

## ‘Nature in the glass’: Principles and practices in low-intervention winemaking

Marc Daferner <sup>a,\*</sup> , Robert Pütz <sup>b</sup> , Christian Steiner <sup>a</sup> , Gerhard Rainer <sup>c</sup> 

<sup>a</sup> Department of Geography, Catholic University of Eichstätt-Ingolstadt | 85072 Eichstätt, Germany

<sup>b</sup> Institute of Human Geography, Goethe University Frankfurt | 60629 Frankfurt am Main, Germany

<sup>c</sup> Department of Geography, University of Passau | 94032 Passau, Germany

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### ABSTRACT

Wine is often portrayed and perceived as a natural product; however, in fact, it's predominantly a highly industrialized, processed commodity. The vast majority of vine is cultivated in monocultural systems, requiring the intensive use of pesticides and agricultural machinery. Advanced cellar technologies and oenological practices standardize vinification, controlling and manipulating microbial and biochemical processes to ensure a uniform product. This approach has faced criticism, primarily due to its ecological implications. In response, a niche market has developed around so-called ‘natural’ or ‘low-intervention’ wines, emphasizing environmentally conscious production methods, resulting in a distinctive product. In a qualitative research approach, we explore the alternative practices which reflect the winemaker's care for soil and plant health, support microorganisms in the must, and preserve the wine's ingredients. Through practices like no-till, soil fertilization, and spontaneous fermentation, low-intervention winemakers aspire to stop soil degradation, regenerate their plants' microbiome and respect the grape's indigenous fermentation capacity, allowing in-situ yeasts to do their job and craft an individual wine flavour. Our article proposes a framework to explore these practices and the underlying philosophy, where the observed processes and winemaker's attitudes reflect an approach of ‘co-producing with nature’, which we explore by adopting conceptual ideas from more-than-human geographies.

### 1. Introduction

In our contribution we explore, analyse, and discuss winemaking practices, often labelled as low-interventional,<sup>1</sup> which seek to establish a more respectful relationship with the natural environment, where elements are seen as co-producers with their own agency, to be supported and cared for rather than controlled and manipulated. This co-producing approach results in a very distinctive product. Within the wine industry, actors speak of the product as natural wine,<sup>2</sup> a “blurry concept”

(Sáenz-Navajas et al., 2024) that lacks a clear legal definition. Unlike in organic or biodynamic winemaking, certification is still in its infancy and contested (Parga-Dans et al., 2023). Moreover, natural winemakers are not unified by a clearly delineated perspective on how to produce wine. Rather, they appear to be engaging in an exploratory process, experimentally testing various approaches to both grape cultivation and vinification. They agree on and adhere to organic, biodynamic, or regenerative farming principles although not all of them are certified. They are united in distinguishing themselves from producers whom they

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\* Corresponding author.

E-mail address: [marc.daferner@ku.de](mailto:marc.daferner@ku.de) (M. Daferner).

<sup>1</sup> We use the term low-intervention winemaking and designate the product as ‘natural wine’. The latter is widely used in the wine industry although contested by some of our research partners.

<sup>2</sup> Natural wine is still a niche market. For example, in Germany only 0.3 per cent of wine produced was labelled as ‘natural’ in 2021 (Szolnoki & Rosenbrock, 2022, p. 22). Even in France, the cradle of low-intervention winemaking, and the largest market worldwide its share is only around 1.5 per cent (Chartier, 2021, p. 49).

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consider to be ‘conventional’,<sup>3</sup> i.e., who rely on industrialized, mechanised and technology-driven processes and significantly apply (agro-)chemical inputs. In developing their own approach, low-intervention winemakers often refer to a well-documented critique of conventional winemaking practices, blaming them for negative environmental impacts in three interrelated dimensions: the soil compaction and degradation caused by frequent drive-overs with heavy machinery (Commission et al., 2020), the loss of biodiversity (Döring et al., 2019) and susceptibility to diseases caused by monocultural cultivation and the destruction of microbial life both in the ground and on the plant caused by fertilisers, herbicides, pesticides and fungicides (Alonso González et al., 2021; Bokulich et al., 2014).

In contrast, low-intervention winemakers aspire to minimize human influence in viticulture and vinification and to co-produce wine with the microbiological life of their vineyard and wine cellar. Concurrently, low-intervention winegrowers often perceive organic and biodynamic farming standards as not strict enough or contradictory, e.g., applying limited quantities of “copper sulphate and elemental sulfur [as an antimycotic], a move that is justified on the grounds that these are natural chemicals” (Goode & Harrop, 2011, p. 84). They strive to minimize its application to avoid influencing the vulnerable microbiome and compacting the soil by frequent drive-overs. In the cellar, the use of additives to filter and clarify the wine is overwhelmingly rejected, as is the use of industrial yeasts to control the fermentation process, and, although a contested issue, natural winemakers try to reduce the application of sulphating compounds used against oxidation and to prevent wine spoilage (Alonso González, Parga Dans, Acosta Dacal, et al., 2022). In sum, low-intervention winegrowers’ philosophy of co-producing wine with nature is based on the ideal of winemaking as a practice, where as little as possible is added and removed, and where the potential and capacities of more-than-human co-producers are valued and enabled. The deviation from conventional cultivation and vinification practices influences the flavour and taste of low-intervention wine (Sáenz-Navajas et al., 2023). It challenges conventional norms of degustation, assessment and description, promoting the idea of a different consumption experience, an experience that shifts the perspective from wine as an intoxicating beverage to an experience of wine as an individual, naturecultural product that encourages consumers to acknowledge and respect the presence and contribution of more-than-human co-producers. Our article adopts an exploratory approach, aiming to provide a comprehensive overview, systematically understand and categorize emerging viticultural co-production practices.

