. H. (2017). A focus group approach to understanding food-related emotions with children using words and emojis. *Journal of Sensory Studies, 32*(3). https://doi.org/10.1111/joss.12264

Gamper, E. M., Zabernigg, A., Wintner, L. M., Giesinger, J. M., Oberguggenberger, A., Kemmler, G., … Holzner, B. (2012). Coming to your senses: Detecting taste and smell alterations in chemotherapy patients. A systematic review. *Journal of Pain and Symptom Management, 44*(6), 880–895. https://doi.org/10.1016/j.jpainsymman.2011.11.011

Green, B. G., Dalton, P., Cowart, B., Shaffer, G., Rankin, K., & Higgins, J. (1996). Evaluating the "labeled magnitude scale" for measuring sensations of taste and smell. *Chemical Senses, 21*(3), 323–334. https://doi.org/10.1093/chemse/21.3.323

Green, B. G., Shaffer, G. S., & Gilmore, M. M. (1993). Derivation and evaluation of a semantic scale of oral sensation magnitude with apparent ratio properties. *Chemical Senses, 18*(6), 683–702. http://chemse.oxfordjournals.org/.

Gregson, R. A. M., & Baker, A. F. H. (1973). Sourness and bitterness: Confusions over sequences of taste judgements. *British Journal of Psychology, 64*, 71–76. https://doi.org/10.1111/j.2044-8295.1973.tb01328.x

Griffioen-Roose, S., Finlayson, G., Mars, M., Blundell, J. E., & de Graaf, C. (2010). Measuring food reward and the transfer effect of sensory specific satiety. *Appetite, 55*(3), 648–655. https://doi.org/10.1016/j.appet.2010.09.018

Griffioen-Roose, S., Mars, M., Finlayson, G., Blundell, J. E., & De Graaf, C. (2011). The effect of within-meal protein content and taste on subsequent food choice and satiety. *British Journal of Nutrition, 106*(5), 779–788. https://doi.org/10.1017/S0007114511001012

Grindel, C. G., Cahill, C. A., & Walker, M. (1989). Food intake of women with breast cancer during their first six month of chemotherapy. *Oncology Nursing Forum, 16*(3), 401–407.

Haidt, J., Mccauley, C., & Rozin, P. (1994). Individual differences in sensitivity to disgust: A scale sampling seven domains of disgust elicitors. *Personality and Individual Differences, 16*(5), 701–713. https://doi.org/10.1016/0191-8869(94)90212-7

Hayes, J. E., Sullivan, B. S., & Duffy, V. B. (2010). Explaining variability in sodium intake through oral sensory phenotype, salt sensation and liking. *Physiology & Behavior, 100*, 369–380. https://doi.org/10.1016/j.physbeh.2010.03.017

IJpma, I., Renken, R. J., Gietema, J. A., Slart, R. H., Mensink, M. G., Lefrandt, J. D., … Reyners, A. K. (2016). Taste and smell function in testicular cancer survivors treated with cisplatin-based chemotherapy in relation to dietary intake, food preference, and body composition. *Appetite, 105*, 392–399. https://doi.org/10.1016/j.appet.2016.06.010

IJpma, I., Renken, R. J., Gietema, J. A., Slart, R. H. J. A., Mensink, M. G. J., Lefrandt, J. D., … Reyners, A. K. L. (2017). Changes in taste and smell function, dietary intake, food preference, and body composition in testicular cancer patients treated with cisplatin-based chemotherapy. *Clinical Nutrition, 36*(6), 1642–1648. https://doi.org/10.1016/j.clnu.2016.10.013

IJpma, I., Renken, R. J., ter Horst, G. J., & Reyners, A. K. L. (2015). Metallic taste in cancer patients treated with chemotherapy. *Cancer Treatment Reviews, 41*(2), 179–186. https://doi.org/10.1016/j.ctrv.2014.11.006

Inbar, Y., Pizarro, D. A., & Bloom, P. (2009). Conservatives are more easily disgusted than liberals. *Cognition and Emotion, 23*(4), 714–725. https://doi.org/10.1080/02699930802110007

