Chapter 2
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The Power of Transdisciplinary Research for Business Innovation: The Case of Rooibos as a Potential Ergogenic Sport Drink

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ABSTRACT

Background: The Centre for Sport Business and Technology Research (CSBTR) and the Applied Microbial and Health Biotechnology Institute **(**AMHBI) at the Cape Peninsula University of Technology (CPUT) are mandated to conduct excellent research with a strong multi- and transdisciplinary focus. Based of the shared expertise of these two research entities a transdisciplinary approach was adopted to best facilitate the study.
Research objective: To investigate whether Rooibos with its unique bioactive compounds modulates oxidative stress and potentially facilitates improved physical performance, with an application as an ergogenic sport drink. Due to the nature of this unique scientific-business collaboration, various beneficial social-economic outcomes were anticipated.
Methodology: Two experimental studies were conducted, the first included thirty-two male participants and the second 30 male participants, both studies were randomized in a blinded, cross-over controlled trial in which participants ingested standardized Rooibos or a placebo drink. The first study involved an upper body maximal fatiguing elbow flexion/extension exercise test entailing 5 sets of 15 repetitions of maximum voluntary contractions separated by 10-second rest intervals on a Biodex System 3 at a speed of 60º per second. The second study involved a lower body modified sub-maximal test and then repeated sprints on a Wattbike cycle-ergometer. Ethical approval was granted for both studies.
Results: During exercise tests on both the upper and lower body preliminary results showed that after ingesting Rooibos various improvements in physical

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performance were observed, notably the generation of higher peak torque in the upper body test and improved endurance during the lower body test, along with modulation of oxidative stress.
Implications: There is an opportunity to develop a scientifically proven sport drink, which could beneficiate the Rooibos industry and the sport/fitness community with a high value product. Furthermore the media and marketing opportunities to promote Rooibos in the high profile sport drink industry could provide increased revenue generation. These developments can ensure better economic and social sustainability of the sector and also support broader responsibilities in terms of the fair and equitable sharing of the benefits arising out of the utilisation of indigenous biological resources.

Keywords: Transdiscipinary; rooibos; indigenous; sport drink; ergogenic; policy; product; marketing; benfit-sharing.

1. INTRODUCTION

The terms transdisciplinary and transdisciplinarity have 50-year history with a significant elevation of the concept following a conference on interdisciplinarity in 1970, and follow up publications on a systems approach to education and innovation by Erich Jantsch and the epistemology of interdisciplinary relationships by Jean Piaget [1,2].

The interest in transdisciplinary research (TDR) has grown over time and has been driven by differing schools of thought and perspectives, which has resulted in numerous definitions [3]. As a consequence there exists some ambivalence around a universally accepted definition of transdisciplinarity [4]. Thus it is necessary to acknowledge that there are varying definitions and understandings of "multidisciplinary", "interdisciplinary" and “transdisciplinary” research, and furthermore that the terms are often used interchangeably.

In order to provide some clarity for the purpose of this paper, it is useful to reflect on the opinion by Lawrence et al. [5] who assert that it is “not sensible to choose one or even a few representative definitions”, however the same authors following a review of widely cited definitions have sought to summarise the key characteristics of transdisciplinary research, namely:

1) A focus on theoretical unity of knowledge, in an effort to transcend disciplinary boundaries;
2) The inclusion of multidisciplinary and interdisciplinary academic research;
3) The involvement of (non-academic) societal actors as process participants;
4) A focus on specific, complex, societally relevant, real world situations or problems;
5) Working in a transformative manner, i.e., going beyond the focus on real-world problems to proactively support action or intervention;
6) An orientation toward the common good (including the betterment of society and a humanistic reverence for life and human dignity);

7) Reflexivity, i.e., consciously contemplating the broader context and ensuring the compatibility of the project's components and tasks throughout the course of the project.

A straightforward characterisation of transdisciplinary studies by Tempelhoff, [5] suggests that it is all about collaborative work, mutual respect for disciplinary boundaries, and the need to foreground ideas and inculcating their complexity by working with all role players towards the co-construction of meaningful science. It is also important to acknowledge that while the key objective(s) of this study were considered within generally accepted scientific paradigms and methodological design approaches, as Van Zyl [6] points out in his paper entitled 'Towards a unified concept of transdisciplinary research' these approaches in themselves are insufficient in scope to address complex real-world problems. These problems include the climate crisis, systemic oppression, poverty, inequality and warfare. Thus the interrelated deliberations, notably the fair and equitable sharing of the benefits arising out of the utilisation of indigenous biological resources relies on elevating discussions on social-economic factors in tandem with the scientific endeavour of the study.

In South Africa, the field of transdisciplinary research has flowered, especially in the fields of sustainability studies; health and medicine; environmental studies and in various branches of the humanities, social and natural sciences [7]. Leading South African researchers have found that in our country we may have to resort to adjustments to the way in which we conduct transdisciplinary research. This may also be the case for the rest of Africa and even the Southern Hemisphere countries of the globe. This point is made because we have increasingly gained insights on indigenous knowledge, African culture and the way in which post-colonial ideas have been shaping the fields of education, governance, management, politics, sociology, economics and technology studies [5].

2. THE CONCEPTUAL TRANSDISCIPLINARY RESEARCH PROCESS ADOPTED FOR RESEARCH

The conceptual transdisciplinary research process for the present scope of research into the efficacy of Rooibos as an ergogenic sport drink and/or supplement was premised on the model developed by Jahn et al. [8] and Bergmann et al. [9] with the depiction shown here as Fig. 1, adapted from Lang et al. [10].

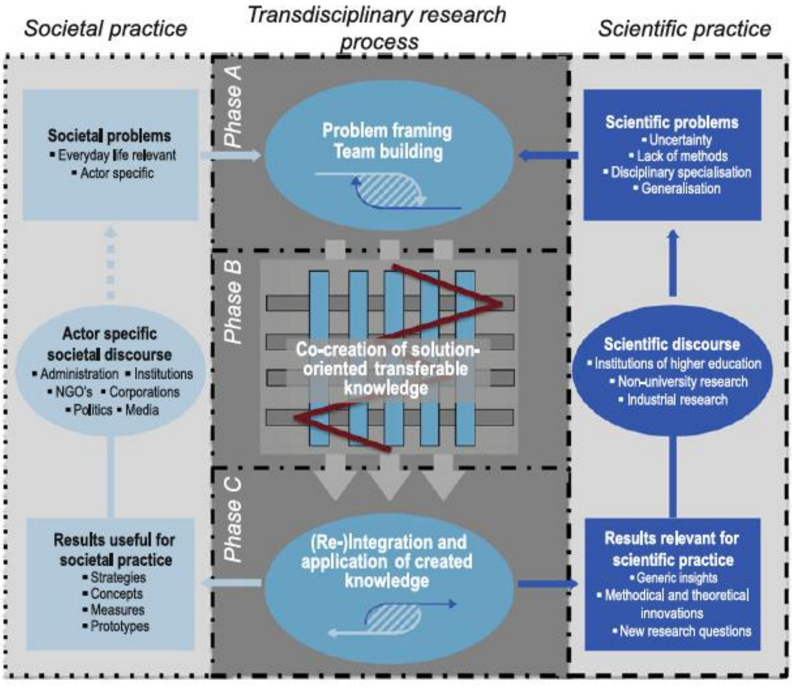

Fig. 1. Depiction of a conceptual model of an idealized transdisciplinary research (TDR) process. Adapted from Lang et al. [10]

In order to familiarise the reader of this paper to the various aspects that were integrated into this TDR project, the following sections seek to elucidate these key elements, along with the latent historical factors and policy / legislative implications that impact on the present project, which furthermore shape and develop what is an evolving study.

