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An update on image forming methods: structure analysis and Gestalt evaluation of images from rocket lettuce with shading, N supply, organic or mineral fertilization, and biodynamic preparations

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Abstract In the image forming methods, copper chloride crystallization (CCCryst), capillary dynamolysis (CapDyn), and circular chromatography (CChrom), characteristic patterns emerge in response to different food extracts. These patterns reflect the resistance to decomposition as an aspect of resilience and are therefore used in product quality assessment complementary to chemical analyses. In the presented study, rocket lettuce from a field trial with different radiation intensities, nitrogen supply, biodynamic, organic and mineral fertilization, and with or without horn silica application was investigated with all three image forming methods. The main objective was to compare two different evaluation approaches, differing in the type of image forming method leading the evaluation, the amount of factors analyzed, and the deployed perceptual strategy: Firstly, image evaluation of samples from all four experimental factors simultaneously by two individual evaluators was based mainly on analyzing structural features in CapDyn (analytical perception). Secondly, a panel of eight evaluators applied a Gestalt evaluation imbued with a kinesthetic engagement of CCCryst patterns from either fertilization treatments or horn silica treatments, followed by a confirmatory analysis of individual structural features. With the analytical approach, samples from different radiation intensities and N supply levels were identified correctly in two out of two sample sets with groups of five samples per treatment each (Cohen's kappa, $p = 0.0079$), and the two organic fertilizer treatments were differentiated from the mineral fertilizer treatment in eight out of eight sample sets with groups of three manure and two minerally fertilized

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samples each (Cohen's kappa, $p = 0.0048$). With the panel approach based on Gestalt evaluation, biodynamic fertilization was differentiated from organic and mineral fertilization in two out of two exams with 16 comparisons each (Friedman test, $p < 0.001$), and samples with horn silica application were successfully identified in two out of two exams with 32 comparisons each (Friedman test, $p < 0.001$). Further research will show which properties of the food decisive for resistance to decomposition are reflected by analytical and Gestalt criteria, respectively, in CCCryst and CapDyn images.

Keywords Copper chloride crystallization · Capillary dynamolysis · Kinesthetic engagement · Perceptual strategies · Emergent properties · Organism

Introduction

With the image forming methods, capillary dynamolysis (CapDyn), circular chromatography (CChrom), and copper chloride crystallization (CCCryst), additive-specific structures are evaluated that emerge from metal salts with organic additives (Doesburg et al. 2015). These structures represent characteristic phenotypic patterns (Gestalts), which via reference series were shown to be related to ripening and decomposition processes (Doesburg et al. 2015; Fritz et al. 2018). Only in a state of full ripeness a product has its typical, species-specific structure, which is comprised in the concept of organic integrity contained in the current framework for concept, definition, and evaluation of organic food quality from the European perspective (Kahl et al. 2012). High resistance to decomposition indicates a high capacity to maintain outer and inner structure under stress and is therefore related to resilience or vital qualities as another important concept in organic food quality (Kahl et al. 2012). As all characteristics of the additive participate in image formation, samples are evaluated as a whole. Thus, the methods complement chemical analysis of individual compounds, meeting the requirements of organic farming calling for a whole food approach in quality evaluation (Kahl et al. 2012).

Image forming methods have been successfully applied in the differentiation and quality evaluation of cereal, fruit, vegetable, wine, or milk samples from different varieties (Busscher et al. 2010), production or fertilization systems (Athmann 2011; Busscher et al. 2010; Fritz et al. 2011, 2014, 2017; Kahl et al. 2015; Mäder et al. 1993, 2007; Szulc et al. 2010; Weibel et al. 2000), or processing steps (Busscher et al. 2010; Kahl et al. 2009, 2014; Seidel et al. 2015; Unluturk et al. 2013).

CCCryst images are analyzed either computer-based (Andersen et al. 1999; Doesburg and Nierop 2013; Unluturk et al. 2013) or visually (Huber et al. 2010; Fritz et al. 2011; Doesburg et al. 2015). For images of the two chromatographic methods, only visual evaluation procedures have been developed. Computer-based analysis guarantees objectivity and comparatively high throughput, but so far samples from different backgrounds have merely been differentiated, while an interpretation of the significance of the detected differences was not possible. In visual evaluation, individual researchers have linked images to plant physiological processes via reference series with images from different ripening or decomposition stages (Balzer-Graf and Balzer 1991; Balzer-Graf 1994; Fritz et al. 2011, 2014, 2017). In all of these studies, encoded samples from different production systems were differentiated and evaluated with respect to their maturity and their resistance to decomposition as aspects of organic integrity and resilience.

Despite their potential to assess domains of product quality relevant for organic farming, image forming methods are still not widely used, partly due to a lack of standardized criteria in visual evaluation. Therefore, a working group has been formed to work out defined structural criteria for CCCryst in line with ISO-norms for sensory analysis (Huber et al. 2010). Structural criteria, e.g., length of crystal needles or color intensity in the paper-based methods, are characterized by pronounced single object identification and a predominantly two-dimensional, static perception of the object, and are also used in computerized image analysis (Doesburg and Nierop 2013). For visual evaluation, in a second step, this analytical evaluation level was extended to the level of Gestalt evaluation utilizing analytical and gestural morphological criteria (Doesburg et al. 2015). Gestalts, or perceptual units, emerge from changes in texture and structure, but are not merely the sum of these changes. Gestalt is defined as a perceptual pattern or structure possessing qualities as a whole that cannot be described merely as a sum of its parts. Their assessment involves kinesthetic engagement, which is defined as bodily sensation of observed motions or implicit motions of living or even inanimate objects (Miyoshi 2019). With respect to the images, this means mentally simulating the growth, curvature, and tension of the dendritic branches in crystallization images or flow forms in CapDyn or CChrom. These image characteristics cannot be assessed with a merely quantitative evaluation and are therefore not targeted by computerized analysis.

Both structural and gestural morphological criteria relating to ripening and decomposition were trained to a panel by supervised classification and successfully applied to rank crystallization images from different cereals, vegetables, and fruits according to the degree of decomposition or ripening (Doesburg et al. 2015; Fritz et al. 2018). In the study of Fritz et al. (2018), additionally wheat samples from organic and conventional production from a controlled field trial were significantly distinguished by the panel based on the level of decomposition, which was perceived higher in the conventional samples. The accuracy of discrimination, however, varied between the individual panel members. An inquiry about the perceptual strategies utilized revealed that the best performing panel members based their evaluation mainly on Gestalt perception, using the analytical perception strategy only in a confirmatory way.

This led to the hypothesis that a holistic perception by means of a conscious kinesthetic engagement in the perception of the Gestalt decomposition succeeded by a confirmatory “atomic feature” evaluation results in a higher accuracy than evaluation of solely analytical criteria. The objective of the present study was to test this hypothesis by applying analytical and Gestalt criteria to rocket lettuce samples from two harvest years 2008 and 2009 from a field trial with the factors light intensity, N supply, fertilizer type, and application of the biodynamic field preparation BD 501 or horn silica. In the first evaluation in 2008/2009, two individual evaluators judged the images based on all three image forming methods, and based their analysis mainly on CapDyn, emphasizing analytical criteria such as colors or presence of certain image structures. In the second evaluation in 2018, a panel, trained specifically on adhering either strictly to quantifiable atomic features or to more globally oriented Gestalt criteria requiring kinesthetic engagement, characterized the same samples exclusively based on CCCryst. The accuracy of both approaches (analytical features in CapDyn vs. Gestalt features in CCCryst) with respect to differentiation of the samples and the direction of the quality ranking was tested and compared.