Ishinaga, K., Higa, M., Yasuda, M., Kuwana, M., Nishiwaki, C., Sunaga, M., & Okamura, H. (2018). Alterations in emotional responses (pleasantness/unpleasantness) induced by sniffing food odors during chemotherapy in patients with lung cancer. *Japanese Journal of Clinical Oncology, 48*(10), 906–912. https://doi.org/10.1093/jjco/hyy123

Jacobsen, P. B., Bovbjerg, D. H., Schwartz, M. D., Andrykowski, M. A., Futterman, A. D., Gilewski, T., … Redd, W. H. (1993). Formation of food aversions in cancer patients receiving repeated infusions of chemotherapy. *Behaviour Research and Therapy, 31*(8), 739–748. https://doi.org/10.1016/0005-7967(93)90004-e

Jaeger, S. R., Chheang, S. L., Roigard, C. M., & Cardello, A. V. (2022). Individual differences in food neophobia and private body consciousness influence product-elicited emotional valence and arousal. *Food Quality and Preference, 99*. https://doi.org/10.1016/j.foodqual.2022.104566

Jensen, S. B., Mouridsen, H. T., Bergmann, O. J., Reibel, J., Brünner, N., & Nauntofte, B. (2008). Oral mucosal lesions, microbial changes, and taste disturbances induced by adjuvant chemotherapy in breast cancer patients. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontology, 106*(2), 217–226. https://doi.org/10.1016/j.tripleo.2008.04.003

Jiang, Y., King, J. M., & Prinyawiwatkul, W. (2014). A review of measurement and relationships between food, eating behavior and emotion. *Trends in Food Science & Technology, 36*(1), 15–28. https://doi.org/10.1016/j.tifs.2013.12.005

Kaizu, M., Komatsu, H., Yamauchi, H., Yamauchi, T., Sumitani, M., & Doorenbos, A. Z. (2021). Characteristics of taste alterations in people receiving taxane-based chemotherapy and their association with appetite, weight, and quality of life. *Supportive Care in Cancer: Official Journal of the Multinational Association of Supportive Care in Cancer, 29*(9), 5103–5114. https://doi.org/10.1007/s00520-021-06066-3

Kano, T., & Kanda, K. (2013). Development and validation of a chemotherapy-induced taste alteration scale. *Oncology Nursing Forum, 40*(2), E79–E85. https://doi.org/10.1188/13.ONF.E79-E85

Keller, K. L., Shehan, C., Cravener, T., Schlechter, H., & Hayes, J. E. (2022). Do children really eat what they like? Relationships between liking and intake across laboratory test-meals. *Appetite, 172*. https://doi.org/10.1016/j.appet.2022.105946

Kim, Y. H., Kim, G. M., Son, S., Song, M., Park, S., Chung, H. C., & Lee, S. M. (2020). Changes in taste and food preferences in breast cancer patients receiving chemotherapy: A pilot study. *Supportive Care in Cancer, 28*(3), 1265–1275. https://doi.org/10.1007/s00520-019-04924-9

King, S. C. (2016). Emotions elicited by foods. In H. L. Meiselman (Ed.), *Emotion measurement* (pp. 455–472). Elsevier. https://doi.org/10.1016/B978-0-08-100508-8.00018-7.

Kourouniotis, S., Keast, R. S. J., Riddell, L. J., Lacy, K., Thorpe, M. G., & Cicerale, S. (2016). The importance of taste on dietary choice, behaviour and intake in a group of young adults. *Appetite, 103*, 1–7. https://doi.org/10.1016/j.appet.2016.03.015

Larsen, A. K., Thomsen, C., Sanden, M., Skadhauge, L. B., Anker, C. B., Mortensen, M. N., & Bredie, W. L. P. (2021). Taste alterations and oral discomfort in patients receiving chemotherapy. *Supportive Care in Cancer, 29*(12), 7431–7439. https://doi.org/10.1007/s00520-021-06316-4

Laureati, M., Bergamaschi, V., & Pagliarini, E. (2015). Assessing childhood food neophobia: Validation of a scale in Italian primary school children. *Food Quality and Preference, 40*(PA), 8–15. https://doi.org/10.1016/j.foodqual.2014.08.003

