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Viability of cork-enriched feed in trout farming

– An agri benchmark Fish study on innovative aquaculture techniques

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Abstract

Feed costs are a crucial factor in trout farms. For farmers endeavoring to maximize profitability, improving feed management is an essential consideration. The introduction of cork-enriched feed has been tested in the previous studies, which focused the technological and environmental performance of the new feed. Against that background our study analyses the potential economic benefits of a cork-enriched feed on farm level. Cork-enriched fish feed in a production systems could enable a twin-track approach, which enhances the quality of water and the profitability of a fish farm at the same time. Based on *agri benchmark* fish farm models our study projects the implementation of the innovative feed in selected German trout farms to test the economic viability and analyse the effects towards farms' profitability. Given that feed is the most important outlay in trout farming, the expense of the cork feed system initially leads to heavy losses or marginal returns and declining operational results in all modeled scenarios. Notwithstanding, the opportunity to reduce labor and oxygen demand or use the saved inputs to increase productivity indicate that cork feed has potential to increase overall profitability depending on the scale of farm. The results of the current study lead us to conclude that the use of cork-enriched feed, with feed costs of € 1.44 per kg trout, is not profitable for smaller operations. The picture for large farms, which are up to now untypical for Germany, using cost intensive filtration techniques is very different. Here, increased profits can be achieved relatively fast, even under current levels of production. If an increase in production is achieved, then the cork feed makes a highly economic alternative to conventional feed.

Keywords: Feed, cork-enriched feed, profitability, aquaculture, trout

Zusammenfassung

In der Forellenerzeugung spielt die Wasserqualität eine entscheidende Rolle für den Erfolg der Produktion. In den heute vorherrschenden (Teil-) Kreislaufsystemen der Forellenzucht fällt ein wichtiges ökonomisches wie ökologisches Augenmerk auf die Wasserreinigung und -aufbereitung. Dessen Aufgabe ist es u.a. Feststoffe wie Kot oder Futterreste aus dem Wasser zu filtrieren und für eine weitere Nutzung, z.B. zur Düngung landwirtschaftlicher Flächen, aufzubereiten. Das Absinken der Feststoffe macht diese Aufgabe sehr aufwändig. Die Fischereiforschungsstelle des Landes Baden-Württemberg untersuchte daher die Verwendung eines Futters mit dichtereduzierendem Füllstoff in der Forellenzucht, das ein Absinken des Kots verhindert. Kork erwies sich als geeignetes Material, das sowohl fischphysiologisch als auch technisch den Tauglichkeitstest bestand. Unser Artikel beschreibt die ökonomischen Auswirkungen für Betriebe und diskutiert etwaige Wettbewerbsvorteile in unterschiedlichen Szenarien, die durch eine Umstellung von konventionellem auf das innovative Korkfutter entstehen könnten. Dabei werden die Einführung des innovativen Kork-Fischfutters mit Hilfe von *agri benchmark* Modellbetrieben simuliert. Unsere Ergebnisse zeigen, dass das System Korkfutter zunächst aufgrund der erheblich höheren Futterkosten zu starken Einbußen führt. Sowohl die Deckungsbeiträge als auch die Betriebsergebnisse sinken in allen Szenarien. Erst die Möglichkeit mit dem Einsatz des Korkfutters Arbeit und Sauerstoff einzusparen oder die eingesparten Ressourcen in eine Produktionssteigerung um 10 bzw. 20 % zu investieren, zeigt das Potential des Korkfutters zur Verbesserung der Profitabilität deutlich. Die Verbesserung der Wirtschaftlichkeit ist dabei stark von der Größe der Aquakultur abhängig. Unsere Untersuchung lässt den Schluss zu, dass sich der Einsatz von Korkfutter bei Futterkosten von 1,44 EUR je kg erzeugten Fisch für kleinere Betriebe nicht rentieren würde. Zu niedrig sind die Einsparungen bei der Maschinenausstattung, der Maschinenwartung, dem Strom und den Abschreibungen; zu hoch die neuen Futterkosten. Für sehr große Betrieb allerdings wie den 500 t Forellen erzeugenden Modellbetrieb kann bereits jetzt die Profitabilität recht schnell und auch mit nur wenigen Änderungen verbessert werden. Kommt zudem noch eine Produktionssteigerung in Frage, so könnte die Umstellung auf das Korkfutter für diese Betriebe eine gute ökonomische Alternative zum konventionellen Futter sein. Solche Betriebe sind in Deutschland aber (noch) selten.

Stichwörter: Fischfutter, Korkfutter, Wirtschaftlichkeit, Aquakultur, Forelle

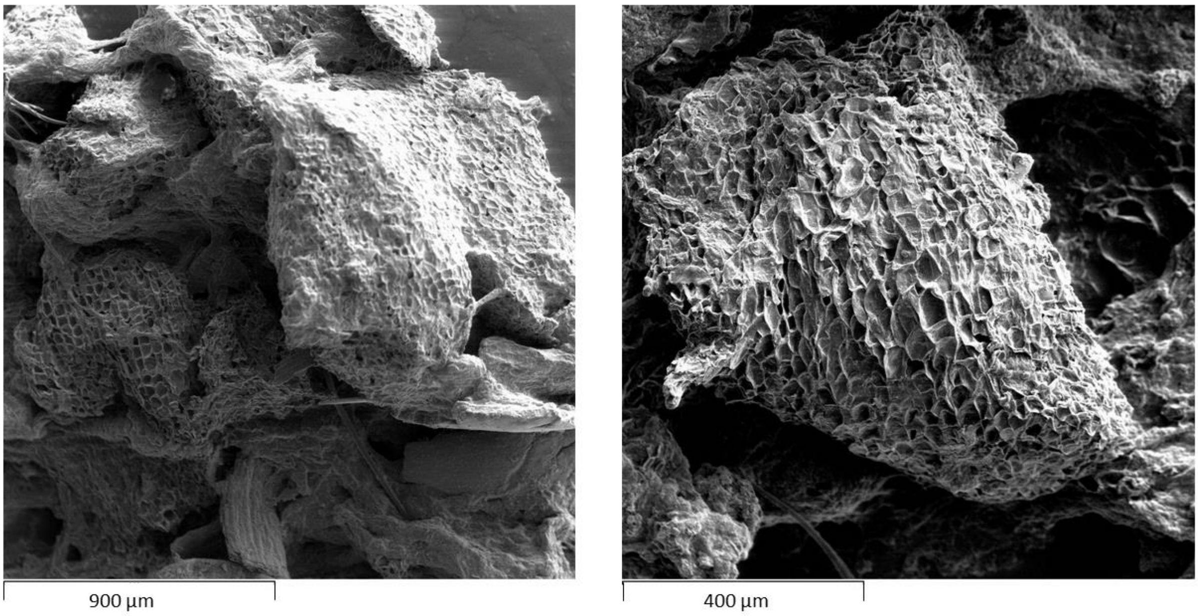
1 Introduction: Cork-enriched fish feed

Feed costs are a crucial factor in salmonid aquaculture, representing between 40 and 70% of total cash costs for trout farms, depending on the financial structure of the facility (Lasner *et al.* 2017). For farmers endeavoring to maximize profitability, improving feed management is an essential consideration. The introduction of a new feed, which is enriched with cork and guar gum (following briefly named as cork-enriched feed), is a highly promising and technologically feasible development with potentially significant economic and environmental benefits. For a better understanding, the following chapter describes the technical background of the cork-enriched feed and synthesizes mainly three studies done about floating feces: i) Schumann, Unger and Brinker 2017 ii) Unger, Schumann and Brinker 2015 and iii) Unger and Brinker 2013.

The effective removal of suspended solids remains one of the main challenges in aquaculture operations (Badiola *et al.* 2012). Fish farm waste comprises principally fecal material excreted directly into system water, where it is inevitably exposed to turbulence resulting in fragmentation into smaller particles and enhanced nutrient leaching, problematic dispersal of fines and an accumulation of dissolved waste in the water column. Particle size is a decisive factor governing the efficiency of waste treatment devices, with larger particles being easier and faster to remove from the system. Firm feces are desirable in waste management terms, being less prone to fragmentation by the action of pumps, fish movement, etc., and thus more quickly and easily removable from the system. The efficiencies of most commonly applied removal devices are limited and the issue is exacerbated by increasing the proportion of plant-based ingredients in modern fish feeds, which have a destabilizing effect on the structure of faecal casts (Brinker and Friedrich 2012). The relatively long waste residence time associated with treatment by sedimentation or micro-screening (e.g. drum filtration) tends to exacerbate the problems of nutrient leaching and particle fragmentation. In semi-recirculating aquaculture systems with integrated water treatment, water quality requirements are high. In such systems, biofilters are key in the removal of dissolved compounds toxic to fish (mainly ammonia and nitrite) and biofilter capacity is the main factor limiting production biomass (Timmons and Ebeling 2010). Organic load in the form of fragmented fecal particles can considerably reduce the efficiency of biological filters by clogging the filter elements, and thereby reducing the surface area available for the growth of desirable nitrifying bacteria (Ling and Chen 2005). Organic carbon also favors the growth of heterotrophic bacteria which compete with and potentially displace autotrophic nitrifiers. Thus the capacity and performance of biofilters depend heavily on the efficacy of mechanical pretreatment in removing as much solid waste as possible.

The two principle removal methods for suspended solids in aquaculture – sedimentation and filtration – both involve substantial periods of time in which fecal wastes are exposed to disruptive forces, with all the consequences set out above. A completely new approach to the problem is the diet-induced reduction of fish fecal density (Unger and Brinker 2013). Indigestible cork granules added to the feed of salmonids have been shown to accumulate in the fecal pellet and provide sufficient buoyancy to raise excreted material to the surface, where direct and rapid removal is easily achieved. In an ideal scenario, the main fraction of solid waste can thus be concentrated in the upper surface layer, limiting the need for treatment to this small volume. Floating fecal casts can be removed efficiently by a low-energy surface separator device, or by existing drum filters to which floating solids can be transported quickly and intact by water flow (Schumann *et al*. 2017).