Materials and methods

Origin of the rocket lettuce samples

Rocket samples (*Eruca sativa* L.) were derived from a four-factorial randomized split-plot field trial with four field replications carried out in autumn 2008 and 2009 at the Wiesengut experimental research station for Organic Agriculture of the University of Bonn, Germany. The test factors considered in the first evaluation with image forming methods in the current study were (i) light intensity (100% photosynthetically active radiation PAR and 55% PAR), (ii) nitrogen supply (low, 30 kg N/ha in 2008 or 15 kg N/ha in 2009, and high, 60 kg N/ha), (iii) fertilizer type (biodynamic (biodyn): composted cow manure with biodynamic preparations, organic (org): composted cow manure, mineral (min): calcium ammonium nitrate, triple superphosphate and potassium chloride), and (iv) application of the biodynamic field preparation BD 501 or horn silica (with (+BD 501), without (-BD 501)). In the second evaluation with image forming methods, only the factors fertilizer type and horn silica application were considered. The field experiment is described in detail in Athmann (2011). Rocket was sown 30 Aug 2008 and 31 Aug 2009, respectively. For reference series with different stages of juice aging, rocket from an adjacent area was used that was sown May 20, 2009.

Study design and sample preparation

For the first image evaluation in 2008/2009, in each harvest year, two sets with ten encoded samples each were analyzed. The different fertilizer types and horn silica treatments are combined with different light intensities in the first set and with different N supply levels in the second set (Table 1). Samples were mixed samples from two field repetitions.

For each sample set, both fresh juice (stored overnight), juice from different aging stages (2008: 6 days; 2009: 6 and 10 days) and juice from leaves stored for a few days after harvest (2008: 7 days; 2009: 4 and 8 days) were analyzed. Directly after harvest at 18–19 Oct 2008 and 26–27 Oct 2009, 400 g rocket leaves per treatment combination were washed, dried with a salad spinner, and pressed in a juice press (Porkert, Czech Republic). 2 × 50 ml juice (2008) or 3 × 50 ml juice (2009) were filled in test tubes, which were then closed with a rubber plug and encoded. The pressed

Table 1 Treatment combinations analyzed in the first image evaluation 2008/2009

Sample set 1			Sample set 2		
Light intensity	Fertilizer type	Horn silica	N supply	Fertilizer type	Horn silica
100%	biodyn	+ BD 501	low	biodyn	+ BD 501
100%	biodyn	- BD 501	low	biodyn	- BD 501
100%	org	- BD 501	low	org	- BD 501
100%	min	+ BD 501	low	min	+ BD 501
100%	min	- BD 501	low	min	- BD 501
55%	biodyn	+ BD 501	high	biodyn	+ BD 501
55%	biodyn	- BD 501	high	biodyn	- BD 501
55%	org	- BD 501	high	org	- BD 501
55%	min	+ BD 501	high	min	+ BD 501
55%	min	- BD 501	high	min	- BD 501

All samples of sample set 1 had high N supply; all samples of sample set 2 had 100% PAR

rocket lettuce juice was stored overnight. After solid particles had settled, 16 ml of the liquid phase was pipetted to sterilized Erlenmeyer flasks, filtered (filter paper Sartorius 288, Göttingen, Germany), and the filtrate either directly used for CCryst, CapDyn, and CChrom as described below, or stored for another 6 or 10 days at 4 °C, inducing a decomposition process. Another 400 g leaves per treatment were carefully dried on towels, regularly turning for 60 min, and then stored in plastic boxes with 200 g leaves each at 4 °C for 4, 7, or 8 days. After storage, these leaves were pressed to juice and processed as described above.

In total, in 2008, 90 CCCryst images, 90 CChrom images, and 120 CapDyn images per sample set were analyzed, corresponding to 9 or 12 images per sample. In 2009, 150 CCCryst images, 150 CChrom images, and 200 CapDyn images per sample set were analyzed, corresponding to 15 or 20 images per sample.

Copper chloride crystallization

Floatglass plates 2-mm thick and 10.5 × 10.5 cm were cleaned with 2% sodium carbonate solution (Merck KGaA, Darmstadt, Germany) and a small brush, then rinsed with hot water, and sorted into frames, each containing 15 plates, for soaking baths. Subsequently, two soaking baths were carried out with chrome sulfuric acid (Merck) (10 min each). The plates were then rinsed in six baths with clear Aqua bidest. Plexiglas rings with an inner diameter of 9 cm were mounted with paraffin on the glass plates. The rocket juice is mixed with Aqua bidest. to reach the desired mixing ratios (Table 2) and filtered with filter paper Whatman 4 (Buckinghamshire, UK). Then the $CuCl_2$. $2H_2O$ cupric chloride 10% (Merck) was added, and 4 ml of this mixture was pipetted into the ring and crystallized in a crystallization chamber at 30 °C with 50% humidity. After 12–15-h crystallization, all images were photographed against a dark-field illuminated background (Sigma SD14 SLR digital camera with macro lens: Sigma 50 mm F2,8 EX DG; JPEG format 2268 × 1512), and printed on photographic paper for evaluation.

Capillary dynamolysis

In the first phase, 0.6 ml of four different mixtures of rocket juice and distilled water (Table 3) were applied to standard sized chromatography paper (Schleicher & Schuell 2043A, Düren, Germany) in Kaelin dishes and left to rise vertically (Balzer-Graf 1987; Zalecka et al. 2010). In the second phase, 0.7 ml of a 0.25% silver nitrate solution (Merck) rose to 1 cm over the extract line. In the third phase, 2.0 ml of a 0.25% iron sulfate

Table 2 Mixing ratios copper chloride crystallization

Rocket juice (ml)	H_2O dest. (ml)	$CuCl_2$* 2 H_2O 10% (ml)
0.10 ŧ	2.40 ŧ	1.50 ŧ
0.15 ŧ Ł	2.35 ŧ Ł	1.50 ŧ Ł
0.20 ŧ Ł	2.30 ŧ Ł	1.50 ŧ Ł
0.30 Ł	2.20 Ł	1.50 Ł

ŧ: fresh juice, Ł: aged juice

Table 3 Mixing ratios capillary dynamolysis

Rocket juice (ml)	H_2O dest. (ml)	$AgNO_3$ 25% (ml)	$FeSO_4$ 25% (ml)
0.100 ꞁ	0.500 ꞁ	0.700 ꞁ	2.000 ꞁ
0.125 ꞁ ꝉ	0.475 ꞁ ꝉ	0.700 ꞁ ꝉ	2.000 ꞁ ꝉ
0.150 ꞁ ꝉ	0.450 ꞁ ꝉ	0.700 ꞁ ꝉ	2.000 ꞁ ꝉ
0.250 ꝉ	0.350 ꝉ	0.700 ꝉ	2.000 ꝉ

ꞁ: fresh juice, ꝉ: aged juice

solution (Merck) rose to a total height of 12 cm. During the second and third phase, the chromatograms were covered with tall beakers to maintain sufficient humidity. The drying time between phases was set for 2 h at 20 °C and 50% humidity.

Circular chromatography

Filter paper discs (Whatman No. 1) with a total diameter of 15 cm were saturated with 0.5% silver nitrate solution (Merck) to a diameter of 8 cm (Pfeiffer 1959; Bangert 1994). The filter papers were dried for 2–3 h after saturation. The diluted rocket juice mixed with NaOH (Merck; for mixing ratios see Table 4) migrated through the filter paper discs from the center to a diameter of 12 cm. In order to maintain sufficient humidity, the paper was covered with a glass container. In diffuse daylight, not direct sun, the images developed to full color formation within 2 days.

Visual evaluation

In the visual evaluation of 2008/2009, the encoded images were characterized as “strong – weak form expression” or “fresh – aged” based on formerly produced reference images with (i) varying amounts of rocket juice per image and (ii) different decomposition stages. Since differences were more pronounced in the images of the two paper-based methods, these were mainly used. Based on the characterizations, (a1) rocket with strong form expression and (b1) fresh rocket was ranked higher than (a2) rocket with weak form expression and (b2) aged rocket. Based on the experience from earlier investigations, the samples were then assigned to light intensities, N supply levels, fertilizer types, or horn silica application (classification).