## 2. Material and methods

Our arguments are developed by building on qualitative research into practices of low-intervention winemaking. The data informing this article is derived from diverse, intensive fieldwork, mostly conducted in Germany. We use secondary sources, including texts, images, videos, newspaper articles, publications from companies and events, business websites, and content from social media platforms. These sources encompass the (self-)presentations of low-intervention winegrowers, wine merchants, and manufacturers of cultivated yeast and oenological products.

We employed an integrated research approach and proceeded as follows: First, we conducted qualitative, unstructured interviews with eight German winemakers and six wine merchants. The interviews were held at the interviewee’s workplaces between February 2024 and February 2025 and included visits to their respective facilities. Second, we visited three natural wine fairs, inter alia, the Berlin RAW wine exhibition hosting more than 100 winemakers from around the world,

where we spoke to winemakers and visitors. Third, we attended seven professional conferences and seminars,<sup>4</sup> to develop a nuanced understanding of low-intervention winemaking and its practices. Forth, to gain an insight into the life-world of winemakers, the first author has volunteered in wine production practices by working in the vineyard and the wine cellar with an organic, artisan winegrower since December 2023.<sup>5</sup> Additionally, to better understand the often-contested flavour and sensory characteristics of natural wine (Sáenz-Navajas et al., 2023), one co-author qualified<sup>6</sup> as a wine jury member to partake in sensory examinations of German agricultural authorities. And, finally, to expand theoretical knowledge and its practical application on alcoholic and malolactic fermentation the first author attended a university module in microbiology.<sup>7</sup> The empirical material, i.e., recorded interviews and comprehensive fieldnotes on participatory observations, was transcribed and underwent – along with secondary sources – a qualitative content analysis.

## 3. Theory

### 3.1. Researching low-intervention wine

Scholarly contributions addressing natural wine are somewhat fragmented, with Wei et al. (2022) providing an overview from a natural science, oenological perspective. Challenges of definitions and differentiation are addressed from a sociological (e.g., Alonso González & Parga-Dans, 2020), food sciences (e.g., Maykish et al., 2021) and a practitioner’s perspective (e.g., Goode & Harrop, 2011). In an economic context, researchers have investigated consumer perceptions (e.g., Palmieri et al., 2023), product distribution (e.g., Szolnoki & Lühring, 2018), and the influence of labelling and certifications (e.g., Alonso González, Parga Dans, & Fuentes Fernández, 2022). Psychologists have investigated consumer involvement with natural wine (Urdapilleta et al., 2021), while historians explored the use of “past ideas and methods as inspiration” (Dolan, 2019, p. 123) in natural winemaking. The growth in “non-conventional wines” is also documented in countries of the Global South such as Argentina (Rojas et al., 2024). Natural wine’s taste is a recurring topic in oenological (e.g., Gerard et al., 2023), sociological research (e.g., Smith Maguire, 2018), and sensory analysis by food scientists (e.g., Sáenz-Navajas et al., 2023, 2024). ‘Terroir’ with a particular focus on biodynamic and natural wine is explored from an anthropological (e.g., Hill, 2022) as well as an STS perspective (e.g., Szymanski, 2018). Finally, and underpinning its relevance in a broader societal context, Alonso González and Parga-Dans (2023) argue that natural wine is a ‘food phenomenon’ that Sage et al., 2021 refer to as ‘Great Transformation’ “that is beginning to offer a new vision for food production, supply and consumption” (ibid, p. 2).

### 3.2. Co-producing

During our research, the concept of co-producing has emerged as a central analytical framework. Both in a broad sense, as ‘co-producing the world’, and in a more applied context as co-producing an agricultural

<sup>4</sup> Cellar management seminar, Federal Viticulture Institute, Freiburg, 2024; Yeast Conference, Federal College for Viticulture, Klosterneuburg, Austria, 2024; Microbiome-Symposium, Association for Regenerative Agriculture, Kressberg, 2024; seminar on regenerative viticulture, Spiesheim, 2024; two workshops on the work of sheep in the vineyard, in Sinzheim and Bad Kreuznach, 2024; Witzenhausen Conference on microbial communities in agricultural processes, University of Kassel, 2024.

<sup>5</sup> The collaboration is ongoing until at least the 2025 harvest period.

<sup>6</sup> Three-day training at the Chamber of Agriculture, Bekond, Germany, 2024.

<sup>7</sup> Microbiology module, bachelor’s degree programme ‘viticulture & oenology’ at Wine Campus, University of Applied Sciences, Neustadt, Germany, winter semester 2024/2025.

<sup>3</sup> On the globalization of the wine industry see in particular Sánchez-Hernández, 2010; Overton & Murray, 2013; Rainer et al., 2021, 2023.

product – natural wine. Within the research field of more-than-human geographies, first conceptually introduced by Whatmore (2002), co-producing the world is seen as an outcome of a collective being in the world with respect to the entangled relationships between humans and other (living) entities, such as animals (Urbanik, 2012), microorganisms (Lorimer, 2020), plants (Head & Atchison, 2009), machines and technical devices (Whatmore, 2002, 2006).