Figure 1: Scanning electron microscope images of cork granules embedded in faecal matrix (right) and recovered from the sludge box (right) (Unger *et al.* 2015, 230p).



The new approach was tested using a diet supplemented with a sufficient quantity of cork to result in floating feces when fed to rainbow trout (Unger *et al.* 2015). The floating material was removed by a prototype surface separator designed on the principle of an endless-belt filter, with an integrated dewatering step and a filter gauze of 1 mm (Unger *et al.* 2015). A control group was fed the commercially available diet Efico Enviro 921 (Biomar) supplemented with 0.3 % guar gum (Table 1). The treatment diet was identical except for the addition of 2.5 % cork granules with a grain size between 0.5 and 1 mm. A homogenous mixture was guaranteed by adding and stirring the cork into the feed dough before it was extruded into pellets. Subsequent investigations by electron microscopy showed that the air-trapping honeycomb structure of the cork particles was intact after extrusion, thereby imparting a functionally significant reduction in density (Unger and Brinker 2013).

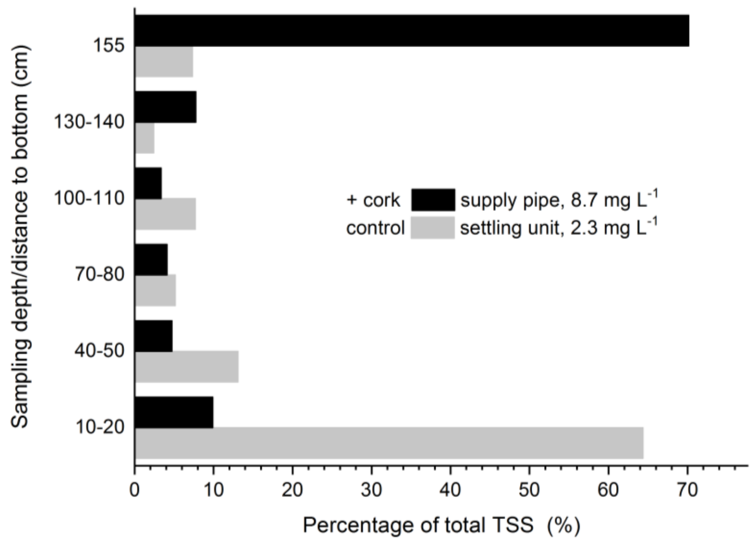
Table 1: Composition of the commercial diet EFICO Enviro 921 (Biomar) + 0.3 % guar gum (Unger *et al.* 2015, 226p).

Grain size	**3 mm**	**4,5 – 6 mm**
Crude protein (%)	48,0	47,0
Crude fat (%)	25,0	26,0
Carbohydrates (NFE) (%)	13.2	12,7
Crude fiber (%)	0,8	0,8
Ash (%)	7,0	7,5
Phosphorus (%)	0,9	0,9
Guar gum (%)[a]*	0,3	0,3
Cork (%)*	2,5	2,5
Gross energy (MJ/kg)	23,7	23,7
Digestible energy (MJ/kg)	21,2	21,3

Feeding trials revealed no ill-effects of the cork-enriched diets on feed conversion or fish performance compared to controls, despite slightly lower dry matter digestibility. A likely explanation is that the enhanced husbandry conditions resulting from superior water quality observed in the treated systems compensated for any reduced digestibility (Schumann *et al.* 2017, Unger *et al.* 2015).

The cork-enriched and control diets were tested over three weeks in a semi-recirculating trout farm, while pertinent water parameters were monitored. When the cork diet was fed, between 62 and 76 % of solids accumulated in the upper surface layer, while in the control treatment trial, about 64 % of solids were found in the bottom 10-20 cm layer (Figure 2). The concentration of solids in the water column was significantly higher during the cork treatment, at about 20 mg/l compared to 7 mg/l for the control, resulting in a greater proportion of mechanically removeable solids.

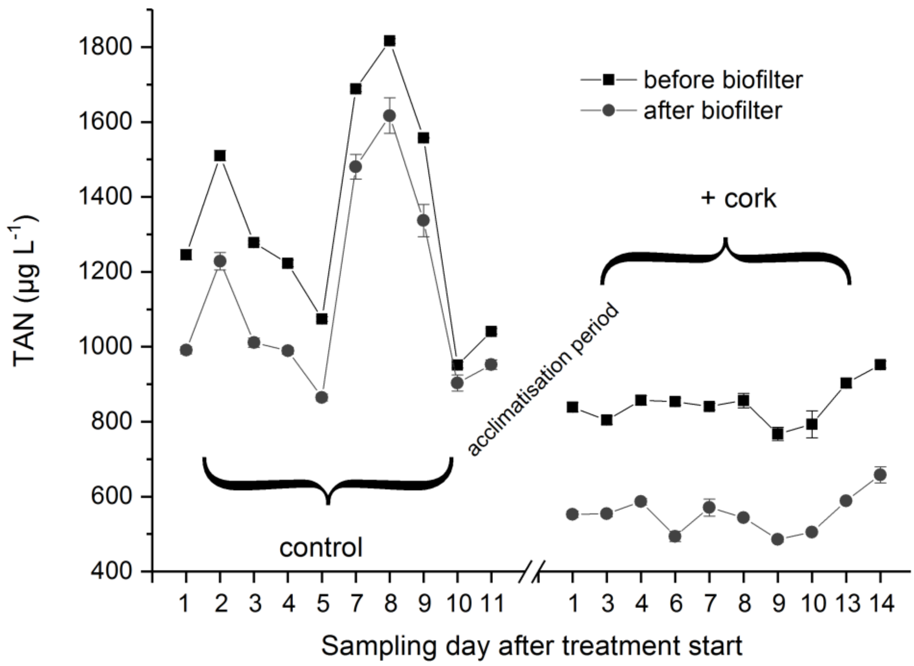
Figure 2: Vertically profiled total suspended solid (TSS) load for the experimental diets before removal (n = 238). The surface separator was deployed during the cork trial; the settling basin operated during the control trial (Unger *et al.* 2015, 231p).



The application of cork produced an extremely positive effect on TAN levels, which were nearly halved when the treatment diet was fed and much more stable than in the control system, where TAN fluctuated over time (Figure 3). The fixed bed biofilter removed about 36 % of TAN during the cork treatment compared to 18 % removal during the control phase. The surface separator yielded several advantages compared to a drum filter – considerably greater removal efficiency and a two-thirds reduction in energy costs compared to a drum system operating on the same scale. A further advantage is the high dry matter content of the sludge removed by the surface separator, about 20 %. This concentrated waste is easier to transport and can be directly applied as a fertilizer or as substrate for biogas plants without need for further thickening or dewatering.

The direct removal of floating fecal matter has several benefits in terms of water quality, animal welfare and environmental impact. Fish production levels can be maintained while important water parameters are considerably improved, or fish production can be increased while values of important/relevant water parameters are maintained.

Figure 3: Timeline of total ammonia nitrogen (TAN) during the trial, measured for both diets before and after biofiltration (n = 160). Values are means **± SE** (Unger *et al.* 2015, 232p).



In the following and based on the abovementioned studies about the technological and environmental performance of the new feed our study projects the implementation of the innovative feed in selected German model trout farms to test the economic viability and analyse the effects towards farms' profitability.

2 Method

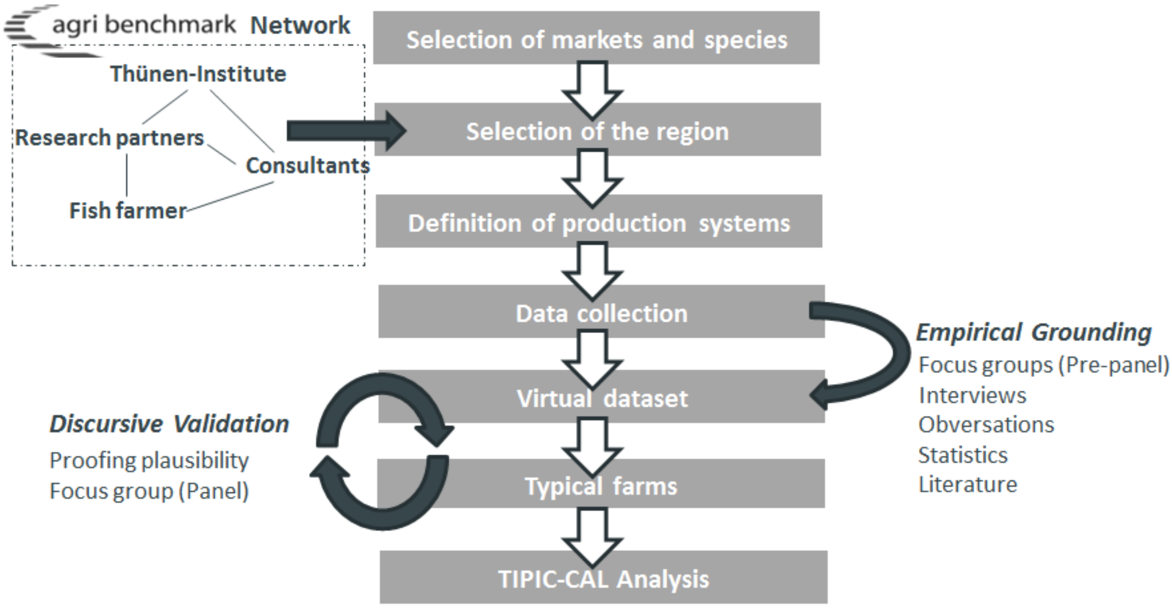
Two typical farms from the established *agri benchmark* Fish network were remodeled to simulate the implementation of the innovative cork diet and associated technical upgrades, and to undertake economic assessments made on the basis of pertinent assumptions and scenarios.