Table 4 Mixing ratios circular chromatography

Rocket juice (ml)	H_2O dest. (ml)	NaOH 0.4% (ml)
0.225 ꞁ	0.835 ꞁ	0.190 ꞁ
0.225 ꞁ ꝉ	0.805 ꞁ ꝉ	0.220 ꞁ ꝉ
0.250 ꞁ ꝉ	0.780 ꞁ ꝉ	0.220 ꞁ ꝉ
0.250 ꝉ	0.750 ꝉ	0.250 ꝉ

ꞁ: fresh juice, ꝉ: aged juice

In the visual evaluation of 2018, only CCCryst images from harvest year 2009 were analyzed by a panel of eight evaluators, following ISO 11035 (1994) as adapted to visual evaluation of crystallization images (Huber et al. 2010) and ISO 8587 (2006) for ranking methodology in sensory analysis as adapted for ranking samples according to the image Gestalt *decomposition* (Doesburg et al. 2015). The focus of the panel was only on ranking different fertilizer types and horn silica application, not on ranking light intensity or nitrogen supply. Before analyzing the samples under question, the panel was trained in recognizing, describing, and ranking decomposition in the images by adhering to the features described in Table 5 via a process of concept learning with supervised classification which is described in detail in Doesburg et al. (2015). For the training, eight sets of images from samples with varying decomposition stages (1, 6, and 10 days of juice aging and 4 days of leave aging) were created from the images produced in 2009. All samples of one set had the same treatment combination of light intensity, N supply, fertilization, and horn silica application, and each sample was presented with all three mixing ratios of $CuCl_2$*$2H_2O$ and rocket juice, as portable document format (PDF) files.

After the training, the panel was asked to evaluate rocket crystallization patterns from different (i) decomposition stages (results described in Doesburg et al. (2021) and (ii) fertilizer types or horn silica application according to the perceived level of decomposition using the criteria listed in Table 5. Out of all images from harvest year 2009, 16 image sets with three different

Table 5 Characteristic features of increased decomposition in wheat crystallization images

1. Level Quantifiable single morphological and local features	2. Level Quantifiable, descriptive single morphological features	3. Level Gestures or implicit motions in the whole pattern	4. Level Emergent Gestalt criteria
Decrease of coarse structural features	Increase of “Flechtwerke” (areas with fuzzy needles)	Decrease of integration	Decrease of fluent interconnected movement
Decrease of side needles	Increase of the angle of side needles	Decrease of “Durchstrahlung” (ease of following needles from the center to the periphery)	Decrease of a sense of presence in the image
		Decrease of center coordination	Decrease of tension in the needle branches from the center to the periphery
		Decrease of motility	Decrease of a consistent dynamic in the filling of the plate

Nomenclature levels 1–3 according to Huber et al. (2010) in Doesburg et al. (2015)

fertilizer types and 32 image sets with or without horn silica application were created, again containing all three mixing ratios of $CuCl_2*2H_2O$ and rocket juice. All images from one set had the same treatment combination of light intensity, nitrogen supply, and juice aging. Biodynamic fertilization was with horn silica application; organic and mineral fertilization were without horn silica application. Panel tests were performed on March 13 and 14, 2018, and repeated on September 27 and 28, 2018, in the sensory laboratory of the University of Kassel, Germany, after another training period of 6 × 1.5 h training sessions via Skype with supervised classification and peer tutoring by the best performing evaluators.

Each panel member simultaneously received encoded image sets in random order. Accordingly, different from the evaluation in 2008/2009, the panel evaluated only one image set at a time, with either fertilizer types or horn silica treatments. On the first day of the exam, half of the panel was asked to assess the images using an analytical perception strategy, with pronounced single object identification and a mainly two-dimensional, static perception of the object, utilizing solely the criteria of the levels 1 and 2 in Table 5. The second half of the panel was asked to evaluate the images focusing predominantly on gestures or implicit movements of the crystallization patterns, i.e., using kinesthetic engagement in Gestalt perception, followed by a secondary, confirmatory analytical evaluation (in Table 5 mainly levels 3 and 4). On the second day, the panel members applied the opposite type of perception compared to the first day.

Statistical analysis

In 2008/2009, the agreement between correct classification and the classification based on image forming methods was tested with interrater agreement. This test is based on a contingency table, which compares the given categories with those determined in the examination. The agreement was determined using the simple Kappa coefficient. The method is described in Agresti (2002). The kappa coefficients and the exact *p* values for the statistical test for agreement were calculated using the procedure FREQ (Frequency) in SAS 9.2 (SAS Institute Inc., Cary, NC, USA, 2008). For the panel evaluation in 2018, the average rank order of the samples was calculated, and the Friedman test recommended for sensory analysis in ISO 8587 (2006)

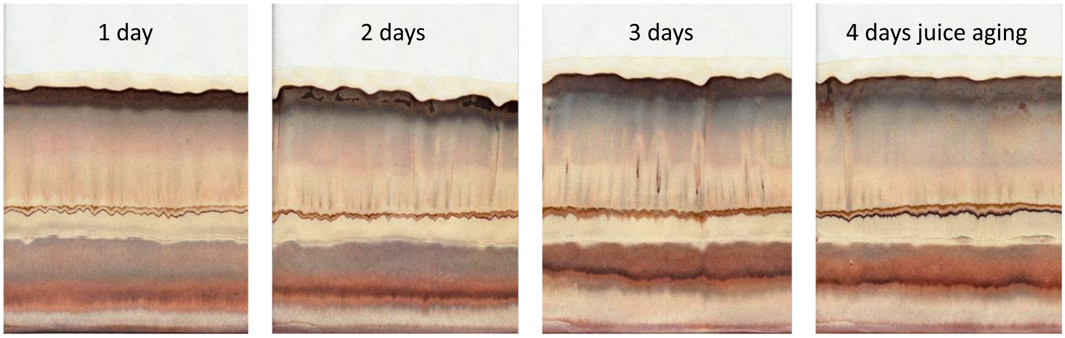

Fig. 1 Capillary dynamolysis: Reference series decomposition. From left to right: 1, 4, 7, and 10 days of juice aging. 0.1 ml rocket juice per image. Rocket harvested June 29, 2009, 40 days after sowing

was applied as an overall measure for correct ranking and for pairwise comparisons of adjacent ranks. The Friedman test was performed with SPSS 19.0 (IBM, Armonk, NY, USA, 2011).

Results

Reference series decomposition 2008/2009

The reference series with rocket juice that was aged for up to 4 days at 8 °C is shown in Fig. 1 for capillary dynamolysis. With increased decomposition, colors in the lower part of the image fade and structures in the upper image part are less pronounced.

Treatment effects 2008/2009: light intensity, N supply, fertilizer type, and horn silica application

In both experimental years, samples with 100 or 55% PAR, low or high N supply, and manure or mineral fertilization were correctly classified in both sample sets, while the two fertilizer types with manure could not be differentiated (Tables 6 and 7).

Samples with or without horn silica application could not be separated when image evaluation was based on CapDyn. Only in sample set 2 in the experimental year 2009, samples +BD 501 were

Table 6 Assignment of encoded rocket samples to experimental factors and factor levels: sample set 1

Sample			Classification 2008			Classification 2009		
Light intensity	Fertilizer type	Horn silica	Light intensity	Fertilizer type	Horn silica	Light intensity	Fertilizer type	Horn silica
100%	biodyn	+ BD 501	100%	biodyn	- BD 501	100%	biodyn	- BD 501
100%	biodyn	- BD 501	100%	org	- BD 501	100%	biodyn	+ BD 501
100%	org	- BD 501	100%	biodyn	+ BD 501	100%	org	- BD 501
100%	min	+ BD 501	100%	min	- BD 501	100%	min	- BD 501
100%	min	- BD 501	100%	min	+ BD 501	100%	min	+ BD 501
55%	biodyn	+ BD 501	55%	org	- BD 501	55%	biodyn	+ BD 501
55%	biodyn	- BD 501	55%	biodyn	+ BD 501	55%	org	- BD 501
55%	org	- BD 501	55%	biodyn	- BD 501	55%	biodyn	- BD 501
55%	min	+ BD 501	55%	min	- BD 501	55%	min	- BD 501
55%	min	- BD 501	55%	min	+ BD 501	55%	min	+ BD 501
Significance (Cohen's kappa, $\alpha = 0.05$)[1]			$p = 0.0079$	$p = 0.0048$	ns	$p = 0.0079$	$p = 0.0048$	ns