3. BACKGROUND TO THE STUDY

The present ongoing transdisciplinary study is located at the Cape Peninsula University of Technology (CPUT), which was formed in January 2005, following the enactment of the National Plan for Higher Education in which the state played a strongly directive role, which sought to recast the higher education landscape through extensive incorporations and mergers [11]. The restructuring of higher education in South Africa was implemented to redress the previous iniquitous higher education landscape based on Apartheid policy. This involved 'establishing a higher education system that is consistent with the vision, values and principles of nonracial, non-sexist and democratic society and which is responsive and contributes to the human resource and knowledge needs of South Africa' [12].

Within this directive two existing autonomous higher education institutions in the City of Cape Town, South Africa, namely the Peninsula Technikon and the Cape Technikon were merged to form the Cape Peninsula University of Technology, which is now the largest higher education institution in the region, boasting of more than 30,000 students, several campuses and service points and more than 70 academic programmes [13]. The merger was underpinned by the institutional vision statement 'to be at the heart of technology education and innovation in Africa' [14]. The revised strategic direction emphasised the transition from a vocational and technical educational paradigm to a University of Technology prioritising research.

The evolvement of research capacity at CPUT included the introduction of 'research entities'. The CPUT institutional preamble indicates that over and above the formal university structures, it has become international best practice to establish other formal academic structures to promote research, technology transfer, non-formal teaching and community service and outreach programmes. These structures form a hub of centres of excellence in research and teaching at universities. In the CPUT context, a major purpose of these structures is to expand and enhance the research, non-formal teaching, community service and outreach opportunities of an engaged university in ways that are not readily possible within faculties [15].

In addition, CPUT research entities are designed to provide the infrastructure that harnesses some of the unique characteristics of a University of Technology. The entities contribute to the development of collaborative strategies that enable CPUT to carry out its education, research and service missions in a productive and resource-efficient way. The university's research strategy aligns these research entities to its research focus areas and research chairs. Whilst CPUT research institutes are institutional and cross-faculty in support of the trans-disciplinary approach, other research entities such as Centres and Units are hosted in faculties or academic departments [16].

Within this institutional context, with an acknowledged predisposition towards a trans-disciplinary approach the following research entities were instituted, namely the Centre for Sport Business and Technology Research (CSBTR) which is housed within the Sport Management Department in the Faculty of Business and Management Sciences and the Applied Microbial and Health Biotechnology Institute (AMHBI), which is housed within the Biomedical Science Department in the Faculty of Health and Wellness Sciences. Both research entities are mandated to conduct excellent research with a strong multi- and transdisciplinary focus [16]. On the basis of the shared expertise of these two research entities a research objective was developed to investigate whether Rooibos with its unique bioactive compounds modulates oxidative stress and potentially facilitates improved physical performance, with an application as an ergogenic sport drink and/or supplement. Due to the nature of this unique scientific-business collaboration, with the research focussing on Rooibos (*Aspalathus linearis*) various beneficial outcomes were anticipated in terms of:

- Scientific advancement
- Rooibos as sport drink with proven scientific properties
- Rooibos as a supplement / sport drink with ergogenic properties (performance enhancement)
- Potential economic benefits by establishing a niche product in the sport drink industry
- Providing scientific rationale to optimise traditional biological resources e.g. Rooibos and provide benefits to indigenous communities
- Enhance the benefits to be derived from Protection Designation of Origin (PDO) status etc.

4. ROOIBOS (*Aspalathus linearis*): PREAMBLE

Rooibos (meaning Red bush in Afrikaans) is a broom-like plant that is scientifically referred to as *Aspalathus linearis*. It is renowned for its beverage quality and is the raw material for the globally popular Rooibos herbal tea. Rooibos is endemic to the Cederberg region, located approximately 200km to the north of Cape Town, South Africa [17]. According to Joubert and de Beer [18] the first person to realise the commercial potential of rooibos as a herbal tea was Benjamin Ginsberg, a merchant of Clanwilliam, who started marketing it in 1904. He obtained the tea from descendants of the Khoi who crudely processed it during the warm summer months. A study by the South African government indicated that the Khoi and San indigenous peoples appear to be the first users of Rooibos as a beverage [19]. The Department of Environmental Affairs in the same study have intimated that traditional knowledge (TK) in the use of Rooibos was likely passed down from generation to generation by the Khoi and San indigenous people before the arrival of Europeans settlers in South Africa, however this assertion is not based on empirical evidence

Rooibos is naturally caffeine free and contains very low levels of tannins when compared to the *Camellia sinesis* teas [20-22]. Since its first documented use in the 1700s, it is interesting to note that Rooibos has been linked to numerous health promoting properties, however, human studies dealing with the health promoting aspects of Rooibos and the bioavailability of rooibos flavonoids, especially aspalathin, have been limited to date [18].

Interestingly Marnewick et al. [23] in their research not only confirmed the popular use of Rooibos, but also that the consumption of fermented, traditional Rooibos significantly improved the lipid profile as well as redox status of individuals who consumed Rooibos in a controlled study, which is relevant to heart disease and for adults at risk for developing cardiovascular disease. Such findings provide substance and support for the popularity of Rooibos as a health beverage not only locally but also internationally.

Rooibos is an important dietary source of antioxidants containing mostly flavonoids, but also the unique C–C linked dihydrochalcone glucoside, aspalathin [24] and the cyclic dihydrochalcone, aspalalinin [25]. Numerous studies have reported on the *in vitro* antioxidant activity of Rooibos, using various types of extracts of Rooibos in a number of different assay systems [26-31], as well as *in vivo* activity in experimental rats [32]. Rooibos has been shown to be antimutagenic [33,34], cancer modulating [35,36] and to regenerate coenzyme Q10 with the resultant inhibition of lipid peroxidation in rat liver [37].

Observational studies linking high dietary intake of plant foods and beverages with a lower incidence of cardiovascular disease (CVD) and other chronic diseases suggest the association may be attributed to the polyphenolic antioxidants in these foods [38-41].

Rooibos, prepared from the leaves and stems of *Aspalathus linearis*, is an important source of antioxidants due to its flavonoid content [42]. The results from the study led by Marnewick and co-workers [23] showed that the dietary intervention with Rooibos modulated not only the serum lipid profile of the participants by significantly decreasing the triacylglycerol and LDL-cholesterol levels and increasing the HDL-cholesterol level, but it also improved the redox status as shown by the increased GSH:GSSG ratio and reduced lipid peroxidation as shown by the significant reduction of the CDs (34.9%) and the TBARS (52%) [23].