2.1 *agri benchmark* Fish and the typical farm approach

Cost and benefits are crucial components of the decision-making processes of businesses considering adopting any novel technique (cf. Rogers 2003), and an innovation that does not offer a clear picture of both is unlikely to diffuse into the market. In the context of aquaculture, establishing the benefits of any innovation requires a demonstration of direct and indirect cost reduction or profit increase. Unfortunately, the economic data available from the sector is not always suitable for making such calculations, making it very difficult to assess costs and benefits in advance. The dearth of comparable economic data from fish farms is partly due to the wide range of species under culture and the variety of production systems in use, both of which contribute to a highly complex segmentation of the sector. The time and cost implications of standardized surveys required for statistically robust farm level projections are significant, and the collection of economic and social data for aquaculture has been not mandatory under the EU Data Collection Framework (DCF) in recent years (EU 199/2008). However, since 2017 the DCF has collected socio-economic data for freshwater facilities (EU 2017/1004), and while this focuses on just few carefully selected variables the data will be very helpful in monitoring the sector's future development. A further obstacle to in-depth analysis is that statistical operations aggregate the data at sector level, making farm-level impact analysis impossible. To project the impact of adopting an innovation such as cork-enriched feed on a parameter such as single fish grow-out, a much greater resolution of data is needed and this cannot be delivered by standardized survey methodology. The *typical farm approach* adopted by the international *agri benchmark* Fish[1] network originates in agricultural economics (Deblitz *et al.* 1998, Isermeyer 1993). The approach can be regarded as an engineering one (Isermeyer 2012), in which sampling strategy and data collection combine desk research (literature reviews and statistical analysis) and fieldwork including expert interviews, observation and focus groups. The focus groups are a core element of the approach, in which producers, consultants and other experts work with the researcher to accurately define virtual facilities or production systems to represent particular segments of the sector (Deblitz und Zimmer 2005).

[1] *agri benchmark* Fish was founded in 2013 by the Thünen-Institute. The international network connects aquaculture and fisheries researchers worldwide to study the profitability of aquatic production systems. Get more information about the network under www.agribenchmark.org

Figure 4: Schematic representation of the typical farm approach (Lasner *et al.* 2017, 3137p.)



The typical farm approach was first applied to aquaculture the in 2014, (Lasner *et al.* 2017), having been previously applied to a number of agricultural institutions and networks (*cf*. IFCN 2015, Richardson *et al.* 2013, Isermeyer 2012): the International Farm Comparison Network (IFCN) coordinated by the IFCN Dairy Research Centre in Kiel, Germany; the Representative Farms dataset maintained by the Texas A&M University (TAMU) in Houston, College Station, USA; the Brazilian National Agency for Supply (CONAB) in Brasilia and the *agri benchmark* network itself. Sharing a common approach helps to streamline collaboration and communication between organizations working with different agricultural production systems and regions (Walther 2014). Although the typical farm models are virtual, their variables are based on real costs, margins and techniques and impacts reported by the focus groups. The farm models are located in an important region of production and combine production factors in a common way for the studied case. For aquaculture, the datasets can cover over 500 variables, a level of detail that leads to a highly coherent picture of operations. Meanwhile, the interdependence of many variables (e.g. feed costs, feed conversation ratio, feed price, fish volume produced, fish loss etc.) ensures the validity of data. The data collection phase ends with a review process in which areas of uncertainty are discussed critically and the consulted experts and fish farmers agree to adjusted values and volumes. However, it’s important to recognize that despite all this, the typical farms are assumptions, and not representative in a statistical manner:

> *“The approach reduces complexity towards the core aspects and refers to more than one situation. It delivers memorable and credible values, because it is based on the knowledge of experts. The values are empirical, and cannot be assigned with a higher degree of statistical significance. However, the approach is far from superficial. It gets to the heart of the matter”* (Häring and Klöble 2015; transl. Lasner)

The difference to banal assumptions is the empiricism behind typical farms. Typical farms are based on empirically-grounded assumptions[2] and form the basis for later analyses of profitability, productivity and rentability, in which *agri benchmark* distinguishes between three classes of costs:

- **Cash Costs** include all fixed and variable costs, interest payments, wages and non-wage expenses including. Variable costs vary in proportion to production volume and include costs of feed, stocking, veterinary services and vaccination, minor operational equipment, electricity, diesel, oxygen and other operational costs. Fixed costs occur regardless of whether or how much is produced. These are outlays for land and water leases, farmstead running costs, mechanical and building maintenance, advisory services, controls and certifications, accounting, memberships, insurances, office operations, promotion and other fixed components.
- **Depreciation** is calculated linearly on replacement values of all buildings, facilities, machines and equipment, so that the dataset reflects the need for investment to maintain future competitiveness.
- **Opportunity costs** describe fictive expenses for using the farm's own production assets, for example:
    (1) Unpaid labour (family working hours * wage for qualified local labour),
    (2) Capital (non-land equity * long-term government bond interest rate),
    (3) Land (land owned * regional land rents).

Once these costs have been identified, the approach documents all revenues of the fish farm, including prices for all products received from all distribution channels. Finally, a single weighted mean of market revenue is calculated. Trout farms are special in the number of salmonid species cultured and the number of associated production systems often integrated into a single farm. In hatcheries, farmers manage broodstock and support the spawning and hatching of fish eggs. In nurseries they feed and grade the fry and grow them up to fingerling stage, at which they are stocked into the grow-out system where they are reared into portion-sized or large-sized trout. Many farms specialize in the grow-out stage, but others operate their own nurseries and hatcheries. A few also process their fish and sell some of it at their own farm shops. This diversity of production system combinations is a challenge to comparative analysis between farms, and the reason why most cost-efficiency benchmarking focuses solely on grow-out, the most important production stage from a political and economic point of view. But because the holistic typical farm database includes costs, quantities and price for all stages, it allows values to be broken down into

[2] In a sense, typical farms in economics remain on the Grounded Theory Approach of Glaser and Strauss (2008) in sociology. Both approaches aim to create hypothesis, whose validation is ensured by extensive empirical case studies.

separate production systems via simple Excel spreadsheet tools. Further variables within the grow-out sector include differences in stocking procedures and in finishing, which generally responds to market demands. The scale of the farms also varies. In order to enhance comparability, all costs are given in € per kg live weight (LW), unless otherwise stated, and exclude value added tax (VAT). Some farms fatten different salmonid species. Multi-cultures are particularly common in German trout farms, which often rear rainbow trout, brown trout or brook trout at the same time. However, for benchmarking purposes it is practical to focus solely on rainbow trout, undoubtedly the most important species in EU trout farming and worldwide (cf. FAO 2018, FEAP 2016). The final *agri benchmark* calculations result in three profitability forecasts: short- (PS), medium- (PM) and long-term (PL). Profitability is calculated simply, by subtracting the values of cash costs (C), depreciation costs (D) and opportunity costs (O) from the mean of market returns (R) (Lasner *et al.* 2017):

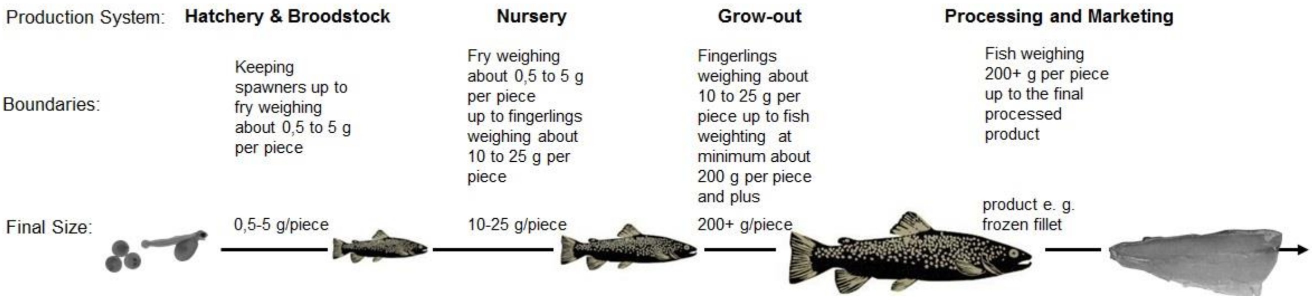
$$P_S = R - C$$
$$P_M = R - (C + D)$$
$$P_L = R - (C + D + O)$$

In the short-term calculations, all cash costs are deducted from revenues. A farm is able to cover all operational costs in a running business year can achieve a profit in that period. In the medium-term, cash costs and depreciation are also subtracted from revenues, resulting in a value over >1-4 years. Subtracting all costs (cash costs + depreciation + opportunities costs) from revenues leads to an indication of long-term profitability (5 years and more). The calculated economic values are shown without VAT, and again, all results are in € per kg live weight (kg LW) and refer to grow-out operations only (not company level), unless otherwise stated.

2.2 Trout grow-out farm models

Two model trout farms from the *agri benchmark* Fish data set were chosen for a study of economic viability. Both are located in Southern Germany and produce portion-sized trout (Table 2). The first farm, designated DE-500, has a flow rate of 550 l/s and produces 500 tons trout per year. The second farm, DE-100, has a lower flow rate of 60 l/s and produces 100 tons trout annually. Both farms are larger than average for their region (and Germany) and benefit from professional operating management and good practice. The results of the following calculation will show whether or not cork diet is profitable for these top-performing farms, and thus whether the protocol can be recommended to average farms. Data is based on the year 2013 and was not updated for reasons: To prevent an identification of the real farms' account standing beyond the models, because the calculations of profit and loss accounts were very detailed. Further the object of the analyses is to compare input and output relation between farm systems with and without the implementation of the cork-enriched feed, while the focus of the economic studies on production costs for the grow-out system, starting with fingerling purchase and ending with the harvesting and selling of portion-sized trout (Figure 5).