[1] With respect to fertilizer type, biodynamic and organic fertilization was joined for statistical analysis. No shading: correct assignments; grey shading: wrong assignments. *biodyn* biodynamic; *org* organic; *min* mineral. + BD 501: with horn silica application; - BD 501: without horn silica application. All samples had high N supply

Table 7 Assignment of encoded rocket samples to experimental factors and factor levels: sample set 2

Sample			Classification 2008			Classification 2009		
N supply	Fertilizer type	Horn silica	N supply	Fertilizer type	Horn silica	N supply	Fertilizer type	Horn silica
low	biodyn	+ BD 501	low	org	- BD 501	low	biodyn	+ BD 501
low	biodyn	- BD 501	low	biodyn	+ BD 501	low	org	- BD 501
low	org	- BD 501	low	biodyn	- BD 501	low	biodyn	- BD 501
low	min	+ BD 501	low	min	+ BD 501	low	min	+ BD 501
low	min	- BD 501	low	min	- BD 501	low	min	- BD 501
high	biodyn	+ BD 501	high	biodyn	- BD 501	high	biodyn	+ BD 501
high	biodyn	- BD 501	high	biodyn	+ BD 501	high	org	- BD 501
high	org	- BD 501	high	org	- BD 501	high	biodyn	- BD 501
high	min	+ BD 501	high	min	- BD 501	high	min	+ BD 501
high	min	- BD 501	high	min	+ BD 501	high	min	- BD 501
Significance (Cohen's kappa, $\alpha = 0.05$)[1]			$p = 0.0079$	$p = 0.0048$	ns	$p = 0.0079$	$p = 0.0048$	$p = 0.0048$

[1] With respect to fertilizer type, biodynamic and organic fertilization was joined for statistical analysis. No shading: correct assignments; grey shading: wrong assignments. *biodyn* biodynamic; *org* organic; *min* mineral. + BD 501: with horn silica application; - BD 501: without horn silica application. All samples had 100% PAR

consistently ranked higher than samples -BD 501 and were therefore correctly classified. In this sample set, the two individual evaluators based their assessment not solely on CapDyn, but also on CCCryst, prioritizing Gestalt over structure evaluation as described for the panel evaluation

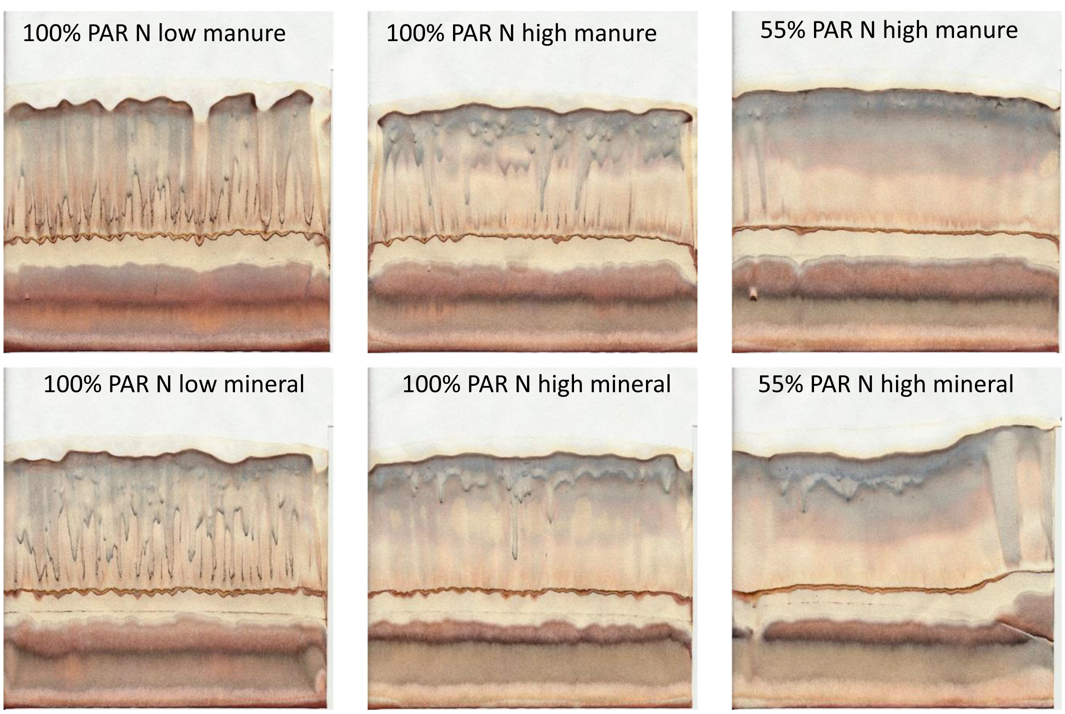

Fig. 2 Capillary dynamolysis: Treatment effects on rocket samples. Top row: manure fertilization; bottom row: mineral fertilization. Both rows from left to right: 55% PAR and high N supply, 100% PAR and high N supply, 100% PAR and low N supply. 0.100 ml rocket juice per image

2018. The criteria used and the results of the semi-quantitative evaluation of the image sets from the experimental year 2009 are given in Table S1.

In Fig. 2, exemplary CapDyn images from the six treatment combinations that were reliably distinguished are shown. The combination 100% PAR–N low–manure had the most colorful and structured image. With either 55% PAR, N high, or mineral fertilization, colors in the lower image part and structures in the upper image part faded; i.e., shading, high N supply, or mineral fertilization resulted in image changes similar to the effect of juice decomposition (see Fig. 1). Consequently, images from the combination 55% PAR–N high–mineral had the strongest signs of decomposition.

Training series decomposition 2018

In the exemplary decomposition training series shown in Fig. 3, with advanced rocket juice aging, image changes can be described on the four different evaluation levels from Table 5: On the two single morphological levels, the coarse needle bundles visible in the image of the fresh juice do not appear in any of the aged juices, and areas with fuzzy needles appear after 6 or 10 days of juice aging. On the gesture level, a decrease of integration can be noted, partially caused by the areas with fuzzy needles which are not integrated into the rest of the image, and, after 10 days of juice aging, also due to needles that do not originate in the center of the crystal, but deviate from the others, which in turn contributes to the impression of reduced center coordination of the crystal and to decreased "Durchstrahlung". Especially after 10 days of juice aging, needles become stiffer, resulting in a decrease of motility. On the Gestalt level, interconnected movement, presence in the image, tension in the needle branches, and consistent dynamic in the filling of the plate decrease with increasing juice aging.

Treatment effects 2018/2019: fertilizer type

With analytical perception only, the results of both exams were not significant in the Friedman test. The error of the classification of the two treatments fertilized with manure compared to the minerally fertilized treatment is with 65% and 70% close to the randomly expected classification of 67% (Table 8). However, with additional kinesthetic engagement in Gestalt perception, the error rate in the classification decreased to 52% in both exams, with the ranking Biodyn < Org < Min and a significant difference between Biodyn and Org. The additional training before the second exam did not improve the results (Table 8).

Exemplary images of rocket samples for the three fertilization treatments are given in Fig. 4. Different from the decomposition training series, analytical and Gestalt evaluation did not result in the same ranking: The organic sample shows the coarsest needle bundles and is the only image without fuzzy image structures on the analytical level. Also, biodynamic and mineral fertilization are very similar with respect to single morphological features. On the gesture and Gestalt level, the sample with biodynamic fertilization shows clearly the greatest motility, interconnected movement, presence in the image, tension in the needle branches, and consistent dynamic in the filling of the plate.