The study by Marnewick and colleagues provided the first clinical evidence in humans that chronic consumption of Rooibos for 6 weeks significantly improved several biomarkers of blood lipid status. In addition, this study also provides supporting evidence that Rooibos reduced oxidative stress by significantly decreasing lipid peroxidation and improving the redox status of adults at risk for developing CVD. Furthermore results from the study by Marnewick and co-workers contribute to our present understanding of the health promoting properties of Rooibos and these authors further assert the findings warrants further studies in this field.

It is also equally important to implement acceptable quality assurance systems among farmers to ensure that a high and consistent quality of rooibos is produced so that consumers are protected from harmful and low-quality products. Van Zyl et al. [43] argued that it was important to build an environment in the rooibos industry that enhances the sustainable impact on various stakeholders, such as suppliers, customers, and export agencies, as this could likely influence the implementation of quality assurance systems.

Given the unique bioactive compounds of Rooibos a rich source of antioxidants it was speculated that the outcomes reported by Marnewick in 2011 and other studies may have beneficial applications not only for health, but also in terms of improving exercise performance and modulating post exercise redox level, or in other words a reduction in the post exercise inflammatory stress on the body.

5. INDIGENOUS BIOLOGICAL RESOURCES: THE CASE OF ROOIBOS

Within the international biodiversity and biotrade economy arena, the Convention on Biological Diversity (CBD) came into force in 2003 as a multilateral treaty with the purpose to structure conservation strategies in participating countries aimed at the sustainable use of genetic resources and conserving the biodiversity, as well as to ensure that the sharing of benefits resulting from the use of biological and genetic resources is done in a fair way. The CBD further oversees an inclusive framework aimed to prevent any further loss to biodiversity by focusing on the conservation of biodiversity; the sustainable use of genetic resources; and fair and equitable benefit-sharing as a result of using the genetic resources [44].

The implementation of the objectives of the CBD has resulted in the creation of the Nagoya Protocol as a legal framework; and South Africa became signatory to the Nagoya Protocol in January 2013. This legal framework addresses the concept of Traditional Knowledge (TK) and Indigenous Knowledge (IK) in relation to the use of genetic resources; stipulates certain compliances relating to Prior Informed Consent (PIC) and mutually agreed terms; and specify the conditions for granting access, and the benefit-sharing and compliance obligations. The benefit-sharing regulations aim to reduce the current disparity between developing and developed nations regarding benefit-sharing as a result of the commercial utilisation of the genetic resource [45]. These regulations are captured in the Bonn Guidelines on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising Out of Their Utilization; and further aims to ensure that access to genetic resources is based on mutually agreed terms and conducted in a fair and transparent way [46].

In summary the Convention on Biological (CBD) was a breakthrough in global policy making. It combined a concern for the environment with a commitment to resolving longstanding human injustices regarding access to and use of biological resources. The CBD aims to conserve biodiversity, achieve its sustainable use, and reward its custodians with fair and equitable benefit sharing [44].

Against a backdrop of inequality enforced by the former apartheid regime, the high conservation value of the country's biodiversity, and an interest in sustainably developing the nation's natural resources for economic development, South Africa ratified the United Nations Convention on Biological Diversity (CBD) in 1995 [47]. The 2004 South African National Environmental Management Biodiversity Act (NEMBA) furthermore prescribed that benefits from the use of biological resources are shared with the holders of TK, in particular indigenous communities [48]. The rights of indigenous peoples and holders of traditional knowledge were also strongly recognized, and bioprospecting was conceptualized as an important mechanism to create incentives for conservation [47].

In practice, however, Wynberg [47] points out that confusion reigns about the distinctions between biological and genetic resources, especially where species such as Rooibos have multiple uses in more than one sector. For example, research and development on Rooibos for new foods, beverages and botanical medicines might include original research on genetic resources and traditional knowledge [18]. At this stage, under the CBD, these activities would be characterized as bioprospecting, or genetic resource use. After companies have investigated new properties or traditional knowledge, demand very quickly shifts into the biological resource trade, or biotrade. Fig. 2 illustrates some of the distinctions and overlaps between these different activities.

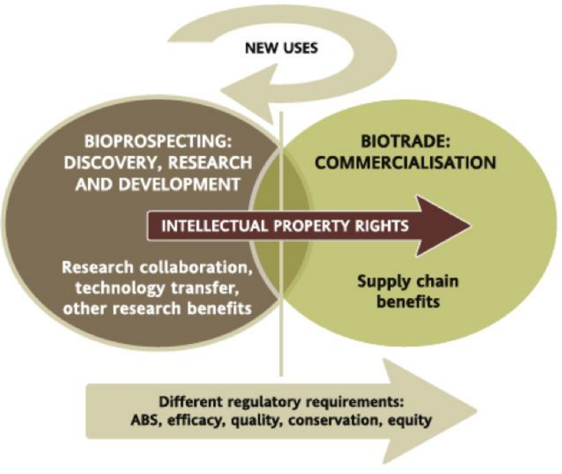

Fig. 2. Distinctions and overlaps between bioprospecting and biotrade [47]

A positive consequence of these legislative and policy developments was the signing of an Access and Benefit-sharing (ABS) agreement between the Rooibos Industry, represented by the South African Rooibos Council (SARC) and the Khoi-Khoi and San, represented by the National Khoi-San Council (NKC) and the South African San Council (SASC). This agreement will see the Khoi-Khoi and San communities benefit from the commercialisation of Rooibos [49]. The Rooibos Benefit Sharing Agreement (RBSA) was the first comprehensive, industry-wide benefit sharing agreement, and globally without parallel. It is exceptional as it not only spans an entire industry, but also because the product is already on the market Schoeder et al. [44].

One also needs to acknowledge the business and marketing acumen of key role players in the South African Rooibos industry, notably the South African Rooibos Council, which saw Rooibos receiving the important commercial registration for Protection Designation of Origin (PDO) in the EU. The Premier of the Western Cape, Alan Winde said: "I welcome the collaboration between the Western Cape Government, the Rooibos industry and the European Union, which has ensured that Rooibos is registered as a PDO. Rooibos is now the first African product to receive PDO status from the EU which will afford greater access to the industry." [50].

The rationale for the registration of Rooibos as PDO is made by Dawie de Villiers, the legal director of the South African Rooibos Council, who said: "As an industry we recognise the close connection between Rooibos, the area where it grows, as well as the community and their traditions. Our goal is to protect, support and promote the sustainability of not only Rooibos, but the rich heritage of the industry as a whole, which is why we so doggedly pursued the registration. Rooibos also forms part of SA's rich biodiversity, and we believe that the registration will make way for other indigenous species, such as Buchu and Aloe ferox to also be indicated as PDOs and reap similar rewards"[50].

Therefore as a signatory to the Nagoya Protocol, and the other aligned legislation and policy evolvements both globally and nationally South Africa requires industries that trade in indigenous biological resources, such as Rooibos, to share benefits with traditional knowledge holders in a fair and equitable way.