Figure 5: Boundaries of single enterprises (production systems) in a vertical integrated trout farm



The raceways deployed in the two study farms are of different types. The classical flow-through system of DE-500 has five production units in different locations, with innovative technology including solar panels and a cascade structure to save energy. DE-100 operates a single production unit, a modern, partly re-circulating raceway like those used in Danish model farms. DE-500, with its larger production has a high-tech water and sludge treatment with micro sieves (drum sieves) for filtration and settling basins for purification. The resulting sludge is treated in a plant lagoon before being deposited on agricultural land. Water treatment in DE-100 comprises sedimentation basins and filter beds only.

Table 2: Characterization of the selected trout farms

	DE-500	DE-100
Production	500 t	100 t
Withdrawal rate	550 l/s	60 l/s
Weight Fingerlings	15 g	15 g
Catching Weight	380 g	317 g
Weight added per animal	365 g	302 g
Farming technique	(Flow through) raceways	Raceway (with partly recirculation)
Water treatment	Drum filter, settling pond, plant lagoon	Settling pond, biological filtration systems
Distribution	Wholesaler	Reseller, direct marketing

The *agri benchmark´*s typical farm approach was used to model three new farms using the new cork diet:

- **DE-500^{cork}** modelled out of DE-500. Like the original, it produces 500 tons rainbow trout a year, but uses cork feed and invests in the necessary changes in farm management.
- **DE-100^{cork}** is based on DE-100, but with the application of cork diet.
- **DE-115^{cork}** is also based on DE-100 and uses the same raceways. But since some basins are no longer needed for sedimentation, the farm operates with an increased water area for fish farming and thus increased production, 15 tons more than the original.

3. Economic viability of farm models

This section analyses the viability of the described farm models, taking into account changes in equipment and cost structure necessitated by the implementation of cork-enriched feed. Assumptions regarding the consequences of the new feed in the three modeled grow-out systems are based on the aforementioned literature review and on in trails run at the Fisheries Research Station of Baden-Wuerttemberg (DBU Project AZ 26128-34).

3.1 Changes in cost structure

The introduction of the innovative cork-enriched feed has cost implications for farm operations, including the cost of the feed itself plus necessary changes in farm infrastructure and management, in particular in terms of water filtration, machinery, technology and structural change, and in the costs of energy, oxygenation and labor. The material costs for cork are estimated at € 60 per ton, based on the current market (2017), and a further € 60 per ton of feed is allocated for licensing, with the result that overall feed costs rise by 5 cents per kg trout production for each farm, an increase of about 4 %.

DE-500^{cork}

An overnight diet-mediated change from settling to floating feces necessitates a change in water filtration technique. Allowing farm DE-500^{cork} to replace the extensive array of drum filters used by the original farm DE-500 with surface separators brings significant savings in investment and energy costs. An investment cost of € 17,000 per piece was assumed for a mechanical drum filter, while the surface separator was allocated a purchase price of € 10,000. In a practical real-world trial, newly installed surface separators used 84% less energy than the old drum filters (Unger *et al.* 2015). A simple settling pond was installed to deal with stray settled feces, and the more complex settling ponds and plant filtration system previously used were no longer needed. Feces collected by the surface separator can be removed immediately from site directly, with no requirement for dewatering or storage. In general, the investment needed for facilities in DE-500^{cork} – shown as current replacement value for re-investment – is reduced by 16 percent, from € 5.7 m to € 4.8 m (see table 2). Of that, the reduced need for settling ponds alone accounts for € 700,000, 18 % cost saving. The costs for equipment and utilities (mobile economic goods) including various machines, vehicles, pumps, feeding devices and filter technologies are reduced by 14 %, due mainly to the replacement of drum filters with less expensive and more efficient surface separators. In consequence, annual debit through depreciation is decreased by 15 %, to € 236,000, or 47 cents per kg trout (formerly 56 cents per kg).

All in all, DE-500^{cork} requires almost € 1 m less investment for farming system, equipment and buildings than the baseline farm DE-500; a reduction from € 6.1 m to € 5.2 m . Assuming the same

15 % rate of borrowed capital, as for DE-500, the annual interest costs of DE-500^{cork} also decrease. Equity capital plays an important role when it comes to the long-term profitability of a farm, and is included in the calculation of opportunity costs, alongside unpaid family labor and land ownership (see also chapter 3.1). Opportunity costs for capital are reduced by 1 cent per kg trout. Energy costs decrease by two thirds, from 3 cents to 1 cent per kg trout. A further 16% cost reduction for DE-500^{cork} is achieved through the reduced maintenance costs of surface separators compared to drum filters.

Table 3: Comparison of investment in facilities and equipment between baseline farms and farms using cork-enriched feed in € and € per kg LW

	DE-500	DE-500^{cork}	DE-100	DE-100^{cork}	DE-115^{cork}
INVESTMENTS			**In absolute terms**		
Replacement value aquaculture	4,150,000	3,438,000	410,000	388,000	410,000
Thereof raceways	4,000,000	3,288,000	130,000	108,000	130,000
Replacement value equipment (machinery, vehicles, pumps, feed automats, filter etc.)	1,563,000	1,348,000	558,000	512,000	512,000
Total replacement value	5,713,000	4,786,000	968,000	900,000	922,000
DEPRECIATION (annual linear calculated)	277,569	235,726	58,013	53,880	54,613
OPERATING COSTS Machinery maintenance	100,000	85,388	8,500	7,623	7,700
			In € per kg LW trout		
Replacement value	11.43	9.57	9.68	9.00	8.02
Depreciation	0.56	0.47	0.58	0.54	0.47
Machinery maintenance	0.20	0.17	0.09	0.08	0.07

DE-100^{cork}

Model farm DE-100^{cork}, which formerly used settling ponds, also encounters changes in cost structure associated with implementing the new feed. Under the new regime it uses surface separators and has far fewer settling ponds than DE-100. Since the implementation of sediment treatment is no longer required, workload is reduced, with implications for investment costs as outlined in Table 2, notably a cost reduction for raceway systems and settling ponds of 17 %(see Hauber *et al.* 2015 for investment costs in a trout farm) and as with DE-500^{cork}, DE-100^{cork} also benefits from requiring fewer pumps, with a cost reduction of 8 %. Thus annual depreciation for DE-100^{cork} decreases by 4 cents per kg of trout, and machine maintenance costs decrease by 1 cent per kg.

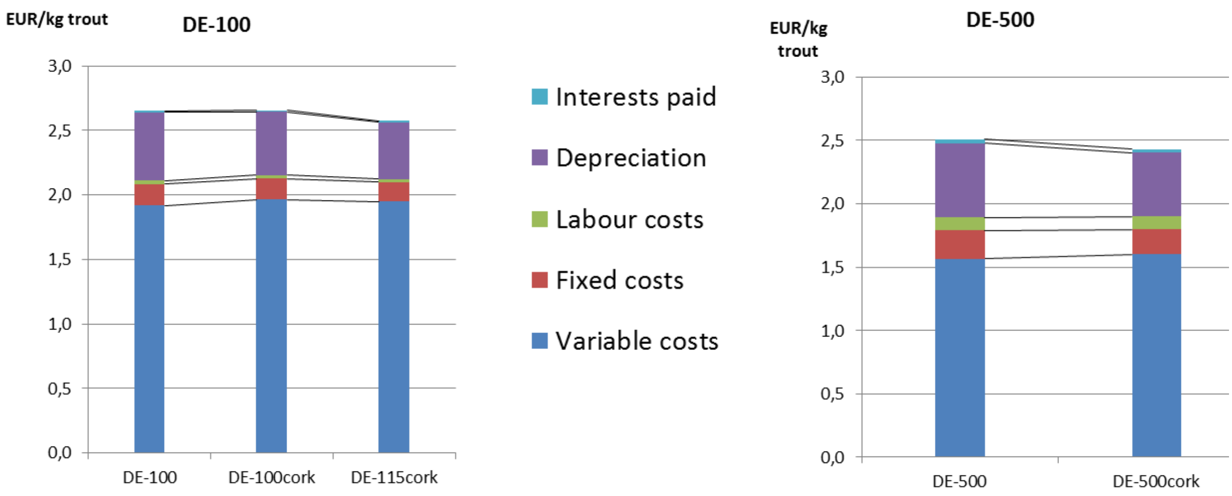
DE-115^{cork}

DE-115^{cork} was also modelled from DE-100. The settling ponds, which are redundant in the cork-feed system, are transformed into grow-out ponds, resulting in a production increase to 115 tons. For DE-100^{cork}, benefits were calculated on the assumption that fewer settling ponds needed to be built in the first place in order to produce 100 tons, while DE-115^{cork} represents the conversion of an existing operation. In other ways, the investment costs and annual depreciation for DE-115^{cork} are identical to those of DE-100. Equipment costs (such as pumps and filter technology) are similar, at € 46,000. All in all, the DE-115^{cork} operation saves 11 cents per kg trout per year in depreciation and 2 cents for machine maintenance, due to production increase compared to the original operation DE-100.

Summary costs

Due to increased feed costs, the variable costs of all model farms switching to the cork diet also increase. But these are more than compensated by the reduced fixed and investment costs associated with reduced technical demand for water treatment. These amount to a saving of 8 cents per kg trout for DE-115^{cork} and DE-500^{cork} (Figure 6) and an overall cost reduction of € 31,000 for DE-115^{cork} and € 40,000 for DE-500^{cork} (including depreciation). For DE-100^{cork}, the cork diet has a smaller effect on costs as a whole amounting to a saving of € 5,000 per year.

