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## AN UPDATE ON IMAGE FORMING METHODS: STRUCTURE ANALYSIS AND GESTALT EVALUATION

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**Abstract:** Rocket lettuce from a field trial with biodynamic, organic and mineral fertilization with or without horn silica application was investigated with the image forming methods copper chloride crystallization, capillary dynamolysis and round filter chromatography with two approaches. Firstly, image evaluation by two individual evaluators was based mainly on analysing structural features in capillary dynamolysis, secondly, a panel of eight evaluators analysed both structural and Gestalt criteria of copper chloride crystals. With the first approach, the two manure fertilizers were differentiated from the minerally fertilized sample, while with the second approach, biodynamic fertilization was differentiated from organic and mineral fertilization, and samples with horn silica application were successfully identified. Apparently, biodynamic preparations affected Gestalt criteria more than structural aspects. Gestalt recognition may be a method to capture properties of the farm organism that emerge from the integration of different components.

**Introduction:** With the image forming methods capillary dynamolysis (CapDyn), round filter chromatography (RFChrom), and copper chloride crystallization (CCCryst), additive-specific structures are evaluated that emerge from metal salts reacting with organic additives (Doesburg et al. 2015). Images are analysed computer-based (e.g. Kahl et al. 2015) or visually (e.g. Fritz et al. 2017). As all components 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).

However, image forming methods are still not used widely, partly due to a lack of standardized criteria in visual evaluation. The most recent catalogue of criteria includes both structural and Gestalt criteria relating to the image as a whole, which have been trained to a panel following ISO-norms used in sensory analyses (Doesburg et al. 2015).

In the present study, recent developments in visual image evaluation are described based on two evaluation approaches of the same set of rocket lettuce images from a field trial (Athmann 2011): In 2008/09, two individual evaluators based their analysis mainly on CapDyn, emphasizing analytical criteria such as colours or presence of certain image structures. In 2018, a panel of eight evaluators characterized the same samples exclusively based on CCCryst, focusing on Gestalt criteria such as image depth, notion of movement or centre coordination of the crystal.

**Material and methods:** 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 farm of the University of Bonn. The test factors considered in the current study were i) fertilizer type (mineral (min); organic manure compost (org); biodynamic manure compost (biodyn)), and ii) horn silica application (with (+501) or without (-501)). Encoded samples from the combinations i. biodyn+501, ii. biodyn-501, iii. org-501, iv. min+501, v. min-501 were analysed using CCCryst, CapDyn and RFChrom (methods see Fritz et al. 2017). In each year 2008 or 2009, the five treatments were analysed four times, each time with several series with varying amounts of rocket juice per image and various decomposition stages (after 1, 4, 6, and 10 days of aging at 8°C). In total, 60 CCCryst images, 60 RFChrom images and 80 CapDyn images per experiment were analysed, corresponding to 12 or 16 images per sample.

In visual evaluation 2008/09, the encoded images were characterized as 'strong – weak form expression' or 'fresh – aged' based on form erly produced reference images with i. varying amounts of rocket juice per image and ii. different deterioration stages. Because differences were more pronounced in the images of 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 experience from earlier investigations, the samples were then assigned to fertilizer types or horn silica application (classification).

In 2018, CCCryst images were analysed by eight evaluators, following ISO norms regulating sensory analyses (Doesburg et al. 2015). Accordingly, the panel evaluated only one image set at a time, with either fertilizer types (16 sets with 3 images per sample) or horn silica treatments (32 sets with 3 images per sample). These sets were generated from the image series from 2008/09. The panel was trained in recognizing the Gestalt of decomposition according to Doesburg et al. (2015), before all 48 encoded image sets were ranked in a panel test.

In 2008/09, the agreement between correct classification and the classification based on image forming methods was tested using the Kappa coefficient. In 2018, the Friedman test recommended for sensory analysis was applied for pairwise comparisons of adjacent ranks.

**Results:** In 2008/09, samples with biodynamic or organic fertilization were ranked higher than samples with mineral fertilization, while the two fertilizer types with manure could not be differentiated (Tab. 1). Samples with or without horn silica application could not be separated when image evaluation was based on CapDyn. Only in two out of four sets 2009, when the assessment was based also on CCCryst, prioritizing Gestalt over structure, samples +501 were ranked higher than samples -501.