6. EXERCISE AND OXIDATIVE STRESS

There continues to be considerable debate regarding the effect of antioxidant supplementation on oxidative stress during exercise in humans. Clarkson and Thompson [51] ask the question "Are antioxidant supplements necessary for individuals who exercise regularly?" Kanter [52] makes the assertion that habitual physical activity promotes a number of adaptations that have an overall positive effect on the body. Despite the undeniable health benefits, exercise may increase mitochondrial formation of reactive oxygen species (ROS) and reactive nitrogen species (RNS), which may cause cellular damage [53]. When produced in excess, free radicals may promote cellular oxidation, damage in the DNA structure, aging and a variety of diseases [54]. These result in impaired skeletal muscle function and causes pain and thereby affects exercise performance [55].

At low and/or moderate concentration, reactive species (RS) are involved in physiological roles such as cellular signalling, defence against infectious agents, upregulation of endogenous enzymatic antioxidant activity to name a few [56]. At high concentration, RS may result in occurrence of oxidative stress (OS) and subsequently damage of macromolecules (lipid and DNA) and alteration of their functions [57] and decline of the antioxidant capacity of defence systems. Living organisms are equipped with a complex network of an antioxidant defence system that can neutralise and/or stabilise these RS [58]. However, once the defence system fails or gets compromised due to depletion of endogenous antioxidant enzyme or due to diseases, ageing or inadequate dietary antioxidant intake this could as well leads to OS [59,60]. Thus, it is advisable to continuously replace the antioxidant sources in the body, through intake of naturally rich antioxidant supplements, so that when the body is subjected to great redox imbalance, it will be in a better position to defend itself.

Generally, during exercising, high volume of oxygen is taken up by body due to high energy demand. This subsequently increases RONS generation resulting in exercise-induced OS, fatigue, muscle damages and overall poor exercise performances and recovery. Surprisingly, to date, there still no official protocol/approach/practice to prevent or mitigate exercise-induced ailments [61]. Nonetheless, many athletes opt to use some nonspecific treatment and preventative approaches such as the use of synthetic drugs. However, the safety and efficacy of these drugs have been questioned by some studies [62,61]. Moreover, these drugs are stimulants, very expensive, can only be obtained through a medical doctor prescription and some have been made known to cause serious side effects and lack tolerance in certain individuals. Therefore, novel interventions are needed to supplement or substitute the use of synthetic drugs. Hence, it is of great need to identify and develop safer, more effective, and well-tolerated non-prescription prophylaxis procedures or preventative approaches.

In this regard, focus on recognising the efficacy of natural bioactive herbals or phytomedicines with antioxidant, anti-inflammatory and anti-fatigue properties could be of great importance. For the past 2 – 3 decades, scientific research into natural products of phytochemicals polyphenol-rich compounds has increased dramatically due to their numerous bioactive properties, including positive health impacts. Moreover, currently, there's increasing trend world-wide in consumers shifting to natural remedies as preventative strategies in the maintenance of health, hence, the use of natural plant products as a means of modulating exercise-induced OS pathologies and other related exercise ailments emerge to have several advantages over synthetic drugs, because natural plant products: a) are easily accessible, b) contain unique compositions of various bioactive, c) low or no toxicity, d) can react to most or all types of reactive species, and e) are more compatible to normal human physiology [63,64,65].

A study by Marnewick et al. [66] profiled a number of oxidative stress biomarkers, as well as exercise performance indicators to assess the efficacy of an acute dose of Rooibos in altering these biomarkers and performance outcomes. Forty healthy adult male volunteers were randomized in a single blinded, cross-over study. They consumed a standardized breakfast snack and an acute dose of antioxidant in the form of three capsules of a fermented/traditional Rooibos extract or placebo before undergoing a muscular isokinetic strength fatiguing trial. Muscle fatigue was induced using elbow extension/flexion test on the Biodex (15 repeats, 5 sets). The results for isokinetic strength performance showed significantly increased total work ($P = 0.019$), average power ($P = 0.021$) and average peak torque ($P = 0.01$) during the 2nd extension when comparing Rooibos with placebo. When considering the blood oxidative stress biomarkers, Rooibos significantly decreased the levels of conjugated dienes at all 5 time points when comparing with the placebo. Rooibos also significantly enhanced ($P < 0.05$) the antioxidant capacity (ORAC) (4–5%). The researchers concluded that an acute dose of Rooibos appears to be protective against exercise-induced oxidative stress, by minimizing the oxidative damage to that of baseline levels possibly due to an enhanced defence system, and may have contributed to improved exercise markers.

The field of sports and exercise science has prioritized research into nutritional strategies to optimise performance and from these investigations best-practice evidence-based recommendations and position stands have been developed [67]. It is becoming increasingly apparent that many athletes and sports professionals are ingesting plant phytochemicals with known antioxidant qualities in an attempt to minimise the effects of oxidative stress during physical activity, including Rooibos *Aspalathus linearis* [23]; ginkgo biloba (Rong et al. 1996); as well as oligomeric proanthocyanidins (OPCs), and polymers of flavanols found in grape extract [68].

Rooibos may also play a role in the possible prevention and/or attenuation of exercise-induced OS effects as well as improving exercise performance and recovery [69,65,70] (Davies et al. 2011), hence its consideration for the current study. Although the antioxidant effects of Rooibos herbal tea have been investigated and well documented [35,23,69,71,72], it's anti-fatigue and immunomodulatory effects in human in relation to exercise-induced OS have rarely been studied, thus, to date, no study has reported on the modulation of exercise-induced oxidative stress using Rooibos herbal tea extracts and it is suggested this warrants further attention.

7. SPORT DRINKS

Sport and energy drinks form a substantial component in the leisure beverage industry, which Thorlton et al. [73] estimated was worth around $52 billion in 2016, with growth to US$ 98 Billion in 2021, and the market expected to reach US$ 149.8 Billion by 2027 [74]. The production and sale of sport and energy drinks according to Coombes and Hamilton, [75] is a lucrative and competitive industry, as demonstrated by the rapidly growing variety of products being marketed, each with claims of benefits superior to rival beverages. The worldwide demand for sports drinks is immense.

Obviously sports and energy drinks mean different things to different people. In its simplest sense, a sports drink and by inference an energy drink is consumed in association with sport or exercise – either in preparation for exercise, during exercise itself or as a recovery drink after exercise. By definition, a drink is a liquid substance and as such, water is a main ingredient [76].

However, it is important at this point to also delineate the difference between sport drinks and energy drinks. The majority of mainstream sports drinks have a carbohydrate content close to 6% weight/ volume and contain small amounts of electrolytes, the main one being sodium [76]. While, in the United States the Food and Drug Administration [77] defines energy drinks (EDs) as “a class of products in liquid form that typically contains caffeine, with or without other added ingredients.” According to Reissig et al. [78] and Sepkowitz [79] many energy drink manufacturers add additional substances such as taurine, guarana, B vitamins, ginkgo, and various other herbal derivatives to their products. In doing so, they may (at least in the United States and other countries with similar regulations) be able to avoid FDA regulation by classifying their products as a supplement rather than a food item under the 1994 Dietary Supplement Health and Education Act, 8, thus legitimizing the higher caffeine content per serving [80].