Figure 6: Cash costs and non-cash costs for model farms DE-100 and DE-500 with and without cork diet



3.2 Operational results

The operational performance of the new model farms DE-100^{cork}, DE-115^{cork} and DE-500^{cork} are compared to that of the original models DE-100 and DE-500 in Table 4. One important indicator of operational results is the contribution margin. The contribution margin is a measure of the ability of a production system to cover variable costs with its revenues (defined as selling price per unit minus variable costs). Total returns vary, not least according to different distribution channels. Variable costs rise with feed costs, and the contribution margin is less for DE-100^{cork} and DE-500^{cork} than for the original model farms DE-100 and DE-500. In DE-115^{cork} however, which adapts former settling ponds into grow-out raceways, the contribution margin is increased by € 34,700 per year. Fixed costs for all operations are reduced by using the cork diet, but the saving are insufficient in themselves to compensate for the additional cost of cork feed. In fact, operational results of all new model operations decreased compared to the original operations.

Incorporating fixed costs does not significantly change the overall picture for farm viability. The operational result for DE-115^{cork} improves by € 34,000 per year, but decreases for DE-100^{cork} and DE-500^{cork} compared to the baseline farms.

If wages, interest rates and depreciation are taken into account, DE-115^{cork} and DE-500^{cork} benefit from lower investment costs and reduced depreciation, resulting in medium-term, profitability increases for these operations.

Declining investment costs are most apparent for DE-500^{cork}: Annual investment costs, indicated by depreciation, decrease by almost € 42,000, with a consequent increase in mid-term profitability from € 395,000 to € 435,000.

Farm operations differ in terms of their unpaid production factors, such as the use of personal capital, owned property (land) and family labor. An operation with high capital resources, owned land and family labor saves on interest payments, land rent and wages. In order to compare different operations, each of these factors are given a fictive value for purposes of modeling (see section 3.1) and these values are incorporated into long-term profitability calculations as opportunity costs. For DE-500 ^{cork}, opportunity costs fall by € 4,400 compared to DE-500, while they remain constant for the cork-enriched feed model DE-100^{cork}, suggesting that DE-100^{cork} cannot improve on DE-100 by implementing the new feed. In terms of cost per kg LW production, DE-115^{cork} performs significantly better in the long-term than DE-100, increasing its long-term profitability by 9 cents per kg LW.

The models suggest that the implementation of cork-enriched feed is beneficial to operations DE-500^{cork} and DE-115^{cork} in the medium and long term, with absolute profit increasing by € 44,000 to € 398,000 and by € 36,000 to € 210,000 per year, respectively. In terms of production, the new diet makes for a surplus of 9 cents per kg LW for both operations. DE-100^{cork}, however, which produces the same amount as the original DE-100, but with lower capital expenditure, does not benefit from the new cork system. Its economic viability is almost unchanged (Table 4).

Table 4: Profit and loss account of portion-sized trout grow-outs with cork-enriched and conventional feed (in €)

	DE-500	DE-500cork	DE-100	DE-100cork	DE-115cork
Total returns	1,650,000	1,650,000	448,747	448,747	516,059
- Variable costs	782,771	800,373	191,612	196,352	224,225
thereof feed	575,000	599,550	132,000	136,740	157,251
Electricity	13,000	6,053	15,185	15,185	17,420
= Contribution margin	**867,229**	**849,627**	**257,135**	**252,395**	**291,834**
- Fixed costs	112,532	99,109	16,736	16,089	17,100
thereof Maintenance machinery	86,100	72,677	6,267	5,620	6,000
= Operating profit	**754,697**	**750,517**	**240,399**	**236,306**	**274,733**
Depreciation	292,636	250,793	52,682	49,088	50,587
Wages	51,000	51,000	2,754	2,754	2,801
Interest costs	15,725	13,361	1,367	1,292	1,339
Opportunity costs	42,115	37,729	9,978	9,703	9,961
Profitability					
- short term	**687,972**	**686,157**	**236,279**	**232,261**	**270,593**
- medium term	**395,336**	**435,364**	**183,596**	**183,172**	**220,006**
- long term	**353,221**	**397,635**	**173,618**	**173,470**	**210,045**

4 Scenarios and sensitivity analysis

A lack of empirical data means that some significant cost implications of implementing cork-feed, such as changes to operating schedules labor savings, oxygen requirements or the potential for surplus production have so far not been taken into account in the calculations. The following sections consider ways in which those factors might influence the economic viability of the farm models. Furthermore, because the feed price is the crucial factor influencing profit and loss accounts of trout farms (Lasner *et al.* 2017), the farm models are assesses for their sensitivity to fluctuating feed prices. An overview is given in Table 5.

Table 5: Overview of applied scenarios and operational outcomes for model farms

Variant farm	*Baseline farm*	*Scenario*	*Description*
DE-500^{cork}	DE-500	**Cork-enriched feed**	Implementation of cork-enriched feed; new water treatment; same production volume
DE-500^{cork_W}	DE-500	**Scenario 1: Work**	Labor saving compared to DE-500^{cork} due to surface separator technique
DE-500^{cork_W_Ox}	DE-500	**Scenario 2: Work and oxygen**	Labor saving and reduced oxygen consumption compared to DE-500^{cork}
DE-600^{cork}	DE-500	**Scenario 3: Increased production**	Reinvestment of labor and oxygen savings to increase the production by 20 %
DE-100^{cork}	DE-100	**Cork-enriched feed**	Implementation of cork-enriched feed; new water treatment; same production volume
DE-100^{cork_W}	DE-100	**Scenario 1: Work**	Labor saving compared to DE-100^{cork} due to surface separator technique
DE-100^{cork_W_Ox}	DE-100	**Scenario 2: Work and oxygen**	Labor saving and reduced oxygen consumption compared to DE-500^{cork}
DE-120^{cork}	DE-100	**Scenario 3: Increased production**	Reinvestment of labor and oxygen savings to increase production volume by 20 %
DE-115^{cork}	DE-100	**Scenario 4: Modification**	Redundant settling ponds transformed into breeding ponds, permitting production increase of 15%
DE-115^{cork_Ox}	DE-100	**Scenario 4a: Modification and oxygen**	Savings from reduced oxygen consumption in DE-115^{cork}
DE-138^{cork}	DE-100	**Scenario 4b: Modification and increased production**	Increase in production volume of 20% compared to DE-115^{cork}

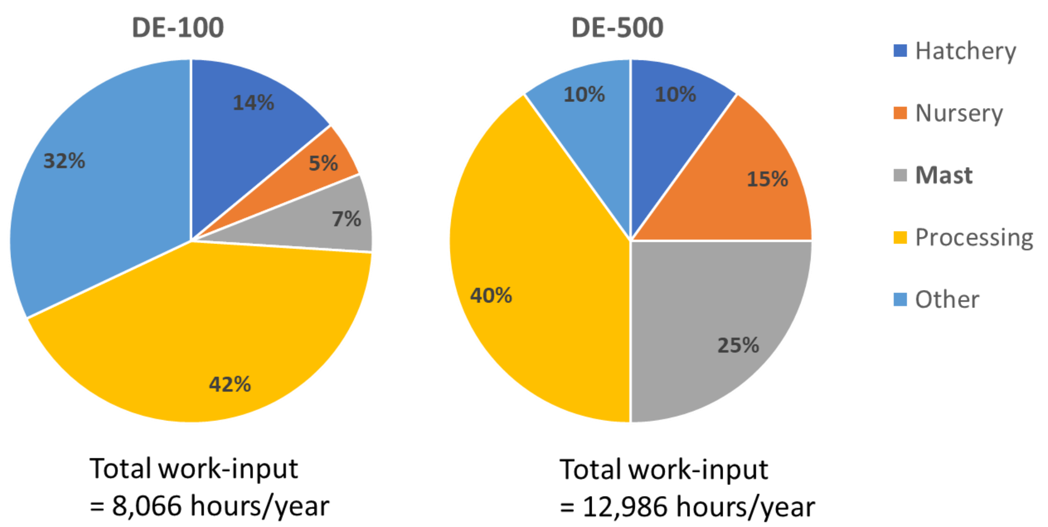
4.1 Scenarios

Several parameters were not considered in the initial calculation, because of a lack of reliable data. This includes the reduction in labor resulting from the direct removal of feces from the surface, the reduced demand for oxygen resulting from decreased fecal decay, and possible increases in productivity due to improved water quality. These potential benefits are modeled in the following scenarios.