In an agricultural context, especially in winemaking, some authors employ the concept of co-producing with a stronger emphasis on its practical application. Krzywoszynska (2012) notes the wilfulness and creativity of more-than-humans in agricultural production, such as plants, yeasts, and chemicals that cannot be fully controlled or predicted. Control and the absence thereof also concerns Brice (2014a, 2014b) in his ethnographic account on the pasteurisation of wine-in-the-making where processes of co-producing are suppressed and rejected while he delves into seasonal labour patterns in Australian winemaking through practices and temporal rhythms of more-than-human participants. Likewise, Chartier (2021), who interprets the production of natural wine as a countermovement resisting the standardisation prevalent in industrial winemaking, and Siimes (2023) bring yeast in natural winemaking centre stage, highlighting the receptivity required when encountering the co-created product of natural wine.

Inspired by these accounts and synthesising from our fieldwork, we propose an understanding of co-production as a farmer-driven process, consisting of four interrelated elements.

- [1] Taking co-producing seriously: Acceptance of (agricultural) products as co-produced, and definition of acceptable co-producers within an overarching production philosophy, e.g., biodynamic production, natural wine.
- [2] Taking co-producers seriously: Enabling co-producers to influence both the production processes, e.g., by relinquishing human control, and the qualities of the product in the glass, e.g., by accepting distinct flavours as a sign of authenticity and liveliness.
- [3] Caring for co-producers: Promoting the welfare and well-being of non-human co-producers, strengthening them ‘to do their job’.
- [4] Learning to be affected by co-producers: Developing multispecies empathy and sensitivity for co-producers’ being-in-the-world.

Taken together, the practices of co-production foster new ways of knowing and engaging with the world. In this article, we endeavour to contextualise these four elements of co-producing within the practices elucidated by our respondents and observed during our fieldwork.

## 4. Results and discussion

Low-intervention wine defines itself in contrast to conventional wine: instead of ‘making’ wine using modern cellar and vineyard technology and designing it by applying mineral, agrochemical and biological substances, low-intervention winegrowers rely on, and consciously foster, co-producing wine with the soil of their vineyards, its vine plants and indigenous microorganisms that ferment grape must into wine. We begin our journey with a focus on the ‘care-full’ (Greenough, 2014) treatment of soil, plants, and microorganisms in the cellar.

### 4.1. Caring for soil

Soil is considered the most important co-producer in winemaking. Low-intervention winemakers, we spoke to, adopt the scientifically supported view that soil is not merely a substrate but a heterogeneous assemblage of living and non-living components, e.g., materials, plants, animals, bacteria, viruses, fungi, that form a complex microbiome, i.e., an entirety of all microorganisms within its specific environment (Leibniz Research Network Biodiversity, 2024, p. 58; Krzywoszynska, 2023). In vineyards, maintaining healthy soils is challenging as they are

perennial monocultures remaining on the same plot for decades or even centuries, which makes them susceptible to “humus depletion, decline in biological activity, soil compaction, reduced water infiltration and retention, and increased susceptibility to erosion” as Buchmann (1979, p. 63) pointed out 45 years ago.

Although recent scientific research underscores the crucial role of soil in viticulture and its influence on wine characteristics (e.g., Belda et al., 2017), Marcus, a German wine merchant with over forty years of experience who promotes his product range as ‘radically different’, believes that conventional production methods often neglect this aspect:

*„People spray something in the vineyard that is meant to help their plants, kills the weeds or any ‘pest’ but destroys their soil, ruins their land, and causes their grapes to rot and destroys the biological structure of the roots and when the root system dies, the nutrient transfer begins to break down. Then the physical destruction of the soil occurs, namely soil compaction. The soil makes the grapes ripe – sugary and ripe – but they don’t contain any nutrients that are essential for natural fermentation.” (Marcus, wine merchant, 2024)<sup>8</sup>*

Based on empirical findings, the following practices to regenerate soil were most important: (a) avoiding soil compaction, (b) stipulating self-regeneration and (c) no-till viticulture.

#### (a) Avoid soil compaction

In 2016, a year with heavy rainfall, conventional cultivation practices became unacceptable and unsustainable for 35-year-old David, professionally trained winegrower, working on his family’s estate in Württemberg, southwest Germany:

*“My father and I had all the machinery we needed for mechanised viticulture. And it was just soaking wet in 2016, so we had to do a lot of driving in the rows in terms of plant protection. We had deep furrows in the ground. And I said, that’s not possible. A soil dies if you drive over it all the time.” (David, winemaker, 2024)*

The sight of his battered soil affects David noticeably and triggers his concern. In pursuit of alternative techniques that meet his criteria for gentle and regenerative soil cultivation, David discovered horses as co-workers in vineyard management. Today, he works his vineyards exclusively with horses and praises the positive effects. However, he admits that this form of agriculture is not applicable on a broad scale, pointing to the steeper parts of his 3.5 ha terrain where he intends to create terraces with isohypsis parallel rows.

Hence, generally winemakers resort to other methods and practices: Susan, graduated with a PhD in oenology, who has taken over her parents’ conventional 10 ha winery in Rhine Hesse, Germany, in 2020, certified organic, following partly biodynamic farming standards, is aware of the damage done by frequent tractor driver-overs but arrives at a different solution: avoiding what she calls ‘bare soil’ she only flattens the vegetation and sometimes, if circumstances require, mulches it, resulting in, as she explains enthusiastically, “such a nice, loose topsoil. Despite being driven over with the tractor, it can take more if you treat it well” (Susan, winemaker, 2024). And as Susan further elaborates cover cropping not only improves humus formation but also reduces heat as “bare soil heats up to over 60 °C and then here is no more microbiology – everything is dead” (ibid.).