A further issue to consider is that the sport and energy drink industry is replete with products with dubious pseudoscientific claims, driven by an industry with huge competitive global market worth approximately US$ 149.8 Billion by 2027. The extensive commercialization of sport and energy drinks may be more about making money than providing a beverage that facilitates exercise performance and /or recovery. This ambivalence is seen by the contrary positions taken by researchers. This divergence in opinion is summed up on the one hand by the claim by Von Duvillard et al. [81] who believe that fluid intake and adequate hydration are essential and more importantly critical during prolonged training sessions and competition events. The same authors go on to say that fluid intake helps to maintain hydration, body temperature (thermoregulations), and plasma volume and state that events lasting longer than 1 hour, athletes should consume fluids containing carbohydrates and electrolytes rather than water alone. The rationale for these assertions by Duvillard et al. [81] and other researchers who espouse this view is that reduction in body water, availability of carbohydrates, and an inadequate electrolyte balance during prolonged exercise events will hamper performance and according to may lead to serious medical disorders such as heat exhaustion or heat stroke. It is interesting to be aware however of the counter arguments made by Noakes [82,83] who disputes these claims, and states that the sports drink industry turned a normal physiological process – fluid loss from sweating – that evolved to protect humans against disease (heatstroke during exercise in the heat) into a novel disease ('dehydration') with a potentially fatal outcome ('dehydration-induced heatstroke'). Noakes suggests there is no good evidence that fluid ingestion during exercise plays any significant role in thermoregulation.

It should be noted that while iced teas are not necessarily viewed as sport drinks, ready-to-drink Rooibos iced tea is a popular variant in South Africa; however, its rooibos content is not regulated [18]. A study by Joubert et al. [84] found that some brands contained no aspalathin or its oxidation products, orientin and isoorientin, suggesting that no rooibos extract was used in their manufacture. In an attempt to understand the low levels of Rooibos flavonoids in commercial iced teas, a study was conducted to assess their stability in fermented [84] and green [85] Rooibos iced tea formulations during heat treatment. Pasteurisation or sterilisation is the most likely processing step during the manufacture of Rooibos iced teas that could decrease their flavonoid content. Pasteurisation caused no loss of rooibos flavonoids in fermented rooibos iced tea, but sterilisation markedly decreased the aspalathin and isoorientin contents [84]. However, Rooibos iced tea could make a valuable contribution to aspalathin intake if care is taken during formulation and processing. The bioavailability of aspalathin when present in a ready-to-drink Rooibos iced tea was recently demonstrated [18]. This research suggests that if Rooibos is prepared as an iced tea in a manner that retains aspalathin and isoorientin contents then there appears to be a reasonable opportunity to develop it as a sport drink.

Coombes and Hamilton [86] in their review article about the effectiveness of commercially available sports drinks note that during intermittent exercise, as well as prior to and during prolonged exercise, sport drinks appear to improve performance. However, the degree of how much performance improvement can be attributed to sport drinks is debatable and there is little evidence that any commercially available sports drink can be deemed superior to the others. The same authors assert that continued research is indicated to elucidate the role of sports drink use particularly in glycogen sufficient individuals and it is this recommendation that has spurred the present TDR project to investigate whether Rooibos with its unique bioactive compounds and antioxidant properties could be developed for production and marketed in the sport drink industry.

8. METHODOLOGY - OVERVIEW

The present TDR project presented in this paper embraces selected research findings from two aligned studies. Both studies utilised an experimental study and followed a randomised, blinded, placebo-controlled crossover design. This design suited the aims of the two and it enabled each participant to act, as self-control and helped to eliminate any possible biological variability. According to the Consolidated Standards of Reporting Trials (CONSORT) statement, controlled trials using a randomized allocation provide the best evidence for the efficacy of health care interventions, as it minimizes bias and confounding in trial testing clinical interventions [87,88].

The two studies conformed to the principles of the Helsinki Accord and were approved by the Institutional Faculty of Health and Wellness Sciences Research Ethics Committee at the Cape Peninsula University of Technology. The upper body exercise test in 2011 (Research ethics approval number: CPUT/HWS-REC2011/H02) and lower body exercise test in 2018 (Research ethics approval number: CPUT/HWS-REC 2018/H2). Written informed consent was provided by each of the study participants before starting the exercise trial regime. The participants were screened for adherence to the inclusion and exclusion criteria, completion of the health and fitness questionnaire and by taking their anthropometric measurements, resting heart rate, blood pressure and in the lower body exercise tests biochemical parameters including glucose, haemoglobin and cholesterol to determine their study eligibility. All participants followed familiarisation/habituation sessions in both the upper body and lower body exercise trials.

8.1 Methodology Upper Body Exercise Test

The sample included thirty-two adult male participants (mean age 22.20 years) who were required to ingest three standardized Rooibos or placebo capsules per day for four weeks prior to the exercise insult. The capsules contained a fermented Rooibos extract (standardized with a content of ~340 mg of total Rooibos polyphenols). The proposed dosage is equivalent to about six cups of Rooibos herbal tea per day and ought not to be perceived as a ‘megadose’ [89].

The exercise test employed involved isokinetic dynamometry, which has been commonly used for the evaluation of muscle strength in sports and medicine. Isokinetic dynamometers are widely used in sport and exercise testing protocols, especially if the study wishes to measure accurately the performance of a muscle and/or joint motion [90]. (see Fig. 3 of elbow-flexion test on Biodex System 3 dynamometer).

Fig. 3. Elbow-flexion test on Biodex System 3 dynamometer

The exercise test protocol for this study entailed a maximal fatiguing elbow extension/flexion exercise including 5 sets of 15 all-out voluntary contractions separated by 10-second intervals on a Biodex System 3 at a speed of 60º per second. The participant was placed in a seated position while the axis of rotation was through the centre of the trochlea and the capitulum, bisecting the longitudinal axis of the shaft of the humerus. The set-up and positioning of the participant including stabilising straps are fully described in the p.3-37 and p.3-38 of the Biodex System 3 Pro Operation Manual. The Biodex System 3 is recognised for its mechanical reliability and validity for exercise testing [91]. Depending on which phase of the study the participant had been randomly assigned (Rooibos or placebo), the protocol was repeated with a change in the supplementation regime.