4.1.1 Scenario 1: Work – labor saving

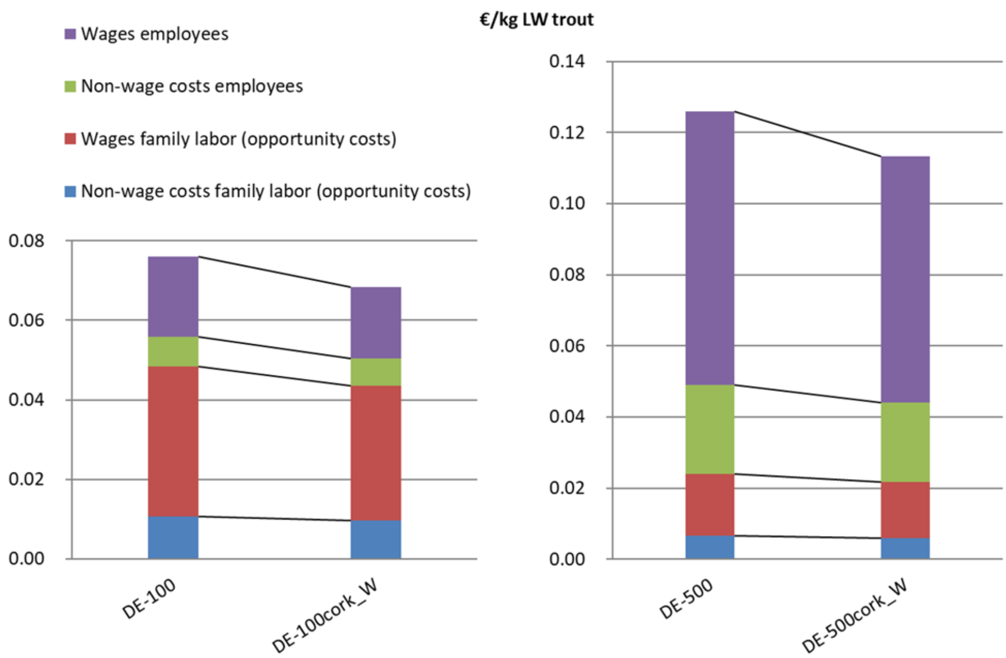
It is typical for German trout farms that the owner and family members often work alongside employees, but without regular pay. Following the *typical farm approach*, this labor is accounted for using fictive wages calculated as opportunity costs, based on the level professional qualification of the family member and their role in the business (Lasner *et al.* 2017). Much of the routine work in a trout farm – maintenance of spawning stock, hatcheries and grow-out (mast) – is comparatively straightforward, but the distribution of labor varies from farm to farm according to infrastructure, production systems, equipment and expertise of the workforce. As a general rule the main tasks are those associated with feeding and grading, with monitoring of fish, routine health care and vaccination, maintenance and repair of breeding ponds, cleaning and disinfection. Downstream efforts, such as slaughter, fish processing and direct marketing activities are not included in the definition of grow-out, and nor is time invested in operational management. Figure 7 shows how labor-hours are distributed in two different examples.

Figure 7: Allocation of labor in two selected trout farms



Total work input considers effort invested in the farm by both paid and unpaid labor. The category "other" represents effort invested in management and facility maintenance. While highly automated farms such as DE-100 devote little labor to feeding and grading, farms with less automization like DE-500 invest significantly more effort in their grow-out systems. Thus the latter stand to benefit most from labor savings brought by the introduction of cork-enriched feed. In the cork-feed system, labor-intensive waste removal and treatment is replaced by technically simpler surface removal of feces, which can be transported off site without the need for further treatment (see chapter 0). It can be assumed that this will result in a reduction in labor while productivity is maintained, but a lack of empirical data means that the saving for operations DE-100^{cork} and DE-500^{cork} is an estimated 10 % . DE-115^{cork} was not considered in this scenario, since its 15%increase in production will incur additional work, resulting in a roughly similar labor costs overall. DE-100 devotes roughly 565 hours per year to trout mast (equivalent to 8% of total work input), compared to approximately 3250 hours per year in DE-500 (25% of total work input). A 10 % reduction in labor thus saves 57 hours in DE-100 and 325 hours in DE-500. Costs for DE-100^{cork} incorporating reduced work (hereafter DE-100$^{cork_W)}$. by 0.8 cents to 7 cents per kg LW, and for DE-500^{cork_W} they decrease by 1.3 cents to 11 cents per kg LW, compared to the original operations (see Figure 8).

Figure 8: Wage and non-wage costs in selected trout farms using cork-enriched and conventional feed



Overall, the total labor costs for DE-100^{cork_W} decrease by € 760 to € 6,800 per year. For DE-500^{cork_W} the reduction is € 6,300, to €56,700 per year. All in all, the profitability of DE-100^{cork_W} barely improves compared to DE-100^{cork}, but the benefit to, DE-500^{cork_W} is considerable and increases long-term profitability by about € 50,000, from € 353,000 to € 404,000 (see annex Table 6). Thus in total production terms, a 10 % work reduction increases profitability for both model operations using cork feed by 1 cent per kg LW (see table 5). However, given that these new models are based on an assumption, a 1 cent per kg increase cannot be considered significant. In any case, labor costs are not the crucial factor in producing trout.

4.1.2 Scenario 2: Labor and oxygen savings

It can be assumed that the use of cork feed, besides reducing work input, also results in a reduced consumption of oxygen, the supply of which is an important cost in professional trout farming. Scenario 2 considers the economic consequences of reduced oxygen demand in addition to the savings in labor costs outlined in Scenario 1. It is expected that improved water quality and absence of fecal decay will cause a reduction in oxygen consumption, but as with the labor saving calculations above, there is no reliable empirical data on which to base an estimate. Therefore a theoretical and highly conservative assumption was made in which oxygen demand is reduced by one third.

Model farm DE-100 uses 87,000 litres of technical oxygen annually, at a cost of about € 11,000 in a typical year. DE-500 uses 320,000 litres at € 38,400. Compared to the original operation using conventional feed, DE-500$^{\text{cork_W_Ox}}$ saves € 12,800 and 3 cents per kg trout per year. DE-100$^{\text{cork_W_Ox}}$ reduces its costs by € 3,750 or 4 cents per kg trout. Compared to DE-500$^{\text{cork}}$ and DE-100$^{\text{cork}}$ (operations with cork feed, but without work and oxygen savings taken into account) profitability in DE-500$^{\text{cork_W_Ox}}$ and DE-100$^{\text{cork_W_Ox}}$ increases by 3 to 4 cents per kg trout (see annex Table 6). Compared to DE-100, costs remain stable and short-term profitability does not change, but the long-term economic situation improves by 4 cents per kg LW trout, a gain of €9000 to € 183,000. DE-500$^{\text{cork_W_Ox}}$ benefits more, due to its higher oxygen usage, and shows improvements in its mid- and long-term profitability of 12 cents per kg trout or an annual increase of € 63,500 to about € 417,000 (see annex Table 7).

DE-115$^{\text{cork}}$ consumes 88,000 litres of technical oxygen. Assuming that one third of oxygen consumption can be saved, the farm reduces its costs by 3,800 € per year or 4 cents by kg LW trout (see annex Table **6**). This leads to an improvement of DE-115$^{\text{cork_O}}$'s profitability of 3-4 cents per kg LW trout compared to DE-115$^{\text{cork}}$.

4.1.3 Scenario 3: Increased production

The rapid removal of feces from the surface water in farms using the cork feed results in immediate and considerable improvements in water quality. This can translate into reduced oxygen demand and cost savings, as described in Scenario 2. But it may also be exploited to increase production, with savings re-invested in infrastructure and labor to rear more fish. According to Unger *et al.*

(2015) a productivity increase of up to 50 % could be achieved when water quality is high. Our economic model assumed a conservative 20 % production increase from otherwise unaltered operational conditions. Thus from DE-100^{cork}, DE-115^{cork} and DE-500^{cork} we derived DE-120^{cork}, DE-138^{cork} and DE-600^{cork}: the same farms, but with 20 % higher production and appropriate changes in cost structure. Our calculations assumed that marketing remains the same and that surplus trout will be distributed via the same sale channels and at the same price as in the original models.

In the short term, increased productivity in the new models is accompanied by higher costs, especially those for feed and stock (total cost calculation cf. annex Table 6 and Table 7), resulting in lower contribution margins for all operations, compared to the original farms DE-100 and DE-500. However, when mid- and long-term expenditures such as depreciation and opportunity costs are taken into account, all model operations show improved profitability. With its 20 % production margin, DE-600^{cork} shows a 7 cent per kg improvement in short term profit over DE-500, and gains in the mid- and long-term are 24 and 27 cents per kg, respectively. Considering all actual and calculative costs, the profitability of DE-600^{cork} increases by € 183,000 compared to DE-500^{cork} and € 227,000 over the initial operation DE-500, to a total of € 580,000 (Figure 10).

DE-120^{cork} also represents an improvement in mid- and long-term profitability over DE-100, with increases of 10 cents per kg trout in the midterm, 12 cents per kg in the long term. The latter amounts to about € 50,000 per year. The production increase applied to DE-115^{cork} lead to an operation producing 138 tons of trout, DE-138^{cork} and further improvements in operational results and profitability compared to DE-100 (see annex Table 6 and Figure 10). Considering all calculated costs, profitability increased by € 58,000 compared to DE-115^{cork} and by € 94,600 compared to DE-100, to € 268,200.

4.2 Sensitivity analysis

How is the profitability of operations impacted by changing costs? Gaps in the empirical data necessitated some estimates to be included in the model calculations including the cost of the cork feed. Given that 90 % of all cash costs in the original models (= fixed + variable costs + interest costs + wages incl. non-wage costs) are attributed to feed and that the costs of ingredients can fluctuate considerably over time, it is important to consider the potential impacts of this variation. How, for example, might operations be affected by a higher cork feed price than the one we assumed so far? Our first cork-feed models assumed a cost increase of 5 cents per kg of feed (for calculation of feed prices see section 3.1), but how expensive can feed be and still offer equivalent or improved profitability compared to the original operation?

To examine these questions, a threshold additional price was calculated for each farm model to determine what kind of price increase operations could absorb while maintaining the same profitability gain compared to initial operations.