With Susan and David, we witness an openness to apply practices uncommon in industrial winemaking. Soil is taken seriously and enabled as a partner whose well-being requires active stewardship. In turn, its tangible, perceptible transformation affects human winemakers.

#### (b) Stipulate self-regeneration

<sup>8</sup> All quotations were translated by the authors.

Conventional viticulture treats the vineyard's soil with industrially manufactured synthetic fertiliser, i.e., a mixture of nitrogen, phosphorus, and potassium, which are meant to stimulate plant growth and root development. In contrast, natural winegrowers endeavour to nourish the complex 'plant-soil-microbe-holobiont' by invigorating the mycorrhiza, a symbiotic association, a co-operation between fungi and plant roots, where the fungi enhance nutrient and water absorption for the plant while receiving carbohydrates in return (Ingham, 2005). Low-intervention winemakers strengthen the mycorrhiza by inoculating the vineyard's soil with compost teas and ferments. David, referring to Ingham, the "The Queen of Compost" (Puig de la Bellacasa, 2017, p. 196) is trying to re-establish a sylvan, fungal environment by treating his compost in a distinct way:

*"We use bark chips. They originate from a very fungal environment. Look at our compost heap: it's always full of fungal growth. We hope that we can re-generate it [the soil] more quickly by incorporating this material. Moreover, I find the smell [takes a deep breath] so pleasant. I find it so pleasant in terms of the climate, the smell and everything. Because it's always metabolised in the soil. There's always energy in the soil and we add that energy to our compost teas." (David, winemaker, 2024)*

Co-producing with nature depends on 'learning to be affected' (Latour, 2004) by (natural) co-producers. Touching the crumbly, warm soil and inhaling the earthy, fresh, and slightly sweet smell, David points to the compost heap admiring that "it's always growing, it's all full of growth with fungus" (David, winemaker, 2024). As we learn, the compost is essential to stipulate life in the vineyard:

*"I make my own compost tea. I favour my own compost, because it's the richest compost you can find – mixed with forest soil and bark chips – a teaspoon of forest soil has 4 million microorganisms. I add some sugary juice, that kicks-off fermentation. Then you leave it for 2–3 days – depends, you stir regularly to add oxygen, helps microbes to multiply. It also foams. I check the smell and know it's right [she smiles]. It smells of fresh earth, it's wonderful. It's sprayed on the ground, on the canopy, everywhere, so there is no room for others [other, unwanted microorganisms] to colonise and cause damage. In a moderate year, you can replace the normal sprays available to us – sulphur and copper – with compost tea." (Susan, winemaker, 2024)*

Knowing about the significance of living soil, the scent of compost and the fermented tea, stimulating her senses, put her into motion to actively tend to her soil and nurture its well-being. Hence, care becomes an "ethico-political commitment to neglected things, and the affective remaking of relationships with our objects" (Puig de la Bellacasa, 2011, p. 100).

#### (c) No-till viticulture

Direct seeding, no-till sowing or simply 'no-till' is defined as farming without a plough or minimum tillage. While some low-intervention winemakers see ploughing as a central task in the vineyard but avoid the use of heavy machinery, others refrain from ploughing altogether. Susan provides her own nuanced impressions of no-till from her experience in her vineyards:

*"Don't mess up the nutrient cycles, otherwise suddenly the anaerobic bacteria are in oxygen and vice versa. But if you no longer plough, you leave the nutrient cycles intact. This creates an intact microbiome in the soil, which has a positive effect on everything: better permanent humus build-up, water storage capacity, that's our big issue because it's always dry here." (Susan, winemaker, 2024)*

Due to climate change, the soil's capacity to become more absorbent and permeable, and to retain water, is becoming increasingly critical for successful viticulture:

*"Then came 45 litres of rain in one heavy rainfall event. But in the vineyard, [she looks at the ground] you would think nothing had happened. I was really impressed. The soil soaked it up like a sponge. There wasn't even the slightest hint of spoilage. And then you see neighbouring plots from winegrowers working classical style – they till, they drive over the open row with the tractor – there, everything was a mud bath. It's really striking to observe this difference." (Susan, winemaker, 2024)*

Susan's statements take us on her own journey through the vineyard, highlighting the entanglements of non-human co-producers, such as soil, water, and plants. She compares her own land with her neighbour's, a conventional winemaker, and recognizes differences, which expand her knowledge:

*"As a result [of healthy soil], I have much more vitality, and much more diversity in the vineyard, an intact microbiology, which is naturally reflected in the balance of flavours of our grapes, in the nutrient composition of their ingredients, and eventually in our wine." (Susan, winemaker, 2024)*

Susan perceives that the careful treatment of her soil enables co-producers, such as the microbiome, the grape vine plants, the nutrient composition in the grapes, 'to do their job' – ultimately influencing her wine. Taking co-producers seriously, strengthens their "vitality and diversity in the vineyard" (ibid.) and creates a more lively and more genuine product. To further explore this claim, we follow the winemakers and learn practices of care for the plants and in the cellar.