8.2 Methodology Lower Body Exercise Test

Forty adult males were recruited into the study (mean age 25.95 years), and each consumed either the Rooibos or placebo beverages (375 mL) with a standardized snack (sandwich). The beverages intervention (placebo and Rooibos) were freshly prepared every day before the exercise session started. A commercially available peach and apricot flavoured powder was dissolved in 375 mL water and served as the placebo beverage. For the Rooibos beverage, 1.6 g of a commercially available standardized fermented Rooibos powdered extract were dissolved in 375 mL of the placebo beverage (peach apricot flavoured water). Thereafter the participants performed a modified submaximal ramp test followed by 10 sets of sprints, on a Wattbike cycle ergometer to induce oxidative stress. Each participant attended two sessions with 7 days apart as washout period. More specifically trial test protocol/procedure was as follows:

After an overnight fast (8 – 12 hours), participants reported to the study site and were given a light snack (162.8 g, four half slices of white bread topped with margarine, pastrami, and cheese) and consumed the 375 mL of either the Rooibos or placebo beverage. Ninety (90) minutes thereafter, research participants commenced with the modified Wattbike submaximal ramp test protocol as detailed below.

Warm-up:

- 5 minutes warm-up, at 50 – 60 rpm on air resistance setting 3 on the Wattbike Pro; Exercise test protocol induced oxidative stress
- Pedal in a seated position for 1 minute at the starting power of 100 watts (W), at a cadence rate of between 70 –100 rpm;
- Increase the air resistance setting and/or cadence as necessary every 1 minute to ensure a 15 W increase in power (W) output every 1 minute, this allowed the body to adapt to the increasing workload and steady rate heart rate to be achieved (at that level);
- Keep increasing the power (W) output by 15 W every minute until the rider reaches the rate of perceived exertion (RPE) of somewhat hard - level 13 on the Borg scale rate of perceived exertion and/or 80% of maximal heart rate;
- Or if the rider experiences any adverse symptoms, requests to stop or experiences an emergency;
- Once the participant reached level 13 on the Borg scale and/or heart rate was equivalent to 80% maximal effort, he stopped cycling for 1 minute and then asked to complete sets of 10 seconds sprints (10 max or until the participant reaches the RPE of maximal exertion - level 20 on the Borg scale), separated by 15 sec of passive recovery rest periods.

8.3 Blood Sampling

A qualified phlebotomist obtained about 5 – 10 mL blood samples from participants antercubital vein. The first blood sample was drawn in the morning after a 10 hour overnight fast (designated as 0 hour). A second sample was drawn before the exercise started, 90 minutes after the ingestion of acute dose of experimental beverage and breakfast (designated 1.5 hour), which is in line with recommendations made as best fluid replacement volume to ensure participants remain well hydrated during exercise and enough time is allowed for the phytochemical flavanols to be absorbed [92]; the third blood sample was drawn immediately after the completion of the exercise (designated IAE), to assess OS indices, if the rooibos beverage mitigates deleterious effects of OS by comparing blood values to placebo values [68]. The fourth blood sample was drawn after a rest period of 1 hour post exercise (designated rest); and the last but also fasting blood sample to assess participant's recovery progress and pharmacokinetics of rooibos ice tea beverage [68,93], was drawn 24 hours post exercise (designated recovery). The blood samples were kept on the ice and immediately transported to the laboratory for processing within 4 hours. At each blood-taking occasion, a volume of 30-40 mL blood was drawn.

9. OVERVIEW OF SELECTED PRELIMINARY RESULTS

It is important to note that the overall scope of this ongoing transdisciplinary study was far reaching. Therefore for the purpose of this paper two key studies and selected preliminary results are shared here to provide a more focussed context / framework and to extol the beneficial outcomes of the transdisciplinary research, namely:

- The potential of Rooibos as a sport drink with ergogenic characteristics (read performance enhancing)
- The opportunity to introduce an alternative beverage to the sport industry global market with a drink that has unique bioactive compounds and antioxidant qualities, which may be beneficial during certain modes of exercise to sport people and athletes.
- To provide the foundational knowledge that facilitates further research into the interaction of Rooibos during exercise and participant responses in terms of metabolomics and human genetics.
- The introduction of a Rooibos sport drink would enable the Rooibos producers and Rooibos industry to consider the utilisation of Rooibos in this niche market based on scientific research.
- The development of Rooibos ‘sport drink(s)’ has the potential to beneficiate Rooibos and in essence provide better returns on investment.
- The overall impact and elevation of the status and value of Rooibos as a sport drink could have direct benefits to the Rooibos producers and the broader Rooibos industry and because of the various enacted legislative agreements in place also benefit rural and indigenous communities associated with Rooibos.
- Health outcomes
- Patents

9.1 Upper Body: Selected Preliminary Results and Comments

The findings that emanated from the upper body fatiguing study by Davies and colleagues show that supplementing with rooibos over a period of four weeks had positive outcomes (although not statistically significant) in terms of physical performance notably during maximal elbow flexion exercise [94]. Thus, the results from this study that employed a chronic dosage regime and the acute dosage regime by Marnewick et al. [66], provide an indication that supplementation with a known antioxidant-rich beverage such as Rooibos may have ergogenic benefits for those persons who participate in competitive sport and perform repeated bouts of high intensity exercise and for those persons habitually engaged in repetitive and physically fatiguing work tasks.

The key data outcomes reported by Davies et al. [94] for the upper body test are included in Tables 1 anthropometric data and Table 2 Elbow extension and flexion: Peak torque (Nm), along with Fig. 4 showing Elbow extension and flexion: Peak torque (Nm).

Table 1. Anthropometric characteristics of study participants

Variable		
	mean	**±SD**
Age (years)	22.22	± 4.27
Mass (kg)	74.61	± 13.50
Stature (cm)	174.20	± 7.17
Circumference	102.53	± 11.48
BMI	24.80	± 5.62
Body fat%	16.27	± 3.21

Values in columns are expressed as mean ± SD (n = 32). Abbreviations: BMI = Body mass index

Table 2. Elbow extension and flexion: peak torque (Nm) during five maximal exercise bouts: mean values with standard deviations in parentheses p-values and effect size

Variable					
Peak torque extension	**Bout 1**	**Bout 2**	**Bout 3**	**Bout 4**	**Bout 5**
Rooibos extension	32.3 (7.5)	30.8 (7.1)	31.6 (8.3)	30.2 (8.5)	32.0 (8.6)
Placebo extension	_33.1 (8.2)_	_31.3 (7.5)_	_29.3 (6.1)_	_30.0 (5.8)_	_31.1 (7.6)_
P=	0.68	0.79	0.21	0.50	0.68
Effect size	0.10	0.06	0.31	0.02	0.11
Peak torque flexion	**Bout 1**	**Bout 2**	**Bout 3**	**Bout 4**	**Bout 5**
Rooibos flexion	48.3 (10.6)	41.8 (10.5)	39.0 (10.1)	36.3 (8.9)	36.9 (8.8)
Placebo flexion	45.4 (9.6)	38.9 (8.8)	35.2 (7.6)	32.9 (7.2)	34.7 (8.1
P=	0.26	0.24	0.08	0.09	0.29
Effect size	0.2	0.29	0.42	0.42	0.26