The unknown variable is the maximum feed price for cork-enriched feed (F_{max}) that does not endanger short-term profitability (P_s). To calculate F_{max}, P_s, all variable costs excluding feed (C_v), fixed costs (C_f), wages (C_w) and interest costs (C_i) are subtracted from total returns of the farm (R_{total}).

$$F_{max} = R_{total} - P_s - (C_v + C_f + C_w + C_i)$$

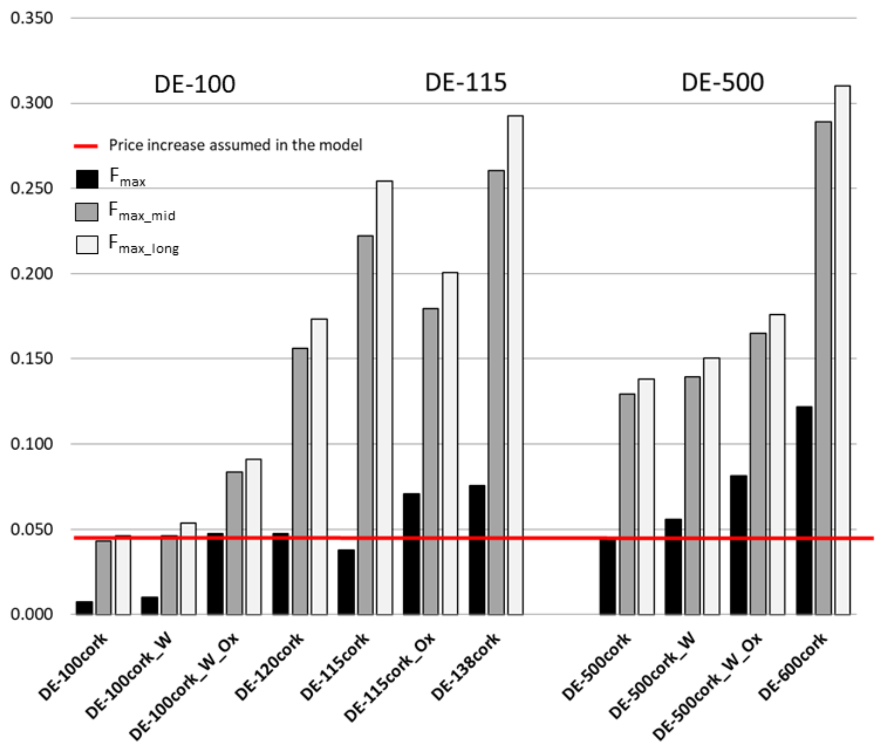
Furthermore, to calculate the threshold additional price in mid-terms (F_{max_mid}) and long-terms (F_{max_long}), the depreciation (D) and the opportunity costs (O) have to be subtracted from F_{max}.

$$F_{max\_mid} = F_{max} - D$$

$$F_{max\_long} = F_{max} - D - O$$

For operations of DE-100^{cork}, DE-100^{cork_W} and DE-115^{cork} to be least as profitable in the short term as the original farm using conventional feed, the price for cork-feed has to be lower than that assumed for DE-100.

Figure 9: Maximum price increase for cork-enriched feed that does not endanger initial profitability in €/kg LW

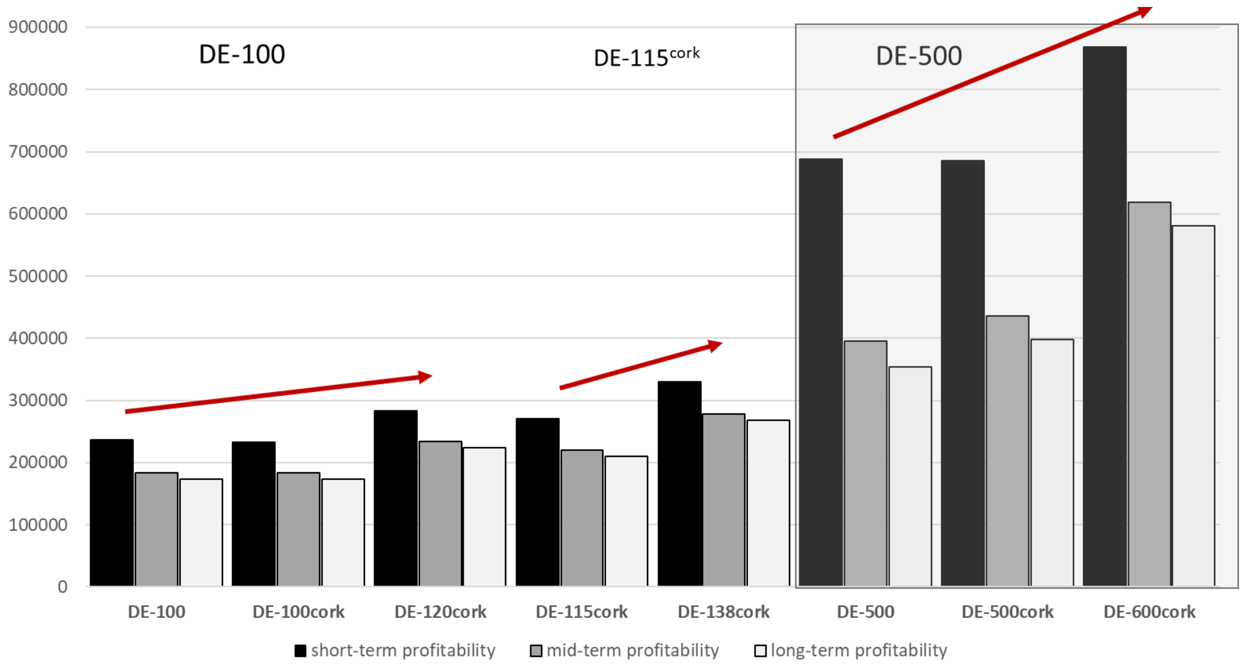


In the short term DE-100^{cork_W_Ox} and DE-120^{cork} as achieve similar profitability to their initial operation (s. Figure 9). Much the same can be said for DE-500^{cork}, while all other variations of DE-500 (taking account of reduced labor, reduced oxygen demand and increased production) are able to absorb feed price increases of up to 12 cents per kg (see also Annex Figure 11). Considering all operational costs (depreciation, opportunity costs and running expenses) the margin for additional cork feed prices varies for DE-100 between 5 cents per kg for DE-100^{cork} and 29 cents per kg forDE-138^{cork}. For DE-500 it varies between 14 (DE-500^{cork}) and 31 cents per kilo (DE-600^{cork}). Thus with a production increase of 20 % achieved through the use of cork feed, the model farms DE-100 and DE-500 can improve their long term profitability in the face of feed price increases of 29 and 31 cents per kg, respectively.

5 Conclusion

Given that feed is the most important outlay in trout farming, the expense of the cork feed system initially leads to heavy losses or marginal returns and declining operational results in all modeled scenarios. DE-100, which already deploys a less costly settling pond to treat its waste is especially severely affected, whereas trout farms using micro sieves and cost intensive settling ponds, such as DE-500, can compensate for part of the higher feed price and counterbalance the costs with economies of scale in feed purchasing (quantity discount) and lower investment costs, which free up depreciation and opportunity costs for capital in the medium- to long-term. The further scenarios considered herein bring in other factors that reflect still more favorably on the potential of the innovative cork feed.

Figure 10: Profitability of selected model farms in different scenarios and trends in long-term profitability for three types of farms in €



The opportunity to reduce labor (scenario 1), reduce labor and oxygen demand (scenario 2) and increase productivity by 20 % (scenario 3) indicate that cork feed has potential to increase profitability (cf. Figure 10). For farm DE-100, the improvements are small - about 1 cent per kg trout, and only apparent in the medium term when achieving 20 % production increase. In the larger scale DE-500, whose mid-term profitability is maintained despite the cost of conversion to cork feed (scenario 0) even before the cost saving scenarios are taken into account, the potential improvements are significant. Assuming a 10 % reduction in labor and a one third reduction in technical oxygen use, a surplus profit of 5 cents per kg trout can be achieved (scenario 2). The best long-term profitability is reached by DE-500 in scenarios 2 and 3, either through the long-term reduction of work and oxygen or through a 10 %production increase.

By German standards, DE-100 and DE-500 are both relatively large, modern trout farms, exhibiting good practice and a highly professional management. They use modern facilities and state of the art technology. The results of the current study lead us to conclude that the use of cork-enriched feed, with feed costs of € 1.44 per kg trout, is not profitable for smaller operations. The cost reductions for machinery, maintenance, energy and depreciation are insufficiently large to make up for the increased and variable costs of the new feed, and a production increase of more than 20 percent would be required to compensate for the additional feed price in an operation such as DE-100, which produces 100 tons of rainbow trout. For operations this size and smaller, prices for the new cork feed would have to fall to a level comparable to that of conventional feed – around € 1.32 per kg at the time of this study – before an investment in change became worthwhile. The picture for large farms using cost intensive filtration techniques however, is very different. In models based on DE-500, increased profits can be achieved relatively fast, even under current levels of production. If an increase in production is achieved, then the cork feed makes a highly economic alternative to conventional feed.

A question remains over how the cork prices would develop if demand for cork-enriched fish feed were to increase, given that cork is a limited resource. The ability to absorb a feed price development is limited and variable for the different model farms. According to one of the leading global suppliers of cork (Amorim, Portugal; D. Zimmermann, pers. Comm.), prices would be expected to drop after an increase in demand and quality (which currently has room for improvement in the special context of aquaculture feed) should increase, thereby reducing the quantity required in order to achieve floating feces. The price drop would be based on upscaling of the production process and reduced production costs (pers. comm., Zimmermann, Amorim) and the quality increase by improved screening processes. A supply bottleneck would only be expected at the point where the entire European salmonid aquaculture sector converted to a cork-feed system, which does not appear to a realistic prospect in foreseeable future.