## 4.2. Caring for grapevine plants

Low-intervention winegrowers understand soil as a living organism and the basis of healthy plant growth. In their eyes, biodiversity is a key element to ensure that the vine plants receive an adequate supply of nutrients, and in turn, stabilize soil life. After all, it takes a species-rich soil ecosystem, including bacteria as well as beneficial fungal mycelia, earthworms, and a variety of insects, to ensure that plants can nourish and that wine can develop its unique, and sometimes unexpected, aroma characteristics (e.g., Siimes, 2023). Rebuilding the plant's habitat and reducing plant protection are key practices that Susan and David experimentally engage in to overcome the disadvantages of conventional viti-cultivation.

### (a) Rebuilding habitat

Grapevine plants are profoundly detached from their natural sylvan habitat. Returning the grapevine back into its natural habitat is therefore another strategy in co-producing with nature. Over centuries, people have become accustomed to landscapes of monocultural vineyards and wine fields, and even winemakers seem to have forgotten what David vividly expresses:

*"The vine is a forest-edge dweller. And what have we done? We've pulled it out of its sylvan, fungal environment, onto an area where a bacterial environment prevails, and have essentially removed its entire habitat. And now, we're saying: 'Be stable!' It can't work. If I drag you out of your home, you probably won't have the most stable and content life." (David, winemaker, 2024)*

Alongside the re-establishment of a fungal mycorrhiza (see above), planting trees among vines, a concept known as 'vitiforestry', is a practice of re-building a more natural habitat and simultaneously providing them with groundwater:

*"A tree has relatively deep and wide roots, and [their] abundant greenery creates a pumping effect that pumps the water upwards. So, the tree brings water, it doesn't take it away. Same goes for grass – some colleagues claim that the grass 'competes' with my vine. What?! If that were true, then*

something is wrong with the vine, not with the grass.” (David, winemaker, 2024)

David’s idea is to create more diverse vegetation communities with symbiotic assemblages of plants, animals, and fungi to help overcome the drawbacks commonly associated with monocultivation. Moreover, trees also provide shade, which is why David envisions a positive cooling effect for his vines in the face of the climate crisis.

(b) Improve resilience – reduce plant protection

“To keep a row naked and open” (Susan, winemaker, 2024) is common practice in conventional viticulture, and there is a twofold rationale behind this: fungal infections such as downy mildew are thought to be less likely to spread upwards, i.e., from the ground cover to the rootstock, and open rows facilitate tractor access for fungicide application. Susan’s urge to learn and care motivated her to explore other, more innovative forms of human-plant companionship experimenting in one plot of her land:

“The idea is to trap the fungal spores in the greenery, so we didn’t mow or mulch at all – in one plot. At first, it looked so wild. I thought, oh my God! That year, we were in transition to organic agriculture – and we had an onsite inspection. And the inspector went to see that plot – I was so nervous! But the inspector said, our vineyard was the healthiest he had seen that season.” (Susan, winemaker, 2024).

Susan’s notion – to trap downy mildew spores in the greenery – contrasts with established oenological interventions, where mildew management follows strict plant protection protocols in both conventional and organic farming. The example underlines that “[a]dequate care requires knowledge and curiosity regarding the needs of an ‘other’ – human or not” (Puig de la Bellacasa, 2011, p. 98). She engages in experimental practices, which one could conceptualize with Lorimer and Driessen (2014) as ‘wild experiments’, attempts to explore the unknown which is “designed to generate surprises [and] to nurture and learn from emergent events” (ibid. p. 171) and the “messy heterogeneity of being-in-the-world” (Whatmore, 2002, p. 147). Susan anxiously, tentatively experiments with a practice she deems suitable for her vineyard, despite contradicting viticultural norms and practices. Yet, by

### 1. GRAPES

**Pyrosulfit de K (KPS)**

(5–10 g/100 kg)  
 Recommendation:  
 5–10 g/100 kg  
 Sulfur for protection against oxidation

### 2. MASH

**ZymTec® Power L**

(2–4 ml/100 kg)  
 Recommendation:  
 4 ml/100 kg  
 Enzym for maceration and sedimentation

### 3. MUST BEFORE SEDIMENTATION

<p><b>ZymTec® Power L</b></p> <p>(2–4 ml/hl)                  Recommendation:                  2 ml/hl                  Enzyme for maceration and sedimentation</p>	<p><b>FineOrigin® Activ</b></p> <p>(10–80 g/hl)                  Recommendation:                  60 g/hl                  Fining against phenols</p>	<p><b>StaboProtect® BentoOrigin</b></p> <p>(80–200 g/hl)                  Recommendation:                  100 g/hl                  Ca-bentonite for sedimentation</p>
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### 4. FERMENTATION

<p><b>FermActiv® First</b></p> <p>(30 g/hl)                  Recommendation:                  30 g/hl                  Yeast activation in the yeast starter</p>	<p><b>FermCraft® Yeast</b></p> <p>(20 g/hl)                  Recommendation:                  20 g/hl                  Yeast strain selection – see SKOFF oenotec’s Choice yeast recommendation</p>	<p><b>FermActiv® Complex</b></p> <p>(20–60 g/hl)                  Recommendation:                  40 g/hl                  Yeast nutrition</p>	<p><b>FermActiv® Power</b></p> <p>(10–50 g/hl)                  Recommendation:                  25 g/hl                  Yeast nutrition</p>
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yeast starter

start of fermentation/  
 yeast addition

3rd day of fermentation  
 (density reduction of 30 °Oe)

<p><b>FermActiv® Power</b></p> <p>(10–50 g/hl)                  Recommendation:                  25 g/hl                  Yeast nutrition</p>	<p><b>FermActiv® DAP</b></p> <p>(10–100 g/hl)                  Recommendation:                  as needed                  Yeast nutrition as needed</p>
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5th day of fermentation  
 (density reduction of 45 °Oe)

last half of fermentation

Fig. 1. Recommendations to make a basic white or rosé win  
 Source: SKOFFoenotec GmbH, 2024, p. 44.

relinquishing control, she creates space for new more-than-human collaborations, taking co-producing seriously. As she reflects, “what seemed wrong to the eye at first was totally great for the plant’s system” (Susan, winemaker, 2024). In the following, the controversial topic of (loss of) control remains central to our exploration.