In 2018, evaluators were more experienced and especially trained in recognizing Gestalt criteria. In their CCCryst evaluation, biodynamic fertilization was ranked higher than organic or mineral fertilization, while organic and mineral fertilization could not be differentiated. Samples +501 were ranked higher than samples -501 (Tab. 1).

*Table 1: Ranking of samples i. with different fertilizer types and ii. with or without horn silica application i. 2008/09 and ii. 2018.*

| Treatment factor | Year of analysis | Evaluator | Method | Ranking of encoded samples | Statistical test |
|---|---|---|---|---|---|
| Fertilizer type | 2008/09 | individual | CapDyn | biodyn = org > min | Cohen's kappa, $p < 0.05$[1] |
| | 2018 | panel | CCCryst | biodyn > org = min | Friedman test, $p < 0.05$[2] |
| Horn silica application | 2008/09 | individual | CapDyn | with = without | Cohen's kappa, $p < 0.05$ |
| | 2008/09 | individual | CCCryst | with = without; with > without | Cohen's kappa, $p < 0.05$[3] |
| | 2018 | panel | CCCryst | with > without | Friedman test, $p < 0.05$[4] |

[1]: successful discrimination and significant identical ranking of biodyn = org > min for all eight analysed experiments, each experiment with 16 images per sample.

[2]: mean ranks of 8 panel members evaluating 16 image sets: biodyn – org – min 1.59, 2.14, 2.29, pairwise comparison biodyn – org significant

[3]: successful discrimination and significant identical ranking of with > without for two out of eight analysed experiments, each experiment with 16 images per sample.

[4]: mean ranks of 8 panel members evaluating 32 images sets: with – without 1.30, 1.70, pairwise comparison significant

**Discussion:** The successful differentiation of samples with organic or mineral fertilization is in line with studies using computer based or visual evaluation (Fritz et al. 2017, Kahl et al. 2015). To date, biodynamic and organic fertilization were differentiated only with visual evaluation (e.g. Fritz et al. 2017). Visual evaluation differs from computer based evaluation by including Gestalt aspects. In our study, Gestalt was best expressed in CCCryst, and biodynamic preparations affected Gestalt criteria more than structural aspects. Individual chemical compounds of samples under study, such as nitrate, sugars, ascorbic acid and glucosinolates, were affected by manure vs. mineral fertilization, but not by horn silica application and were thus in line with structural evaluation results in CapDyn, but not with Gestalt evaluation in CCCryst. Gestalt evaluation is unusual in agricultural research, but is common in other disciplines working with living organisms, e.g. clinical intuition, language and music processing (see Doesburg et al. 2015), where Gestalt recognition and application are used to evaluate emergent properties of the organism. Organic farming relies on intensification of synergies between different components of a well-balanced farm organism. Gestalt recognition may be a method to capture properties of the farm organism that emerge from the integration of different components. Interdisciplinary research will help to adapt and further develop this method for agriculture.

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**References**

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Kahl J, Baars T, Bügel S, et al. (2012): Organic food quality: a framework for concept, definition and evaluation from the European perspective. J Sci Food Agric 92: 2760-2765
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Fig. 1 shows CapDyn image examples, representing manure and mineral fertilization, with the latter showing fewer structures.