Macht, M. (2008). How emotions affect eating: A five-way model. *Appetite, 50*(1), 1–11. https://doi.org/10.1016/j.appet.2007.07.002

Mahmoud, F. A., Aktas, A., Walsh, D., & Hullihen, B. (2011). A pilot study of taste changes among hospice in patients with advanced cancer. *American Journal of Hospice & Palliative Medicine, 28*(7), 487–492. https://doi.org/10.1177/1049909111402187

Martini, S., Iorio, G. C., Arcadipane, F., Olivero, F., Silvetti, P., Rampino, M., … Franco, P. (2019). Prospective assessment of taste impairment and nausea during radiotherapy for head and neck cancer. *Medical Oncology, 36*(5). https://doi.org/10.1007/s12032-019-1269-x

Masi, C., Dinnella, C., Monteleone, E., & Prescott, J. (2015). The impact of individual variations in taste sensitivity on coffee perceptions and preferences. *Physiology & Behavior, 138*, 219–226. https://doi.org/10.1016/j.physbeh.2014.10.031

Mattes, R. D., Arnold, C., & Boraas, M. (1987). Learned food aversions among cancer chemotherapy patients. Incidence, nature, and clinical implications. *Cancer, 60*(10), 2576–2580. https://doi.org/10.1002/1097-0142(19871115)60:10<2576::aid-cncr2820601038>3.0.co;2-5

McAuliffe, W. K., & Meiselman, H. L. (1974). The roles of practice and correction in the categorization of sour and bitter taste qualities. *Perception & Psychophysics, 16*, 242–244. https://doi.org/10.3758/BF03203936

McGettigan, N., Dhuibhir, P. U., Barrett, M., Sui, J., Balding, L., Higgins, S., … Walsh, D. (2019). Subjective and objective assessment of taste and smell sensation in advanced Cancer. *American Journal of Hospice & Palliative Medicine, 36*(8), 688–696. https://doi.org/10.1177/1049909119832836

Meiselman, H. L. (2021). The (gradual) development of emotion measurement for food. *Current Opinion in Food Science, 40*, 187–191. https://doi.org/10.1016/j.cofs.2021.03.017

Meiselman, H. L., & Dzendolet, E. (1967). Variability in gustatory quality identification. *Perception & Psychophysics, 2*(12), 496–498. https://doi.org/10.3758/BF03210253

Monteleone, E., Spinelli, S., Dinnella, C., Endrizzi, I., Laureati, M., Pagliarini, E., … Tesini, F. (2017). Exploring influences on food choice in a large population sample: The Italian taste project. *Food Quality and Preference, 59*, 123–140. https://doi.org/10.1016/j.foodqual.2017.02.013

Mulder, N. H., Smit, J. M., Kreumer, W. M., Bouman, J., Sleijfer, D. T., Veeger, W., & Schraffordt Koops, H. (1983). Effect of chemotherapy on taste sensation in patients with disseminated malignant melanoma. *Oncology, 40*(1), 36–38. https://doi.org/10.1159/000225687

Ng, M., Chaya, C., & Hort, J. (2013). Beyond liking: Comparing the measurement of emotional response using EsSense profile and consumer defined check-all-that-apply methodologies. *Food Quality and Preference, 28*(1), 193–205. https://doi.org/10.1016/j.foodqual.2012.08.012

Nielsen, S. S., Theologides, A., & Vickers, Z. M. (1980). (1980) influence of food odors on food aversions and preferences in patients with cancer. *The American Journal of Clinical Nutrition, 33*(11), 2253–2261. https://doi.org/10.1093/ajcn/33.11.2253

Nolden, A. A., & Hayes, J. E. (2017). Perceptual and affective responses to sampled capsaicin differ by reported intake. *Food Quality and Preference, 55*, 26–34. https://doi.org/10.1016/j.foodqual.2016.08.003

Nolden, A. A., Hwang, L. D., Boltong, A., & Reed, D. R. (2019). Chemosensory changes from cancer treatment and their effects on patients' food behavior: A scoping review. *Nutrients, 11*(10), 2255. https://doi.org/10.3390/nu11102285