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7 Annex

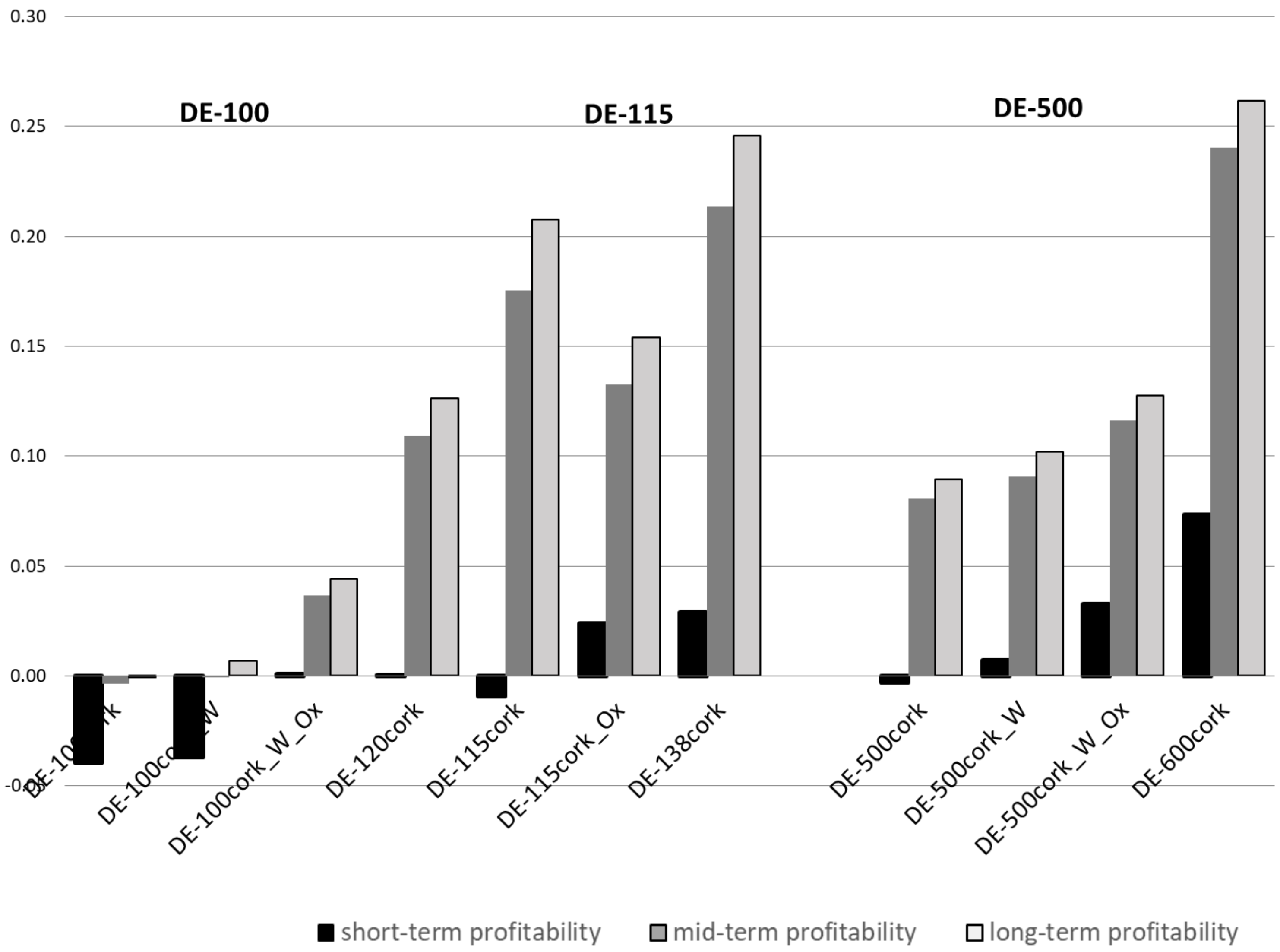
Table 6: Overall account for different scenarios of trout mast of the model farms DE-100 and DE-500 in €

Scenarios	DE-100					DE-115^{cork}			DE-500				
	DE-100	DE-100^{cork}	DE-100^{cork_W}	DE-100^{cork_W_Ox}	DE-120cork	DE-115cork	DE-115cork_Ox	DE-138cork	DE-500	DE-500^{cork}	DE-500cork_W	DE-500^{cork_W_Ox}	DE-600^{cork}
Total returns	**448,747**	**448,747**	**448,747**	**448,747**	**538,496**	**516,059**	**516,059**	**619,271**	**1,650,000**	**1,650,000**	**1,650,000**	**1,650,000**	**1,980,000**
- Variable costs	191,612	196,352	196,352	192,598	233,506	224,225	220,407	266,886	782,771	800,373	800,373	787,573	947,125
Thereof feed	132,000	136,740	136,740	136,740	164,088	157,251	157,251	188,701	575,000	599,550	599,550	599,550	719,460
Stocking	32,650	32,650	32,650	32,650	39,180	37,547	37,547	45,057	134,211	134,211	134,211	134,211	161,053
Oxygen	11,261	11,261	11,261	7,507	11,511	11,456	7,637	11,681	38,400	38,400	38,400	25,600	38,400
= Contribution margin	**257,135**	**252,395**	**252,395**	**256,149**	**304,990**	**291,834**	**295,652**	**352,385**	**867,229**	**849,627**	**849,627**	**862,427**	**1,032,875**
- Fixed costs		16,089	16,089	16,089	17,334	17,100	17,100	18,200	112,532	99,109	99,109	99,109	99,375
Thereof maintenance machinery	6,267	5,620	5,620	5,620	5,878	6,000	6,000	6,194	86,100	72,677	72,677	72,677	72,871
= Operating profit	**240,399**	**236,306**	**236,306**	**240,060**	**287,657**	**274,733**	**278,552**	**334,185**	**754,697**	**750,517**	**750,517**	**763,317**	**933,500**
- Wages	2,754	2,754	2,478	2,478	2,815	2,801	2,801	2,856	51,000	51,000	45,900	45,900	51,000
- Interests costs	1,367	1,292	1,292	1,292	1,321	1,339	1,339	1,365	15,725	13,361	13,361	13,361	13,396
= Short-term profitability	**236,279**	**232,261**	**232,536**	**236,290**	**283,521**	**270,593**	**274,412**	**329,963**	**687,972**	**686,157**	**691,257**	**704,057**	**869,103**
- Depreciation	52,682	49,088	49,088	49,088	50,179	50,587	50,587	51,579	292,636	250,793	250,793	250,793	250,793
= Mid-term profitability	**183,596**	**183,172**	**183,448**	**187,201**	**233,342**	**220,006**	**223,825**	**278,384**	**395,336**	**435,364**	**440,464**	**453,264**	**618,311**
- Opportunity costs	9,978	9,703	9,218	4,363	9,918	9,961	9,961	10,157	42,115	37,729	36,529	36,529	37,798
Long-term profitability	**173,618**	**173,470**	**174,230**	**182,838**	**223,423**	**210,045**	**213,864**	**268,228**	**353,221**	**397,635**	**403,935**	**416,735**	**580,513**

Table 7: Overall account for different scenarios of trout mast of the model farms DE-100 and DE-500 in €/kg live weight

Scenarios	**DE-100**						**DE-115^{cork}**		**DE-500**				
	DE-100	DE-100^{cork}	DE-100^{cork_W}	DE-100^{cork_W_Ox}	DE-120cork	DE-115cork	DE-115cork_Ox	DE-138cork	DE-500	DE-500^{cork}	DE-500cork_W	DE-500^{cork_W_Ox}	DE-600^{cork}
Total returns	**4.49**	**4.49**	**4.49**	**4.49**	**4.49**	**4.49**	**4.49**	**4.49**	**3.30**	**3.30**	**3.30**	**3.30**	**3.30**
- Variable costs	1.92	1.96	1.96	1.93	1.95	1.95	1.92	1.93	1.57	1.60	1.60	1.58	1.58
Thereof feed	1.32	1.37	1.37	1.37	1.37	1.37	1.37	1.37	1.15	1.20	1.20	1.20	1.20
Stocking	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.27	0.27	0.27	0.27	0.27
Oxygen	0.11	0.11	0.11	0.08	0.10	0.10	0.07	0.08	0.08	0.08	0.08	0.05	0.06
= Contribution margin	**2.57**	**2.52**	**2.52**	**2.56**	**2.54**	**2.54**	**2.57**	**2.55**	**1.73**	**1.70**	**1.70**	**1.72**	**1.72**
- Fixed costs	0.17	0.16	0.16	0.16	0.14	0.15	0.15	0.13	0.23	0.20	0.20	0.20	0.17
Thereof maintenance machinery	0.06	0.06	0.06	0.06	0.05	0.05	0.05	0.04	0.17	0.15	0.15	0.15	0.12
= Operating profit	**2.40**	**2.36**	**2.36**	**2.40**	**2.40**	**2.39**	**2.42**	**2.42**	**1.51**	**1.50**	**1.50**	**1.53**	**1.56**
- Wages	0.028	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.10	0.10	0.09	0.09	0.09
- Interests costs	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.03	0.03	0.03	0.03	0.02
= Short-term profitability	**2.36**	**2.32**	**2.33**	**2.36**	**2.36**	**2.35**	**2.39**	**2.39**	**1.38**	**1.37**	**1.38**	**1.41**	**1.45**
- Depreciation	0.53	0.49	0.49	0.49	0.42	0.44	0.44	0.37	0.59	0.50	0.50	0.50	0.42
= Mid-term profitability	**1.84**	**1.83**	**1.83**	**1.87**	**1.94**	**1.91**	**1.95**	**2.02**	**0.79**	**0.87**	**0.88**	**0.91**	**1.03**
- Opportunity costs	0.10	0.10	0.09	0.09	0.08	0.09	0.09	0.07	0.08	0.08	0.07	0.07	0.06
Long-term profitability	**1.74**	**1.73**	**1.74**	**1.78**	**1.86**	**1.83**	**1.86**	**1.94**	**0.71**	**0.80**	**0.81**	**0.83**	**0.97**

Figure 11: Marginal price increase for cork-enriched feed in terms of short-, mid- and long-term profitability of selected model farms (€/kg LW)



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