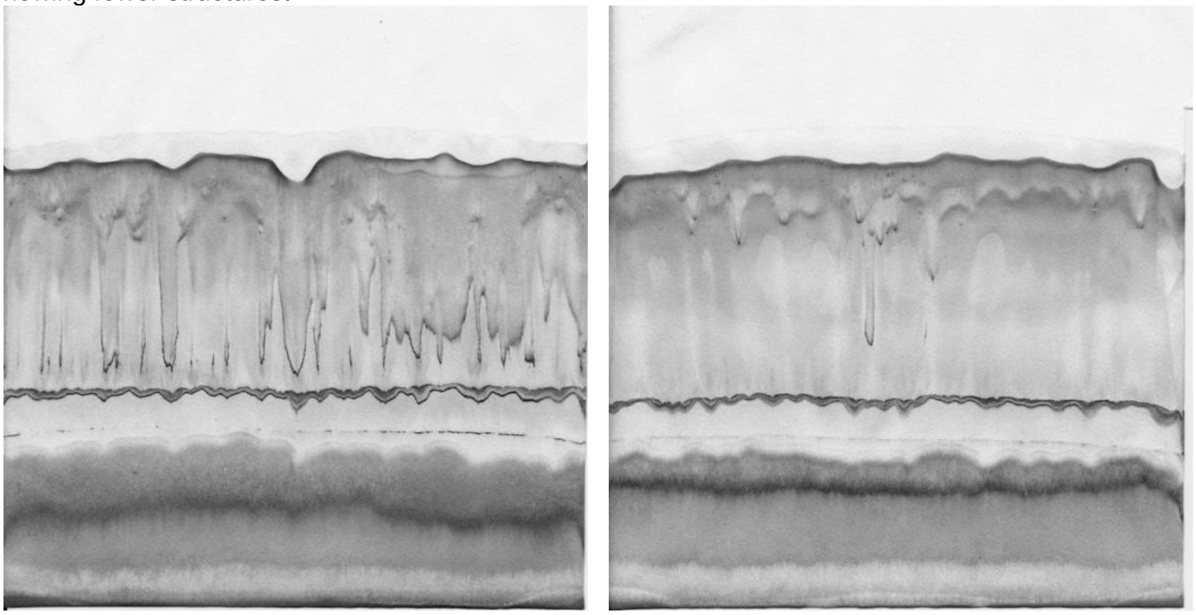

*Figure 1: Images from capillary dynamolysis, trial year 2009, left: biodynamic fertilization, right: mineral fertilization. Rocket juice aged for 1 day, 0.1 ml juice per image.*

Fig. 2 shows CCCryst image examples of biodyn+501 and org -501, with the former being characterized by more curved needle bundles suggesting movement, and a sensation of higher tension in the crystal.

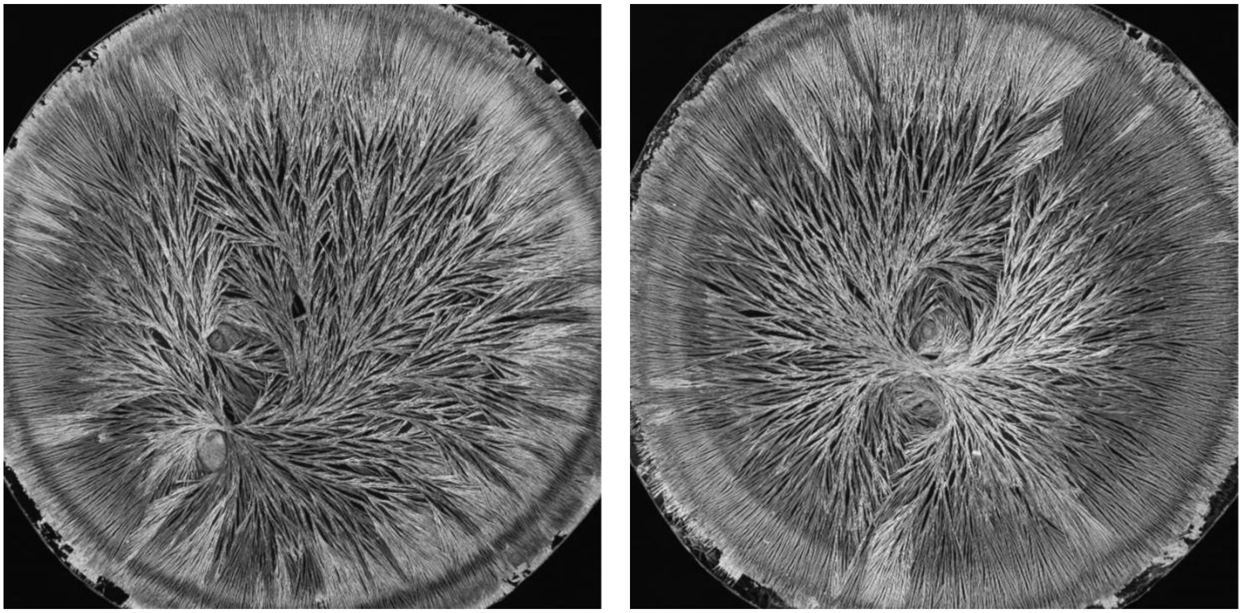

*Figure 2: Images from copper chloride crystallization, trial year 2009: left: biodynamic fertilization, right: organic fertilization. Rocket juice aged for 1 day, 0.2 ml juice per image.*