Nucci, D., Santangelo, O. E., Provenzano, S., Nardi, M., Firenze, A., & Gianfredi, V. (2022). Altered food behavior and Cancer: A systematic review of the literature. *International Journal of Environmental Research and Public Health, 19*(16), 10299. https://doi.org/10.3390/ijerph191610299

Obayashi, N., Sugita, M., Shintani, T., Nishi, H., Ando, T., Kajiya, M., … Naito, M. (2023). Taste–taste associations in chemotherapy-induced subjective taste alterations: Findings from a questionnaire survey in an outpatient clinic. *Supportive Care in Cancer, 31*(9). https://doi.org/10.1007/s00520-023-08013-w

O'Donoghue, A., Barrett, M., Dhuibhir, P. U., Kennedy, A., O'Leary, N., & Walsh, D. (2023). Taste and smell abnormalities in advanced cancer: Negative impact on subjective food intake. *Nutrition in Clinical Practice, 38*(4), 807–816. https://doi.org/10.1002/ncp.10943

O'Mahony, M., Goldenberg, M., Stedmon, J., & Alford, J. (1979). Confusion in the use of the taste adjectives 'sour' and 'bitter'. *Chemical Senses, 4*(4), 301–318. https://doi.org/10.1093/chemse/4.4.301

Pagliarini, E., Proserpio, C., Spinelli, S., Lavelli, V., Laureati, M., Arena, E., Di Monaco, R., Menghi, L., Gallina Toschi, T., Braghieri, A., Torri, L., Monteleone, E., & Dinnella, C. (2021). The role of sour and bitter perception in liking, familiarity and choice for phenol-rich plant-based foods. *Food Quality and Preference, 93*, Article 104250. https://doi.org/10.1016/j.foodqual.2021.104250

Pangborn, R. M. (1961). In discussion for pilgrim, F. J. Interactions of suprathreshold taste stimuli. In *physiological and behavioral aspects of taste* (p. 72). University of Chicago Press.

Parma, V., Ohla, K., Veldhuizen, M. G., Niv, M. Y., Kelly, C. E., Bakke, A. J., … Hayes, J. E. (2020). More than smell-COVID-19 is associated with severe impairment of smell, taste, and chemesthesis. *Chemical Senses, 45*(7), 609–622. https://doi.org/10.1093/chemse/bjaa041

Pedersini, R., di Mauro, P., Bosio, S., Zanini, B., Zanini, A., Amoroso, V., … Berruti, A. (2021). Changes in eating habits and food preferences in breast cancer patients undergoing adjuvant chemotherapy. *Scientific Reports, 11*(1). https://doi.org/10.1038/s41598-021-92138-7

Pedersini, R., Zamparini, M., Bosio, S., di Mauro, P., Turla, A., Monteverdi, S., … Berruti, A. (2022). Taste alterations during neo/adjuvant chemotherapy and subsequent follow-up in breast cancer patients: A prospective single-center clinical study. *Supportive Care in Cancer, 30*(8), 6955–6961. https://doi.org/10.1007/s00520-022-07091-6

Pelchat, M. L., & Rozin, P. (1982). The special role of nausea in the acquisition of food dislikes by humans. *Appetite, 3*(4), 341–351. https://doi.org/10.1016/S0195-6663(82)80052-4

Pierguidi, L., Prescott, J., Spinelli, S., Dinnella, C., De Toffoli, A., White, T. L., & Monteleone, E. (2023). Chemosensory quality and intensity reflected in implicit affective responses. *Food Quality and Preference, 108*, Article 104857. https://doi.org/10.1016/j.foodqual.2023.104857

Pliner, P., & Hobden, K. (1992). Development of a scale to measure the trait of food Neophobia in humans. *Appetite, 19*(2), 105–120. https://doi.org/10.1016/0195-6663(92)90014-W