#### 4.3. Caring for microorganisms

Low-intervention production philosophy does not end in the vineyard but extends to the cellar: cellar masters intervene situationally, as little as possible, and engage in experimental practices. Again, low-interventionists reject the path taken by conventional winegrowers, a ‘downward spiral’ as Marcus explains:

*“After World War II, synthetic fertilizers were applied extensively. Leading to larger grapes that eventually burst and attracted more fungal infections, so winegrowers intensified their use of fungicides. While one problem was solved, another popped up in the cellar: the must no longer fermented because the ‘helpful’ fungicides inhibited yeasts and destroyed their habitat. Subsequently, in the 1960s and 1970s, the yeast industry started to develop solutions and [nowadays] winemakers can buy the full treatment package to repair their destroyed soil and ruined grapes in the cellar.” (Marcus, wine merchant, 2024)*

Consequently, industrially produced and laboratory-grown dried yeasts began their advance in the cellar. Nowadays, the ‘full treatment package’ is a combination of mineral, chemical and biological substances, invented to help winemakers to engineer their wine.

Applying oenological substances in the correct dosage and sequence (see Fig. 1) not only streamlines the winemaking process but allows winemakers to tailor specific flavour profiles to meet market demands in a controlled manner. By using industrially designed yeast cultures, bacteria, wood chips, and other additives according to grape variety and desired wine style, winemakers can assemble a marketable wine with a uniform taste experience year after year. In contrast, low-intervention viticultural principles extend to the work in the cellar, relying on (a) spontaneous fermentation and (b) sensory judgment to co-produce with nature.

##### (a) Spontaneous fermentation

Spontaneous fermentation is a defining principle of low-intervention vinification, reflecting a deep commitment to the careful treatment of soil, plant health, and the vineyard’s microbiome. This gentle treatment is important to low-intervention winemaking because the yeast travels with the grapes from the vineyard, where it grows wild, to the cellar. These wild yeasts allow the wine to ferment spontaneously in the cellar. In this way, winemakers and yeasts co-produce trans-local microbiological ecosystems: After fermentation, lees are often added to compost and return as fertilizer to the vineyard, enhancing soil fungal diversity and community composition, i.e., linking the cellar to the vineyard and contributing to forming the specific wine style of a winery (see Di et al., 2019).

However, spontaneous fermentation does not occur instantaneously; the process involves significant uncertainty and requires patience, as yeast behaviour can exhibit considerable variability from year to year. The ever-changing diversity, abundance, and composition of yeast strains that co-produce wine have a considerable influence on vintage specific wine aromas, which David alludes to:

*“It’s perfectly logical: in 2018, when it was extremely warm, yeasts were abundant – in 2021, when it was extremely cool, it took the must a while to ferment. If the wines from the two years taste the same, then I must question the winemaker and ask him what else he’s doing in his cellar. Yes, they’re all from the same vineyard, but they all taste completely different. That’s vintage!” (David, winemaker, 2024)*

Vintage differences reflect the complex and heterogeneous

assemblage of the “living and lively ecosystems [...] inhabited and formed by a variety of still largely unknown biota, including bacteria, archaea, and fungi as well as the meso- and macroorganisms such as soil animals, and the plant and animal life with whom they form complex relations” (Krzywoszynska, 2020, p. 229). Together with David’s minimal interventions, this multidimensional assemblage makes his product appear different every year – which he sees as a clear competitive advantage:

*“The consumer has been educated to expect a repeatable quality with a uniform taste. With industrial, cultured yeast you can ensure that you always make very similar wines – always very close to each other. But increasingly the demand is to remain exciting for the market. I don’t have to worry about launching a product to remain exciting for the market. I have new wines every year.” (David, winemaker, 2024)*

For David, his work in the vineyard, the care for soil, plants, and the microbiome is inseparably interwoven with more-than-human processes in the cellar: he enables his yeast to ferment must spontaneously – co-creating a genuine, unique product that reflects its socio-spatio-temporal provenience. In our final empirical section, we examine how winegrowers negotiate their role in winemaking where managing uncertainty is a crucial factor.