Treatment effects 2018/2019: horn silica application

Both with analytical perception and with kinesthetic engagement in Gestalt perception, samples with horn silica were ranked significantly higher than samples without horn silica. However, with Gestalt perception, the error rate in the classification of the encoded images decreased from 43 to 30% in the first exam and from 43 to 29% in the second exam. The additional training before the second exam did not improve the results (Table 9).

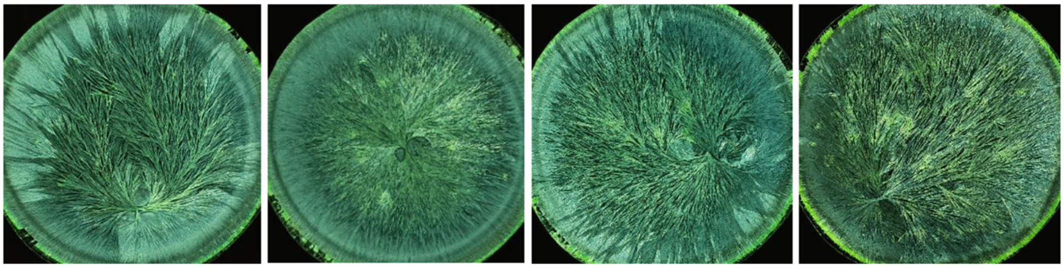

Fig. 3 Copper chloride crystallization: Training series decomposition of rocket samples. From left to right: fresh, 4 days of leave aging, 6 days of juice aging, 10 days of juice aging. 0.1 ml rocket juice per image. All samples had 100% PAR, high N supply and biodynamic fertilization with horn silica application

Exemplary images of rocket samples for the two horn silica treatments are given in Fig. 5. In this example, expression of single morphological features is very similar in the two images: Both show regular, coarse needles that originate in the center of the crystal, resulting in a strong center coordination and high integration on the gesture level. However, motility is clearly higher in the image of the sample with horn silica application, accompanied by a stronger expression of all criteria on the Gestalt level: interconnected movement, presence in the image, tension in the needle branches, and consistent dynamic in the filling of the plate.

Discussion

Development of visual evaluation: from structural features to Gestalt evaluation

The two image evaluation approaches utilized in the present study describe the development that visual evaluation in image forming methods has undergone in the last decade. The approach used in 2008/2009 followed the procedure established by Balzer-Graf and Balzer (1991) and Balzer-Graf (1994): visual evaluation is performed by one or two individual, experienced evaluators, who base their evaluation on all three image

Table 8 Ranking fertilization treatments of rocket crystallization images according to decomposition levels from fresh to decomposed: Two separate exams per date, one with analytical perception only and one with kinesthetic Gestalt perception and confirmatory analytical perception

	Analytical perception				Kinaesthetic Gestalt perception with confirmatory analytical perception			
Fertilizer type	Biodyn	Org	Min	Error classification Biodyn+Org vs. Min	Biodyn	Org	Min	Error classification Biodyn+Org vs. Min
Exam March 2018								
Evaluator 1-8	1.95	1.98	2.07	64.8 %	1.59	2.12	2.29	51.6%
Pairwise comparison	Test not significant				└> $p < 0.001$ <┘ └> $p = 0.169$ <┘			
Evaluator 1	1.88	1.94	2.19	56%	2.00	1.88	2.13	62%
Evaluator 2	2.00	1.63	2.31	50%	1.50	2.00	2.50	71%
Evaluator 3	1.88	1.75	2.38	44%	1.88	2.19	1.94	69%
Evaluator 4	2.31	1.88	1.81	81%	1.38	2.31	2.31	56%
Evaluator 5	1.31	2.31	2.38	50%	1.31	2.25	2.44	44%
Evaluator 6	2.38	1.75	1.88	81%	1.81	1.88	2.31	56%
Evaluator 7	2.38	2.06	1.56	94%	1.44	2.25	2.31	44%
Evaluator 8	1.50	2.50	2.06	62%	1.44	2.19	2.38	50%
Exam September 2018								
Evaluator 1-8	1.99	2.01	2.00	70.3%	1.58	2.14	2.28	52.3%
Pairwise comparison	Test not significant				└> $p < 0.001$ <┘ └> $p = 0.261$ <┘			
Evaluator 1	1.75	1.88	2.39	44%	1.69	2.25	2.06	62%
Evaluator 2	2.31	1.81	1.88	87%	2.13	1.69	2.19	56%
Evaluator 3	2.25	2.06	1.69	81%	1.69	2.00	2.31	44%
Evaluator 4	2.13	2.06	1.81	81%	1.88	2.25	1.88	75%
Evaluator 5	1.63	2.06	2.31	50%	1.31	2.19	2.50	44%
Evaluator 6	2.13	1.94	1.94	75%	1.63	2.31	2.06	69%
Evaluator 7	2.31	2.00	1.69	94%	1.13	2.06	2.81	19%
Evaluator 8	1.44	2.25	2.31	50%	1.19	2.38	2.44	50%

Friedman test pairwise comparisons ($\alpha = 0.05$) were performed between adjacent ranks

Fig. 4 Fertilization treatments in rocket crystallization images, harvest year 2009. From left to right: biodynamic, organic and mineral fertilization. Rocket juice aged for 1 day, 0.2 ml juice per image. All samples had 100% PAR and high N supply. Biodynamic fertilization was with horn silica application; organic and mineral fertilization were without horn silica application

forming methods and differentiate and rank encoded samples according to signs of ripening and decomposition in the images, using both single morphological and Gestalt criteria, which by that time were not well-defined. With respect to different production or fertilization systems, in all studies published using this visual evaluation approach (Athmann 2011; Fritz et al. 2011, 2014, 2017; Mäder et al. 1993, 2007; Weibel et al. 2000) as well as in studies with computer-based evaluation (Busscher et al. 2010; Kahl et al. 2015; Szulc et al. 2010), production systems based on manure or mineral fertilization were identified with high accuracy. However, only in some of the studies with visual evaluation, biodynamic and organic fertilization were successfully distinguished—possibly because in some studies structural and in other studies Gestalt aspects were leading the assessment.

In contrast, the CCCryst evaluation in 2018 was performed by a trained panel that had agreed on a defined catalogue of criteria published by Doesburg et al. (2015) and Fritz et al. (2018) and had been trained to consciously use either only single morphological criteria or kinesthetic engagement in Gestalt evaluation followed by a confirmatory analysis of "atomic features". This means, instead of focussing on single object identification, the panel members concentrated on non-selectively extracting global information from the entire image (Wolfe et al. 2011). In their analysis, manure and mineral fertilization were not significantly distinguished, but treatments with biodynamic preparations were ranked significantly higher at both exam dates when Gestalt aspects were leading the evaluation. Parallel to analyzing the fertilization and horn silica treatments presented in the current study, the panel also ranked images from samples with different decomposition stages in the exams. Here, kinesthetic engagement in Gestalt perception with subsequent confirmatory "atomic feature" evaluation also led to higher accuracy in the evaluation of decomposition levels in rocket and wheat crystallization images than analytical perception alone (Doesburg et al. 2021). Thus, in the current study, the crystallization image Gestalt features affected by biodynamic preparations seem to be even more closely related with decomposition than the structural features analyzed with CapDyn.

Resistance to decomposition as an aspect of food quality

Resistance to decomposition as indicated by CapDyn images can be regarded as an aspect of static resilience, i.e., as the capability to maintain functionality, in this case structure formation in interaction with metal salts, under the stress imposed by juice aging (Döring et al. 2015). The mechanisms underlying the detected differences in resistance to decomposition are not fully understood yet. Aging induces changes both on the level of chemical composition, microbiology, and physical structure of the food and is clearly connected to quality loss. From a physical point of view, the branching conditions in CCCryst depend on the transport abilities of the solution regarding mass and heat transfer (Busscher et al. 2014). For the polymer polyvinylpyrrolidone, these transport abilities were influenced by molecular weight, as higher molecular weight of PVP gave higher viscosity and lower heat conductivity (Busscher et al. 2014).