Ponticelli, E., Clari, M., Frigerio, S., De Clemente, A., Bergese, I., Scavino, E., Bernardini, A., & Sacerdote, C. (2017). Dysgeusia and health-related quality of life of cancer patients receiving chemotherapy: A cross-sectional study. *European Journal of Cancer Care, 26*(2). https://doi.org/10.1111/ecc.12633

Postma, E. M., Kok, D. E., de Graaf, C., Kampman, E., & Boesveldt, S. (2020). Chemosensory perception and food preferences in colorectal cancer patients undergoing adjuvant chemotherapy. *Clinical Nutrition ESPEN, 40*, 242–251. https://doi.org/10.1016/j.clnesp.2020.09.012

Prescott, J. (1999). The generalizability of capsaicin sensitization and desensitization. *Physiology & Behavior, 66*(5), 741–749. https://doi.org/10.1016/s0031-9384(99)00012-8

Prieto-Callejero, B., Rivera, F., Fagundo-Rivera, J., Romero, A., Romero-Martín, M., Gómez-Salgado, J., & Ruiz-Frutos, C. (2020). Relationship between chemotherapy-induced adverse reactions and health-related quality of life in patients with breast cancer. *Medicine, 99*(33), Article e21695. https://doi.org/10.1097/MD.0000000000021695

Prinyawiwatkul, W. (2023). Food-evoked emotion, product acceptance, food preference, food choice and consumption: Some new perspectives. *Foods, 12*(11), Article 2095. https://doi.org/10.3390/foods12112095

Ravasco, P. (2005). Aspects of taste and compliance in patients with cancer. *European Journal of Oncology Nursing : The Official Journal of European Oncology Nursing Society, 9*(Suppl. 2), S84–S91. https://doi.org/10.1016/j.ejon.2005.09.003

Riantiningtyas, R. R., Valenti, A., Dougkas, A., Bredie, W. L. P., Kwiecien, C., Bruyas, A., … Carrouel, F. (2023). Oral somatosensory alterations and salivary dysfunction in head and neck cancer patients. *Supportive Care in Cancer, 31*(12). https://doi.org/10.1007/s00520-023-08086-7

Robinson, J. O. (1970). The misuse of taste names by untrained observers. *British journal of psychology (London, England: 1953), 61*(3), 375–378. https://doi.org/10.1111/j.2044-8295.1970.tb01254.x

Rorandelli, C., Lippi, A., Spinelli, S., Pierguidi, L., Monteleone, E., & Dinnella, C. (2024). Remote testing for PROP taster status assessment using solutions and paper disks. *Food Quality and Preference, 113*, Article 105045. https://doi.org/10.1016/j.foodqual.2023.105045

Russell, J. A., Clement, J., Jiwani, D., Ridgeway, K., & Schroeder, M. (1980). A circumplex model of affect. *Journal of Personality and Social Psychology, 39*(6), 1161–1178. https://doi.org/10.1037/h0077714

Ryan, A. M., Prado, C. M., Sullivan, E. S., Power, D. G., & Daly, L. E. (2019). Effects of weight loss and sarcopenia on response to chemotherapy, quality of life, and survival. *Nutrition*, 67–68. https://doi.org/10.1016/j.nut.2019.06.020

Salminen, E., Bishop, M., Poussa, T., Drummond, R., & Salminen, S. (2004). Dietary attitudes and changes as well as use of supplements and complementary therapies by Australian and Finnish women following the diagnosis of breast cancer. *European Journal of Clinical Nutrition, 58*(1), 137–144. https://doi.org/10.1038/sj.ejcn.1601760

Sánchez-Lara, K., Sosa-Sánchez, R., Green-Renner, D., Rodríguez, C., Laviano, A., Motola- Kuba, D., & Arrieta, O. (2010). Influence of taste disorders on dietary behaviors in cancer patients under chemotherapy. *Nutrition Journal, 9*, 15. https://doi.org/10.1186/1475-2891-9-15

Santini, D., Armento, G., Giusti, R., Ferrara, M., Moro, C., Fulfaro, F., … Ripamonti, C. I. (2020). Management of orphan symptoms: Esmo clinical practice guidelines for diagnosis and treatment. *ESMO Open, 5*(6). https://doi.org/10.1136/esmoopen-2020-000933