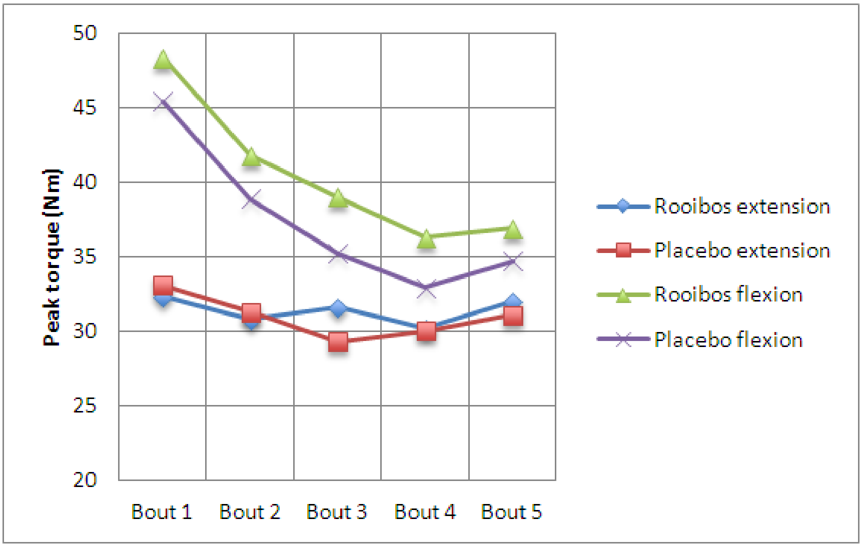

Fig. 4. Graph depicting mean peak torque for placebo and Rooibos trials over five bouts of maximal elbow extension-flexion exercise

9.2 Lower Body: Selected Preliminary Results and Comments

Table 3 depicts the mean anthropometric characteristics of the participants in the lower body exercise test.

Table 3. Anthropometric characteristics of study participants

Variable		
	mean	**±SD**
Age (years)	25.95	± 6.25
Mass (kg)	76.37	± 21.64
Stature (cm)	1.73	± 0.08
Circumference	102.53	± 11.48
BMI (kg/m)	25.19	± 6.15
Resting SBP (mm Hg)	125.40	± 11.53
Resting DBP (mm Hg)	73.33	± 7.76
Hb (g/dl)	15.30	± 1.12

Values in columns are expressed as mean ± SD (n = 30). Abbreviations: BMI = Body mass index; DBP = Diastolic blood pressure; SBP = Systolic blood pressure; Hb = Haemoglobin

During the submaximal exercise test on the Wattbike *(withdrawal point at effort = 75 – 80% of maximum)* the results indicated that during the Rooibos beverage intervention the participants on average (based on aggregated totals for Placebo versus Rooibos) were able to exercise and complete a greater distance and higher mean power, the percentage increase was 15.8% and 19.3% respectively (See Figs. 5 and 6).

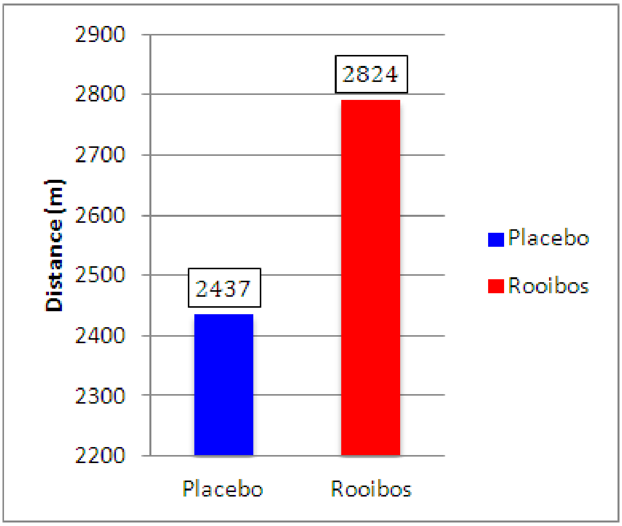

Fig. 5. Mean distance achieved in submax test

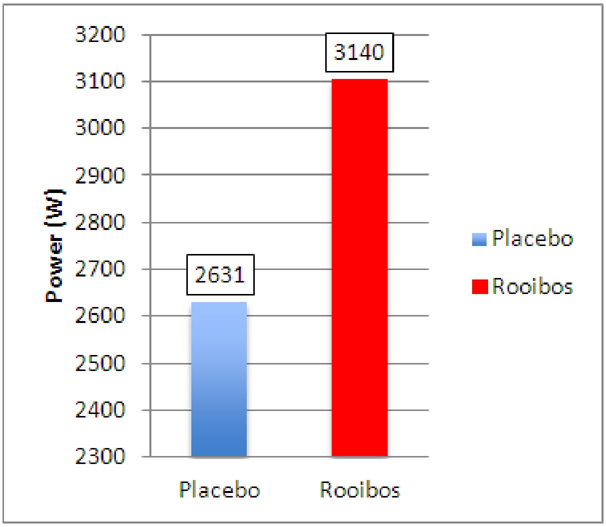

Fig. 6. Mean power output in submax test

9.3 Selected Blood Sample: Triglycerides

Triglycerides can be broken down during exercise and used as an energy substrate by the working muscles, as Powers and Howley, [95] note "the entire glyceride molecule is a useful source of energy for the body". It is suggested that the improvement in the mean distance achieved by participants during the submaximal phase of the exercise test may be an indication that supplementation with a Rooibos beverage prior to exercise enhanced the retention of triglycerides in the body, thus affording additional energy source for work (when compared to the placebo trial) and as a consequence delayed the switch to anaerobic metabolism and the onset of rapid fatigue. This can be seen in Table 4 for mean triglyceride levels for both placebo and Rooibos trials immediately after exercise (IAE) and one hour after exercise (1 hour rest). A summary of the findings displayed in Table 4 show that following Rooibos ingestion triglyceride levels had a longer peak/increase immediately after exercise (IEA) and up to 1 hour after exercise, serving as energy (fuel) to the cells to maintain a longer aerobic metabolism. It is tentatively proposed here that Rooibos appears to delay the switch to anaerobic metabolism, and thus facilitates improved and longer utilisation of the aerobic metabolism.

Table 4. Triglyceride values during lower body Wattbike ergometer test

Marker	0h Placebo (Mean ± standard deviation)	0h Rooibos (Mean ± standard deviation)	1,5h Placebo (Mean ± standard deviation)	1,5h Rooibos (Mean ± standard deviation	IAE Placebo (Mean ± standard deviation)	IAE Rooibos (Mean ± standard deviation)	1h rest Placebo (Mean ± standard deviation)	1h rest Rooibos (Mean ± standard deviation	24h rest Placebo (Mean ± standard deviation)	24h rest Rooibos (Mean ± standard deviation)	Time Effect (p-Value)	Group Effect (p-Value)	Time x Group (p-Value)
TRIG	0.81 ± 0.35	0.91 ± 0.52	0.94 ± 0.40	1.05 ± 0.75	1.03 ± 0.44	1.23 ± 0.79	0.85 ± 0.31	1.03 ± 0.67	0.81 ± 0.29	0.91 ± 0.41	<0.001 *a	0.308 a	0.148 a

Triglycerides (TGs), stored in adipose tissue and within muscle fibres, are considered to be the main source of the free fatty acids (FFAs) oxidised during exercise.