##### (b) Sensory judgement

In conventional winemaking, the testing of wine for quality, off-flavours, and disease contamination is common, and winemakers send samples of their wines to specialist laboratories for analysis. David has stopped following this conventional practice:

*“I smell the wine, and I drink. Then I decide after that. And I’m relatively calm now. The wines go their own way a bit. And they sometimes stink during fermentation. Sometimes you also get vinegar forming – but usually that disappears. And that’s why I try not to let myself be carried away by fear. Fear is not a good counsellor.” (David, winemaker, 2024)*

While David relies on his nose and taste buds, others listen to the sound of their yeasts. David’s testimony not only underlines the significance of sensory judgement in the production of low-intervention wine but goes far beyond that: practices and attitudes of low-intervention wine production become evident, highlighting the philosophy behind the production process. David demonstrates a receptive openness, an attunement to his wine’s ‘own way’, an attentiveness that David retains even if ‘off-tones’, such as the smell of vinegar, temporarily accompany his fermentation. David’s response to his sensory judgement is no run-of-the-mill approach:

*“The wines must be developed differently. I believe there is always room for improvement, and the wines can continuously become cleaner, more precise, and better. Mistakes are normal, and it is also normal for my system to have some flaws.” (David, winemaker, 2024)*

David’s sensory judgements are dynamic trajectories, tentative, experimental explorations that require constant learning and situational awareness – ‘flaws’, e.g., alleged off-tones, are normal in a system whose complexity challenges human comprehension, as low-intervention wine co-production is “an attempt at cohabitation, collaboration between humans and nonhumans, rather than an attempt to coerce the living world or a relationship of domination” (Chartier, 2021, p. 46). The relationship between winemakers and their living co-producers can be conceptualized through the lens of embodied communication, a framework applied to describe human-animal interactions (see Pütz, 2024). Low-intervention winemaking requires experimental experience – fermentation occurs only once annually – and its outcome, an interplay of human and non-human factors, remains unpredictable to a certain extent. Staying calm and accepting uncertain outcomes is not part of conventional winemakers’ DNA (anymore), as “[r]emoving the verb ‘to control’ from a winemaker’s vocabulary goes against the conventional

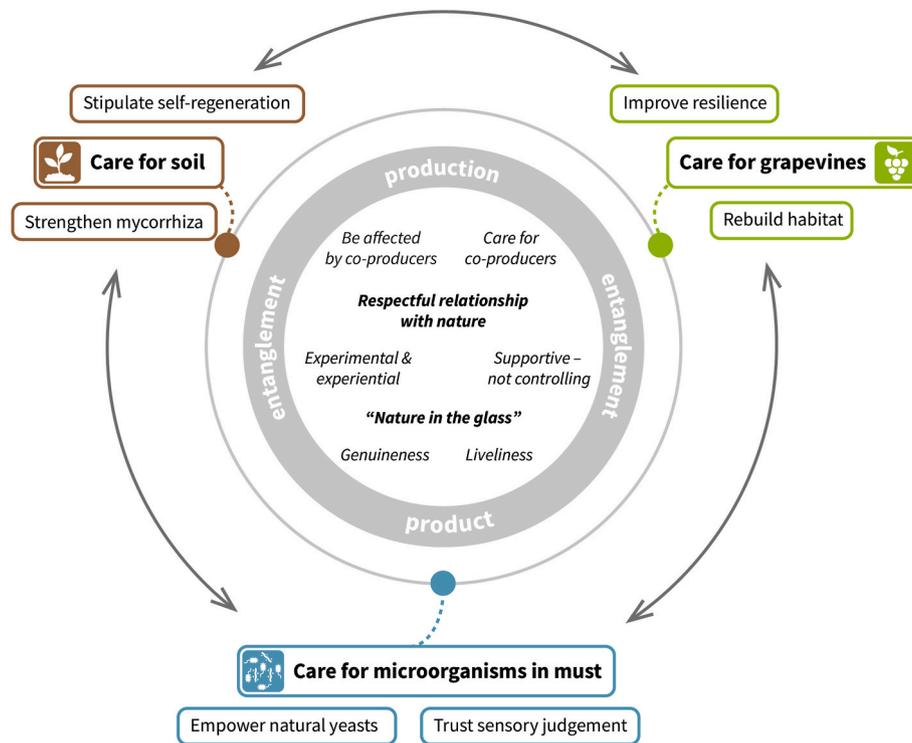


Fig. 2. Principles and practices in low-intervention winemaking  
Source: Own empirical research.

concept of wine-making” (Chartier, 2021, p. 53). The absence of fear allows David not only to care for soil, the plants, microorganisms, fauna, and flora present in the vineyard but also to co-produce wines with “a taste for uncertainty [...] a roaming taste that thrives on diversity [...] changeable and surprising” (Krzywoszynska, 2015, p. 500).

Therefore, low-intervention winemakers reject a technology and measurement-oriented, materialistic, reductionist and mechanistic approach of winemaking, which strives for total control and domination of the vinification process. Their experimental openness to uncertainty and their willingness to embrace the ‘learning to be affected’ paves the way for co-producing wine with nature.

#### 4.4. Consolidated discussion

In the vineyard low-intervention winemakers aim to break the cycle of soil degradation, disrupted microbiological habitats, and an increased plant susceptibility to disease – issues that can only be concealed – but are further aggravated – by the excessive use of fertilizer and fungicides. In the cellar, true to their production principles of a respectful relationship with nature and an awareness of its more-than-human entanglements, they co-produce wine that – consequently – expresses the limitless multitude of possible combinations of socio-spatio-temporal conditions, of human and non-human, professional, family, environmental and economic parameters. To achieve this, our research partners adapt existing viticultural practices, apply out fashioned ones, or tentatively, open-mindedly, and attentively experiment with new practices to care for their soil, their grapevines, and to carefully treat must and wine in their cellar. Our exploration shows – and our research partners affirm – that there is no one-size-fits-all approach to low-intervention winemaking.