Schalk, P., Kohl, M., Herrmann, H. J., Schwappacher, R., Rimmele, M. E., Buettner, A., … Zopf, Y. (2018). Influence of cancer and acute inflammatory disease on taste perception: A clinical pilot study. *Supportive Care in Cancer: Official Journal of the Multinational Association of Supportive Care in Cancer, 26*(3), 843–851. https://doi.org/10.1007/s00520-017-3898-y

Sevryugin, O., Kasvis, P., Vigano, M. L., & Vigano, A. (2021). Taste and smell disturbances in cancer patients: A scoping review of available treatments. *Supportive Care in Cancer, 29*(1), 49–66. https://doi.org/10.1007/s00520-020-05609-4

Sick, J., Monteleone, E., Pierguidi, L., Ares, G., & Spinelli, S. (2020). The meaning of emoji to describe food experiences in pre-adolescents. *Foods, 9*(9). https://doi.org/10.3390/foods9091307

Silva, I. M. V., Donaduzzi, L. C., Perini, C. C., Couto, S. A. B., Werneck, R. I., de Araújo, M. R., … Couto-Souza, P. H. (2021). Association of xerostomia and taste alterations of patients receiving antineoplastic chemotherapy: A cause for nutritional concern. *Clinical Nutrition ESPEN, 43*, 532–535. https://doi.org/10.1016/j.clnesp.2021.03.006

Singh, V., & Singh, A. K. (2020). Oral mucositis. *In National Journal of maxillofacial surgery, 11*(2), 159–168. Wolters Kluwer Medknow publications https://doi.org/10.4103/njms.NJMS_10_20.

Speck, R. M., Demichele, A., Farrar, J. T., Hennessy, S., Mao, J. J., Stineman, M. G., & Barg, F. K. (2013). Taste alteration in breast cancer patients treated with taxane chemotherapy: Experience, effect, and coping strategies. *Supportive Care in Cancer, 21*(2), 549–555. https://doi.org/10.1007/s00520-012-1551-3

Spence, C. (2015). Multisensory flavor perception. *Cell, 161*(1), 24–35. https://doi.org/10.1016/j.cell.2015.03.007

Spinelli, S. (2021). Emotions elicited by foods. In H. L. Meiselman (Ed.), *Emotion measurement* (2nd ed., pp. 707–730). Woodhead Publishing. https://doi.org/10.1016/B978-0-12-821124-3.00022-3.

Spinelli, S., De Toffoli, A., Dinnella, C., Laureati, M., Pagliarini, E., Bendini, A., Braghieri, A., Gallina Toschi, T., Sinesio, F., Torri, L., Gasperi, F., Endrizzi, I., Magli, M., Borgogno, M., di Salvo, R., Favotto, S., Prescott, J., & Monteleone, E. (2018). Personality traits and gender influence liking and choice of food pungency. *Food Quality and Preference, 66*, 113–126. https://doi.org/10.1016/j.foodqual.2018.01.014

Spinelli, S., & Jaeger, S. R. (2019). What do we know about the sensory drivers of emotions in foods and beverages? *Current Opinion in Food Science, 27*, 82–89. https://doi.org/10.1016/j.cofs.2019.06.007

Spinelli, S., Masi, C., Dinnella, C., Zoboli, G. P., & Monteleone, E. (2014). How does it make you feel? A new approach to measuring emotions in food product experience. *Food Quality and Preference, 37*, 109–122. https://doi.org/10.1016/j.foodqual.2013.11.009

Spinelli, S., Mini, E., Monteleone, E., Angiolini, C., & Roviello, G. (2021). ALTERTASTE: Improving food pleasure and intake of oncology patients receiving chemotherapy. *Future Oncology, 17*(20), 2573–2579. https://doi.org/10.2217/fon-2020-0871

Spinelli, S., Pierguidi, L., Gavazzi, G., Dinnella, C., De Toffoli, A., Prescott, J., & Monteleone, E. (2023). Skin conductance responses to oral stimuli: The role of taste quality and intensity, and personality traits. *Food Quality and Preference, 109*, Article 104917. https://doi.org/10.1016/j.foodqual.2023.104917