It can be hypothesized that in foods the chemical composition and its change during aging may also affect viscosity and heat conductivity and therefore the branching conditions. In the present study, shading as compared to full sunlight, high as compared to low N supply, or mineral as compared to manure fertilization resulted both in lower maintenance of structure formation in CapDyn images (Tables 6, 7, Fig. 2) and in lower dry matter content, higher contents of nitrate and lower contents of monosaccharides, ascorbic acid and glucosinolates (Athmann 2011). In contrast to changes of structural features in CapDyn images, differences in Gestalt criteria detected with CCCryst had no parallels with plant morphology or chemical composition. Of the many parameters analyzed, only very few were affected by application of the biodynamic preparations (Athmann 2011), while in the current study, treatments with horn silica application were consistently ranked higher in CCCryst Gestalt evaluation (Table 9, Fig. 5). Similarly, in a study on grapes, plant development in the field and chemical analyses of grapes and wood were linked to structure formation in CChrom and CapDyn, but not to Gestalt evaluation in CCCryst (Fritz et al. 2017). Besides the chemical compounds commonly associated with food, the complex microstructures in which these compounds are embedded and termed as "food matrix" affect physical properties of foods. For example, higher viscosity may be imparted via network exocellular matrices constituted by exopolysaccharides secreted by microorganisms (Aguilera 2019). Future research will show whether properties of the food matrix may be linked to Gestalt evaluation in CCCryst. The fact that image forming methods reveal characteristics of the whole food matrix that lie beyond the scope of compound-specific analyses

Table 9 Ranking horn silica application treatments of rocket crystallization images according to decomposition levels from fresh to decomposed: Two separate exams per date, one with analytical perception only and one with kinaesthetic Gestalt perception and confirmatory analytical perception

	Analytical perception			Kinesthetic Gestalt perception with confirmatory analytical perception		
Horn silica application	+ BD 501	-BD 501	Error classification	+ BD 501	-BD 501	Error classification
Exam March 2018						
Evaluator 1-8	1.43	1.57	43.4 %	1.30	1.70	30.1%
Pairwise comparison	└> $p = 0.034$ <┘			└> $p < 0.001$ <┘		
Evaluator 1	1.44	1.56	44%	1.44	1.56	44%
Evaluator 2	1.44	1.56	44%	1.22	1.78	22%
Evaluator 3	1.50	1.50	50%	1.28	1.72	28%
Evaluator 4	1.50	1.50	50%	1.38	1.62	38%
Evaluator 5	1.25	1.75	25%	1.22	1.78	22%
Evaluator 6	1.44	1.56	44%	1.41	1.59	41%
Evaluator 7	1.47	1.53	47%	1.12	1.88	12%
Evaluator 8	1.44	1.56	44%	1.34	1.66	34%
Exam September 2018						
Evaluator 1-8	1.43	1.57	42.6%	1.29	1.71	28.5%
Pairwise comparison	└> $p = 0.018$ <┘			└> $p < 0.001$ <┘		
Evaluator 1	1.13	1.87	13%	1.25	1.75	25%
Evaluator 2	1.53	1.47	53%	1.53	1.47	53%
Evaluator 3	1.53	1.47	53%	1.28	1.72	28%
Evaluator 4	1.56	1.44	56%	1.41	1.59	41%
Evaluator 5	1.22	1.78	22%	1.16	1.84	16%
Evaluator 6	1.53	1.47	53%	1.28	1.72	28%
Evaluator 7	1.46	1.54	46%	1.12	1.88	12%
Evaluator 8	1.47	1.53	47%	1.25	1.75	25%

Friedman test pairwise comparisons ($\alpha = 0.05$) were performed between adjacent ranks has been repeatedly pointed out (e.g., Fritz et al. 2011; Busscher et al. 2014; Doesburg et al. 2015).

Prospects and risks of Gestalt evaluation

Science must guarantee objectivity in that its theories, laws, experimental results, and observations constitute accurate representations of the external world and are not tainted by human desires, goals, capabilities, or experience (Reiss and Sprenger 2017). In natural science, this is usually achieved by measuring parameters that can be expressed in quantities with calibrated measuring instruments ("mechanical objectivity"), minimizing the human factor as a potential source of bias and error. However, the properties of the instrument and the properties of the environment measured influence the results and their interpretation. Thus, instruments also provide a perspective view on the world (Giere 2006 cited in Reiss and Sprenger 2017). Moreover, technical instruments only cover a part of the peculiarities of their subjects when it comes to subject areas that deal with living organisms. Consequently, both in all clinical contexts in human medicine (Woolley and Kostopoulou 2013) and in the characterization and diagnosis of mental disorders (Parnas 2012; Westen 2012), Gestalt evaluation is a common practice.

For a fundamental understanding of living entities, also in biological and agricultural research, the analytical approach explaining organisms solely by the chemical functions of their component parts needs to be complemented by concepts and methods that meet all properties of life, including dynamic properties such as reciprocal interdependencies in organic functions, integrative system functions, information content and processing within organisms, the ability to evolve, and growth and development (Rosslenbroich 2016).

Due to the danger of personal bias and emotional arbitrariness, careful attention has to be paid to compare Gestalts and investigate their interdependent aspects in ways that allow for scientific generalizations to ensure objectivity (Nordgaard et al. 2013). In the current study, scientific generalization is possible by analyzing encoded samples and training on well-defined criteria. Intersubjectivity is ensured by working with a panel as in sensory analysis.

Possible modes of action of the biodynamic preparations

The relevance of the differences in Gestalt expression in the CCCryst images is not clear yet. The approach was particularly successful in identifying treatments with application of the biodynamic preparations. The effects of biodynamic preparations on yield and chemical contents measured in the various studies available convey a yield stabilizing or compensatory effect, i.e., effects also related to crop resilience. While only a part of individual studies shows effects of these preparations, a meta-

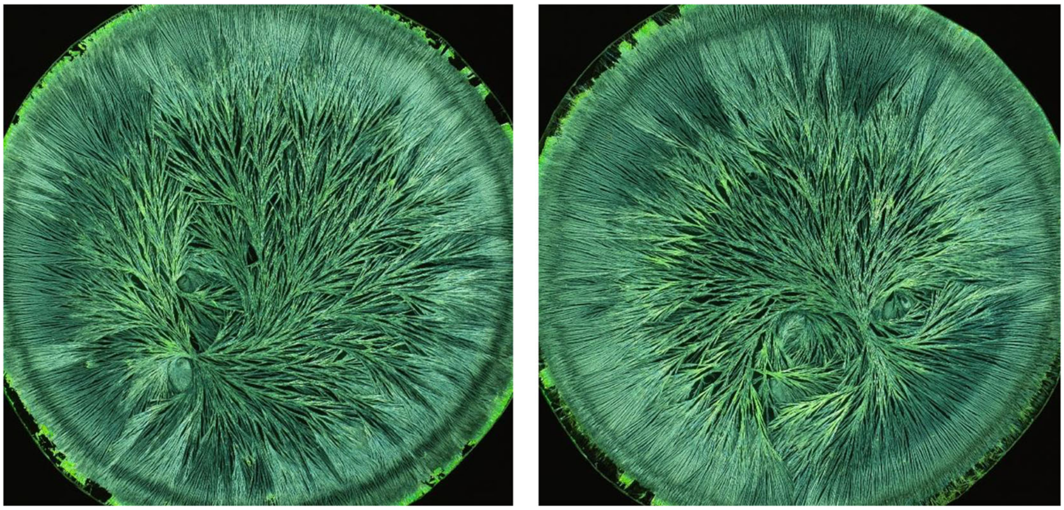

Fig. 5 Horn silica treatments in rocket crystallization images, harvest year 2009. Left: with horn silica application; right: without horn silica application. Rocket juice from leaves that had been aged for 1 day, 0.2 ml juice per image. All samples had 100% PAR, high N supply and biodynamic fertilization. The left image is the same as in figure 3

analysis of several studies published between the 1960s and 1990s found that in years with favorable conditions and overall high crop yield, yield was not increased or even reduced, while in years with lower overall crop yield due to, e.g., drought stress or late sowing, yield was often increased (Raupp and König 1996; Fritz 2000; Fritz and Köpke 2005). Compensatory effects of biodynamic preparations were also observed for quality parameters, with higher increases of secondary metabolites in pumpkin cultivars with a genetically low level of these compounds (Juknevičienė et al. 2019).