Fig. 2 illustrates the message in a bottle that natural winemakers aim to send: the first and foremost principle of low-intervention winemaking is not the care for soil, plants, fungi or any other co-producer but taking co-producing seriously, i.e., the respectful relationship with nature, and the strive to rebuild and re-experience our belonging to the community

of life. It illustrates the interdependency and connectedness of practices applied to overcome the ecological devastation caused by conventional, extractivist, industrial viticulture and agriculture, the disconnection and separation from the environment that leads to indifference for more-than-human entanglements. Yet, it remains to be examined whether the call for a more affective engagement with agricultural production and a more harmonious interaction with the environment is effectively communicated and understood: An investigation into “attitudes towards natural wines among Spanish winemakers” (Sáenz-Navajas et al., 2024) as well as anthropological and ethnographic studies (Alonso González & Parga-Dans, 2023; Alonso González & Parga-Dans, 2023; Dandrieux, 2020; Vicelli, 2021) of the natural wine movement support our assumption, as winemakers emphasise that “ethical, philosophical and lifestyle motivations underlie the adoption of natural winemaking practices” (Sáenz-Navajas et al., 2024). However, as a “major negative attitude towards the flavour of [natural wine]” (ibid.) amongst (Spanish) winemakers still prevails, we are curious to learn whether and how winemakers’ and consumers’ ideas are negotiated in the markets for natural wine – which nature gets into the glass?

#### 5. Conclusion

In our fieldwork the idea of ‘co-producing with nature’ has proved fruitful in understanding and conceptualizing the practices and principles in natural winemaking. [1] Taking co-producing seriously demands for the recognition of wine production as a shared process where legitimate co-producers must be defined, thereby sketching an epistemic and ontological framework of co-production that is constantly questioned and refined. In our fieldwork this finds its expression in the dedication, enthusiasm and affection with which the elements of co-producing are explored. [2] We observed practices which re-enable co-producers, taking them seriously acknowledging and respecting their essential needs and existence. This sometimes demands for a spirit of ‘wild experiments’, a swimming against the tide, an acceptance of complexity, partially surrendering control. This experimental ethos is evident in

practices and processes, such as planting trees, trapping downy mildew in greenery, or the revival of traditional wine cellar techniques. Consequently, in the wine cellar, our winemakers allow for a different product, a distinct taste, that some coin as off-tones, but that natural winemakers describe as livelier, better reflecting the wine's socio-spatio-temporal provenance. [3] Caring for the well-being of co-producers, e. g., microorganisms, fauna, plant and fungal flora in the soil, through practices such as the application of compost teas ensures that these organisms can fulfil their ecological functions effectively and co-create 'the nature in the glass'. [4] Learning to be affected by one's co-producers, the winemakers we spoke to, open-mindedly and sensitively familiarize themselves with their co-producers' being-in-the-world in their day-to-day winemaking practices. They train their senses to detect the subtle aromas and the tactile feeling of compost and its living and non-living components, in turn drawing insights and producing knowledge that guide their practices. In sum, our research partners perceive themselves as engaged in a continuous, reciprocal process of winemaking appreciating the role of non-humans in co-producing the world. In this respect, they aim to contribute to a change in human-environment relations – from domination and control of the non-human world towards a more collaborative, balanced, sometimes experimental but respectful relationship with other entities in a shared world – fostering a deeper sense of interconnectedness and mutual flourishing within shared ecosystems.

However, we realise that more research is required to get a deeper understanding of the four elements of co-production. [1] Taking co-producing seriously requires a bearing point to decide which materials, practices and processes in the vineyard and cellar qualify as low-interventional co-producers. E.g., we note, that while adding SO<sub>2</sub> – at all, in which quantity – sparks controversy amongst natural winemakers, so-called 'Bordeaux mixture',<sup>9</sup> is commonly applied even in a biodynamic cultivation system – with few natural winemakers raising an eyebrow – notwithstanding its negative impact on non-human co-producers. [2] Next, taking co-producers seriously challenges the balance between humans and non-humans – particularly when enabling non-humans jeopardises the economic viability. How do winegrowers deal with invasive species that threaten their harvest? [3] Care for non-human co-producers requires knowledge: initiatives, such as 'traction animal', an Alsatian platform on horsey co-producers, provide practical skills for implementing appropriate, more caring measures. [4] And, moreover, is learning to be affected employed differently for different co-producers? E.g., if emerging off-tones threaten the marketability of the co-produced wine, affection might be overturned by consumer preferences.

By addressing these issues, future research can refine our understanding of co-production in low-intervention winemaking, critically reflecting on its ethical, ecological, and practical implications in an ever-changing environment.

#### CRediT authorship contribution statement

**Marc Daferner:** Writing – review & editing, Writing – original draft, Visualization, Methodology, Investigation, Formal analysis, Conceptualization. **Robert Pütz:** Writing – review & editing, Writing – original draft, Visualization, Methodology, Investigation, Formal analysis, Conceptualization. **Christian Steiner:** Writing – review & editing, Writing – original draft, Visualization, Methodology, Investigation, Funding acquisition, Formal analysis, Conceptualization. **Gerhard Rainer:** Writing – review & editing, Writing – original draft, Visualization, Methodology, Investigation, Funding acquisition, Formal analysis, Conceptualization.

#### Declaration of competing interest

We have no conflicts of interest to disclose.

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<sup>9</sup> A suspension of copper sulfate (CuSO<sub>4</sub>) and slaked lime (Ca(OH)<sub>2</sub>).

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