Steinbach, S., Hummel, T., Böhner, C., Berktold, S., Hundt, W., Kriner, M., … Harbeck, N. (2009). Qualitative and quantitative assessment of taste and smell changes in patients undergoing chemotherapy for breast Cancer or gynecologic malignancies. *Journal of Clinical Oncology, 27*(11), 1899–1905. https://doi.org/10.1200/JCO.2008.19.2690

Stribiţcaia, E., Evans, C. E. L., Gibbons, C., Blundell, J., & Sarkar, A. (2020). Food texture influences on satiety: Systematic review and meta-analysis. *Scientific Reports, 10*(1). https://doi.org/10.1038/s41598-020-69504-y

Tabachnick, B. G., & Fidell, L. S. (2001). *Using multivariate statistics*. Needham Heights, MA: Allyn & Bacon.

Tan, P. C., Kartik, B., Thanendran, P., Zakaria, R., Win, S. T., & Omar, S. Z. (2020). Taste, smell and food-related nausea and vomiting responses in hyperemesis gravidarum: A case-controlled study. *Scientific Reports, 10*(1), 4445. https://doi.org/10.1038/s41598-020-61114-y

Thorne, T., Olson, K., & Wismer, W. (2015). A state-of-the-art review of the management and treatment of taste and smell alterations in adult oncology patients. In *, 23. Supportive Care in Cancer* (pp. 2843–2851). Springer Verlag. https://doi.org/10.1007/s00520-015-2827-1. Issue 9.

Trant, A. S., Serin, J., & Douglass, H. O. (1982). Is taste related to anorexia in cancer patients? *The American Journal of Clinical Nutrition, 36*(1), 45–58. https://doi.org/10.1093/ajcn/36.1.45

Tueros, I., & Uriarte, M. (2018). Innovative food products for cancer patients: Future directions. *Journal of the Science of Food and Agriculture, 98*(5), 1647–1652. https://doi.org/10.1002/jsfa.8789

de Vries, Y. C., Boesveldt, S., Kampman, E., de Graaf, C., Winkels, R. M., & van Laarhoven, H. W. M. (2019). Low reported taste function is associated with low preference for high protein products in advanced oesophagogastric cancer patients undergoing palliative chemotherapy. *Clinical Nutrition, 38*(1), 472–475. https://doi.org/10.1016/j.clnu.2017.12.001

de Vries, Y. C., Boesveldt, S., Kelfkens, C. S., Posthuma, E. E., van den Berg, M. M. G. A., de Kruif, J. T. C. M., … Winkels, R. M. (2018). Taste and smell perception and quality of life during and after systemic therapy for breast cancer. *Breast Cancer Research and Treatment, 170*(1), 27–34. https://doi.org/10.1007/s10549-018-4720-3

de Vries, Y. C., Winkels, R. M., van den Berg, M. M. G. A., de Graaf, C., Kelfkens, C. S., de Kruif, J. T. C. M., … Boesveldt, S. (2018). Altered food preferences and chemosensory perception during chemotherapy in breast cancer patients: A longitudinal comparison with healthy controls. *Food Quality and Preference, 63*, 135–143. https://doi.org/10.1016/j.foodqual.2017.09.003

Webb, J., Bolhuis, D. P., Cicerale, S., Hayes, J. E., & Keast, R. (2015). The relationships between common measurements of taste function. *Chemosensory Perception, 8*, 11–18. https://doi.org/10.1007/s12078-015-9183-x

Yeomans, M. R., Tepper, B. J., Rietzschel, J., & Prescott, J. (2007). Human hedonic responses to sweetness: Role of taste genetics and anatomy. *Physiology & Behavior, 91*. https://doi.org/10.1016/j.physbeh.2007.03.011, 2–3 264 273.

Zhao, L., Kirkmeyer, S. V., & Tepper, B. J. (2003). A paper screening test to assess genetic taste sensitivity to 6-n-propylthiouracil. *Physiology and Behavior, 78*(4–5), 625–633. https://doi.org/10.1016/S0031-9384(03)00057-X