The mode of action of biodynamic preparations is still not understood. The non-linear compensatory effects of the biodynamic preparations are similar to the mode of action of adaptogens first described in botany, human nutrition, and medicine. Adaptogens are pharmacologically active compounds, mostly from plant extracts, that have been shown to increase non-specific stress resistance, adaptive ability, and possibly lifespan (Wiegant et al. 2009) in several model systems, including animals and humans (Panossian and Wagner 2005). An adaptogen conveys the organism from its normal steady state (homeostasis) to a heightened level of dynamic equilibrium (heterostasis), normalizing independently of the direction of the pathological state (Brekhman and Dardymov 1969). In this regard, the adaptogenic concept anticipates the efficacy of the nutritive measure depending on the physiological or mental status of the target organism including stress resilience.

The theories concerning the modulating effects of the biodynamic preparations entail bacterial regulation, as bacteria detect and react to extremely low levels of signal molecules such as carbohydrates and peptides that arise from microbially mediated slow maturation under low oxygen conditions during production of the preparations (Spaccini et al. 2012), e.g., with greater rhizospheric activity (Reeve et al. 2010; Giannatasio et al. 2013) or stimulation of natural defense compounds (Botelho et al. 2016; Schneider and Ullrich 1994). Another theory possibly complementing bacterial regulation is that the biodynamic preparations act via hormonal effects, as bacterial strains contained in the horn manure preparation BD 500 were found to produce indole acetic acid (Radha and Rao 2014), and undegraded lignin residues contained in BD 500 are known to exhibit indole acetic acid-like activity (Spaccini et al. 2012). Additionally, Giannatasio et al. (2013) found strong auxin-like effects of BD 500, and Fritz 2000 found gibberellic acid-like effects of BD 501. Future research will show the impact of microbial communities on plant health and possibly resilience, and study potential impacts of biodynamic preparations on plant-associated microbiomes.

Conclusion

In the presented study, rocket lettuce samples with full sunlight or shading, low or high N supply, biodynamic, organic, or mineral fertilization, and with or without horn silica application were evaluated with respect to their resistance to decomposition in image forming methods as aspects of organic integrity and resilience. Differences in single morphological structural image criteria were found for full sunlight and shading, low and high N supply, and mineral and manure fertilization, while differences in Gestalt criteria were found for samples with or without biodynamic preparations. Both single morphological and Gestalt criteria are now well-defined and can be trained to evaluation panels in accordance with norms adapted from sensory analysis. Research is needed to link the results of image forming methods, especially differences in Gestalt expression, to properties of the food decisive for resistance to decomposition.

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Code availability Not applicable.

Author's contributions MA carried out the field experiment as part of her Ph D thesis supervised by UK, organized sampling, processing and encoding of rocket, performed the laboratory work with image forming methods, evaluated the images in 2008/2009 together with JF, provided the image sets for the second analysis in 2018/2019, and wrote the manuscript with assistance from all authors. JF and PD conceptualized the panel assessment. JF led training and exam of the panel and evaluated the results of the exams. MA, RB, NB, PD, UG, GM, CS, and JF participated in the panel evaluation.

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Declarations

Ethics approval Not applicable.

Consent to participate Not applicable.

Consent for publication Not applicable

Conflict of interest All authors declare that they have no conflict of interest.

References

Agresti A (2002) Categorical data analysis, 2nd edn. Wiley, Hoboken, NJ, USA

Aguilera JM (2019) The food matrix: implications in processing, nutrition and health. Critical Reviews in Food Science and Nutrition 59:22

Andersen JO, Henriksen CB, Laursen J, Nielsen AA (1999) Computerised image analysis of biocrystallograms originating from agricultural products. Comput Electron Agric 22: 51–69

Athmann M (2011) Produktqualität von Salatrauke (*Eruca sativa* L.) und Weizen (*Triticum aestivum* L.): Einfluss von Einstrahlungsintensität, Stickstoffangebot, Düngungsart und Hornkieselapplikation auf Wachstum und Differenzierung. Dissertation, University of Bonn, Germany

Balzer-Graf U (1987) Vitalaktivität von Nahrungsmitteln. Elemente der Naturwissenschaft 46:69–92

Balzer-Graf UR (1994) Die Qualität ökologisch erzeugter Produkte. In: Mayer J, Ries M, Faul O, Gerber A, Kärcher A (eds) Ökologischer Landbau - Perspektive für die Zukunft! Sonderausgabe 58. Stiftung Ökologie und Landbau, Bad Dürkheim, Germany, pp 261–290

Balzer-Graf UR, Balzer FM (1991) Steigbild und Kupferchloridkristallisation - Spiegel der Vitalaktivität von Lebensmitteln. In: Meier-Ploeger AM, Vogtmann H (eds) Lebensmittelqualität - ganzheitliche Methoden und Konzepte, 2nd edn. C. F. Müller, Karlsruhe, Germany, pp 163–210

Bangert D (1994) Zu den naturwissenschaftlichen Grundlagen des Chroma-Boden-Tests als bildschaffender Methode – Empirische Untersuchungen und theoretische Deutungen. Edition Zukunft, Barsinghausen, Germany

Botelho RV, Roberti R, Tessarin P, García-Mina JM, Rombolà AD (2016) Physiological responses of grapevines to biodynamic management. Renewable Agric Food Syst 31(5):402–413

Brekhman II, Dardymov IV (1969) New substances of plant origin which increase non-specific resistance. Annu Rev Pharmacol 9:419–430

Busscher N, Kahl J, Andersen JO, Huber M, Mergardt G, Doesburg P, Paulsen M, Ploeger A (2010) Standardization of the biocrystallization method for carrot samples. Biol Agric Hortic 27(1):1–23

Busscher N, Kahl J, Ploeger A (2014) From needles to pattern in food quality determination. J Sci Food Agric 94:2578–2581

Doesburg P, Nierop AF (2013) Development of a structure analysis algorithm on structures from $CuCl_2.2H_2O$ crystallization with agricultural products. Comput Electron Agric 90:63–67

Doesburg P, Fritz J, Athmann M, Bornhütter R, Busscher N, Geier U, Mergardt G, Scherr C (2021) Kinesthetic engagement in Gestalt evaluation outscores analytical 'atomic feature' evaluation in perceiving aging in crystallization images of agricultural products. Plos One, https://doi.org/10.1371/journal.pone.0248124

Doesburg P, Huber M, Andersen JO, Athmann M, Bie G, Fritz J, Geier U, Hoekman J, Kahl J, Mergardt G, Busscher N (2015) Standardization and performance of a visual Gestalt evaluation of biocrystallization patterns reflecting ripening and decomposition processes in food samples. Biol Agric Hortic 31(2):128–145

Döring TF, Vieweger A, Pautasso M, Vaarst M, Finckh MR, Wolfe MS (2015) Resilience as a universal criterion of health. J Sci Food Agric 95:455–465

Fritz J (2000) Reaktionen von Pflücksalat (*Lactuca sativa* L. *var. crispa*) und Buschbohnen (*Phaseolus vulgaris* L. *var. nanus*) auf das Spritzpräparat Hornkiesel. Dissertation, University of Bonn, Germany

Fritz J, Köpke U (2005) Einfluss von Licht, Düngung und biologisch-dynamischem Spritzpräparat Hornkiesel bei Buschbohne (*Phaseolus vulgaris* L. *var. Nanus*) auf die Keimeigenschaften der neu gebildeten Samen. Pflanzenbauwissenschaften 9(2):55–60

Fritz J, Athmann M, Kautz T, Köpke U (2011) Grouping and classification of wheat from organic and conventional production systems by combining three image forming methods. Biol Agric Hortic 27:320–336

Fritz J, Athmann M, Meissner G, Köpke U (2014) Quality assessment of wine from integrated, organic and biodynamic viticulture using image forming methods. In: Rahmann G, Aksoy U (eds) Building Organic Bridges. Proceedings of the 4th ISOFAR Scientific Conference at the Organic World Congress Oct 13-15 2014, Istanbul, Turkey, pp 497–500

Fritz J, Athmann M, Meissner G, Kauer R, Köpke U (2017) Quality characterization via image forming methods differentiates grape juice produced from integrated, organic or biodynamic vineyards in the first year after conversion. Biol Agric Hortic 33(3):195–213

Fritz J, Athmann M, Andersen JO, Doesburg P, Geier U, Mergardt G (2018) Advanced panel training on visual Gestalt evaluation of biocrystallization images: ranking wheat samples from different extract decomposition stages and different production systems. Biol Agric Hortic 35(1):21–32

Giannatasio M, Vendramin E, Fornasier F, Alberghini S, Zanardo M, Stellin F, Concheri G, Stevenato P, Ertani A, Nardi S, Rizzi V, Piffanelli P, Spaccini R, Mazzei P, Piccolo A, Sqartini A (2013) Microbiological features and bioactivity of a fermented manure product (preparation 500) used in biodynamic agriculture. J Microbiol Biotechnol 23(5):644–651

Giere R (2006) *Scientific Perspectivism*. University of Chicago Press, Chicago, IL, USA

Huber M, Andersen JO, Kahl J, Busscher N, Doesburg P, Mergardt G, Kretschmer S, Zalecka A, Meelursan A, Ploeger A, Nierop D, van de Vijver L, Baars E (2010) Standardization and validation of the visual evaluation of biocrystallizations. Biol Agric Hortic 27(1):25–40

ISO 11035 (1994) Sensory analysis: identification and selection of descriptors for establishing a sensory profile by a multidimensional approach. International Organization for Standardization, Geneva, Switzerland

ISO 8587 (2006) Sensory analysis – methodology - ranking. International Organization for Standardization, Geneva, Switzerland

Juknevičienė E, Danilčenko H, Jarienė E, Fritz J (2019) The effect of horn-manure preparation on enzymes activity and nutrient contents in soil as well as great pumpkin yield. Open Agriculture 4:452–459

Kahl J, Busscher N, Doesburg P, Mergardt G, Huber M, Ploeger A (2009) First Tests of standardized biocrystallization on milk and milk products. Eur Food Res Technol 229:175–178

Kahl J, Baars T, Bügel S, Busscher N, Huber M, Kusche D, Rembialkowska E, Schmid O, Seidel K, Taupier-Letage B, Velimirov A, Zalecka A (2012) Organic food quality: a framework for concept, definition and evlauation from the European perspective. J Sci Food Agric 92(14):2760–2765

Kahl J, Busscher N, Hoffmann W, Mergardt G, Clawin-Raedecker I, Kiesner C, Ploeger A (2014) Development and performance of crystallization with additives applied on different milk samples. Food Anal Methods 7:1373–1380

Kahl J, Busscher N, Mergardt G, Mäder P, Torp T, Ploeger A (2015) Differentiation of organic and non-organic winter wheat cultivars from a controlled field trial by crystallization patterns. J Sci Food Agric 95:53–58

Mäder P, Pfiffner L, Niggli U, Balzer U, Balzer FM, Plochberger A, Velimirov A, Besson JM (1993) Effect of three farming systems (bio-dynamic, bio-organic, conventional) on yield and quality of beetroot (*Beta Vulgaris* L. Var. Sculenta L.) in a seven year crop rotation. Acta Hortic 339:10–31

Mäder P, Hahn D, Dubois D, Gunst L, Alföldi T, Bergmann H, Oehme M, Amadó R, Schneider H, Graf U, Velimirov A, Fließbach A, Niggli U (2007) Wheat quality in organic and conventional farming: results of a 21 year field experiment. J Sci Food Agric 87:1826–1835

Miyoshi K (2019) What allows us to kinesthetically empathize with motions of non-anthropomorphic objects? Journal of Somaesthetics 4:52–67

Nordgaard J, Sass LA, Parnas J (2013) The psychiatric interview: validity, structure, and subjectivity. Eur Arch Psy Clin N 263: 353–364

Panossian A, Wagner H (2005) Stimulating effect of adaptogens: an overview with particular reference to their efficacy following single dose administration. Phytother Res 19:819–838

Parnas J (2012) The core Gestalt of schizophrenia. World Psych 11:67–69

Pfeiffer E (1959) Eine qualitative chromatographische Methode zur Bestimmung biologischer Werte. Lebendige Erde:205-215 and 245-249

Radha TK, Rao DLN (2014) Plant growth promoting bacteria from cow dung based biodynamic preparations. Indian J Microbiol 54(4):413–418

Raupp J, König UJ (1996) Biodynamic preparations cause opposite yield effects depending upon yield levels. Biol Agric Hortic 13(2):175–188

Reeve JR, Capenter-Boggs L, Reganold JP, York AL, Brinton WF (2010) Influence of biodynamic preparations on compost development and resultant compost extracts on wheat seedling growth. Bioresour Technol 101(14):5658–5666

Reiss J, Sprenger J (2017) Scientific Objectivity. In Zalta EN (ed) *The Stanford Encyclopedia of Philosophy*, winter 2017 edn. https://plato.stanford.edu/archives/win2017/entries/scientific-objectivity/. Accessed March 30 2020

Rosslenbroich B (2016) Properties of Life: Toward a Coherent Understanding of the Organism. Acta Biotheor 64:277–307

Schneider S, Ullrich WR (1994) Differential induction of resistance and enhanced enzyme activities in cucumber and tobacco caused by treatment with various abiotic and biotic inducers. Physiol Mol Plant Pathol 45(4):291–304

Seidel K, Kahl J, Paoletti F, Birlouez I, Busscher N, Kretzschmar U, Särkkä-Tirkkonen M, Seljåsen R, Sinesio F, Torp T, Baiamonte I (2015) Quality assessment of baby food made of different pre-processed organic raw materials under industrial processing conditions. J Food Sci Technol 52:803–812

Spaccini R, Mazzei P, Squartini A, Giannattasio M, Piccolo A (2012) Molecular properties of a fermented manure preparation used as field spray in biodynamic agriculture. Environ Sci Pollut Res 19(9):4214–4225

Szulc M, Kahl J, Busscher N, Mergardt G, Doesburg P, Ploeger A (2010) Discrimination between organically and conventionally grown winter wheat farm pair samples using the copper chloride crystallisation method in combination with computerised image analysis. Comput Electron Agric 74: 218–222

Unluturk S, Pelvan M, Unluturk MS (2013) The discrimination of raw and UHT milk samples contaminated with penicillin G and ampicillin using image processing neural network and biocrystallization methods. J Food Compos Anal 32:12–19

Weibel F, Bickel R, Leuthold S, Alföldi T, Balzer-Graf U (2000) Are organically grown apples tastier and healthier? A comparative study using conventional and alternative methods to measure fruit quality. Acta Hortic 517:417–427

Westen D (2012) Prototype diagnosis of psychiatric syndromes. World Psychiatry 11:16–21

Wiegant FAC, Surinova S, Ytsma E, Langelaar-Makkinje M, Wikman G, Post JA (2009) Plant adaptogens increase lifespan and stress resistance in C. Elegans. Biogerontology 10(1):27–42

Wolfe JM, Võ MLH, Evans KK, Greene MR (2011) Visual search in scenes involves selective and nonselective pathways. Trends Cogn Sci 15:77–84

Woolley A, Kostopoulou O (2013) Clinical intuition in family medicine: more than first impressions. Ann Fam Med 11:60–66

Zalecka A, Kahl J, Doesburg P, Pyskow B, Huber M, Skjerbaek K, Ploeger A (2010) Standardization of the Steigbild Method. Biol Agric Hortic 27:41–57