Values (mmol/L) in columns are expressed as mean ± SD (n = 30). Abbreviations: TRIG = triglyceride.

10. CONCLUDING COMMENTS ABOUT THE IMPLICATIONS OF THIS TDR PROJECT FOR BUSINESS INNOVATION AND THE CASE OF ROOIBOS AS A POTENTIAL ERGOGENIC SPORT DRINK

Wynberg (2017) summarizes in Fig. 7 some of the central issues that require deliberation for TDR in terms of the access and benefit-sharing (ABS) model; which seeks to recognizing all traditional knowledge holders to sustainable use and exploitation, as well as recognizing the wide spectrum of benefits that should be considered [47]. The model also describes some of the broader contextual aspects that impact on 'benefit sharing', which ought to be considered holistically in order to appreciate the complexities involved. This study has involved diverse expertise in the research space, while also taking cognizance of the social, economic and potential environmental issues that are likely to be associated with the Rooibos industry. The same author alerts stakeholders in the Rooibos industry that it is poised for transformation. Decisions taken today will not only influence the local industry but also have impacts across the seas.

Fig. 7. Access and benefit sharing (ABS) model (after Wynberg, 2019)

It is acknowledged that TDR by its nature is ambitious, after all TDR was construed to be the approach best suited to tackle the pinnacle of complexity for societal challenges, the so-called 'wicked problems' that stemmed from the seminal work by Rittel and Webber [96] about the complex social and environmental aspects of planning. These refer to challenges that are so complex and interconnected that they cannot really be solved, rather only resolved in multiple ways, with differing costs and benefits for those involved [3]. However, whilst it would be somewhat disingenuous to describe the present TDR study into Rooibos and its effectiveness as a sport drink as a 'wicked problem', what has become apparent is the need to contextualize the research within a complex appreciation of the economic, historical and cultural antecedents, notably the recognition of traditional indigenous knowledge systems and ways of life that have informed and inspired the researchers at AMHBI to conduct research into Rooibos and other indigenous plants with a reputation for traditional medical applications, as demonstrated by the study by Marnewick and colleagues who investigated the antimutagenic properties of South African herbal teas [33]. In short, this study has demonstarted that different aspects of individual learning seem to contribute to a researcher's ability to interact with researchers from other research fields and work collaboratively. These include learning new material from different research fields, learning how to learn new material and learning how to integrate different material [96]. Thus the need for involving several different disciplines arose as scientists realized that particular problems are too complex to be effectively addressed by a single field of study [98]. This paper is further informed by the observation by Klein [99] where it is also recognized that many systems or phenomena can and should be investigated at different levels and from different points of view, given their multidimensional nature. Take for example human beings, which can be referred to as physical, chemical, biological, cognitive, and sociocultural objects. In terms of this paper this is illustated by the complex interactions associated with human beings, both socially, historically and economically in relation to Rooibos as well as the understanding of its bioactive properties and application as a sport drink. These factors integrate into research that investigated the efficacy of Rooibos as potentially ground breaking sport drink and how this may impact on economic considerations for the Rooibos industry and the enactment of various benefit sharing policies.

Therefore, it is suggested that this study is characteristic of TDR because it is a complex and interconnected study that has evolved over time and is dependent on many key stakeholders and role players. This is reflected by the roles played and the interaction / collaboration between differing research entities at CPUT, notably AMHBI, CSBTR, Sport Management, the Faculty of Business and Management Sciences, the Faculty of Health and Wellness Sciences, along with further enhancement of the study by the involvement of North West University (Metabolomics), University of Stellenbosch (Genetics), University of Vienna (Biostatistics) and the SARC in terms of funding and policy guidance. It may be the case that the study into the effectiveness of Rooibos as a sport drink with potential performance enhancing attributes, could be also strategically positioned for beneficiation within the burgeoning global sport drink industry. It is apparent that the study has in the course of the investigation piloted the full circumference of factors that characterize the 'access and benefit sharing model' (ABS) model, which reflects the spectrum of issues that require attention when considering access and benefit sharing in the Rooibos industry (Wynberg, 2017) [47]. Furthermore, the present TDR study takes cogniscance of the cautionary comment by Gollin who highlights that there is no international agreement on the optimal interplay between biodiversity, biotechnology transfer, and intellectual property rights [100]. It is therefore suggested that the debate that may emanate from this paper will facilitate what Gollin foresees as future interpretations of existing conventions and domestic laws around the world, which in turn may help to promote mechanisms that make habitat conservation worthwhile and ensure that those who conserve the habitat are properly rewarded for their efforts [100].

In particular, the present TDR study has opened up the possibility to deliver a scientifically researched sport drink into the highly lucrative sport drink industry with the opportunity to deliver economic and social benefits in terms of the established access and benefit sharing policies and conventions that uniquely characterise the South African Rooibos industry and the communities that support the production of Rooibos.

In providing context for the conclusion we need to be aware that the ethnobotany of Cape plants has remained poorly recorded despite the global scientific interest in both the unique flora and the indigenous Khoisan people [101]. In should be noted that the available information on hot beverages used by the Khoisan in ethnographical and anthropological records is scarce and often inconsistent, making it virtually impossible, in most instances, to determine if those beverages were consumed in the pre-colonial era [101]. However, there is evidence that some plant species were mainly used as adulterants or to improve the flavour of the tea (e.g. by enhancing the fermentation process) [101].

While only a few medicinal plants were described and illustrated by the early European settlers, which includes only one detailed account – on the use and value of kanna or channa (Mesembryanthemum tortuosum), a traditional masticatory that may also be taken as an infusion in milk or water [102]. Burchell [103] in his account of travels in the Interior of Southern Africa, recounts that when he visited Klaarwater (now Griekwastad) and referring to the local people of Khoi descent, he pointed out: “All are exceedingly fond of tea, and when the Chinese kind is not to be procured, they make use of the leaves of various wild plants”. It would be reasonable to assume that the Khoi and San indigenous people from the Cederberg region in South Africa had utilised plants for beverages, medicinal uses and as supplements, especially as the well-known Cape flora comprises close to 9000 species of seed plants [104].

The second aspect of the unique historical legacy that shapes the transdisciplinary research investigating the potential of Rooibos as a ‘sport drink’ is to recognize the fact that according to Schulkin ‘human running’ for speed of movement as well as endurance—the ability to just keep going—were historically crucial for survival; indicating human beings were (are) very good at distance running [105]. The same author notes that today, running, in addition to other physical sports, is primarily performed for enjoyment and exercise. In respect to the present study it is interesting to note that in the contemporary world the only hunters known to practice what is known as the ‘persistence hunt’ live in the central Kalahari, Southern Africa, namely the Khoi and San people, which is a form of hunting they have practiced for time immemorial [106]. The hunt takes place during the hottest time of the day, with maximum temperatures of about 39–42 degrees (Celsius). Liebenberg reported that one of the hunts, which he observed in the heat of the day took the hunters on foot 3 hours 35 minutes to cover about 35 km, for an average speed of about 10 km/hr. A prerequisite for persistence hunting would have been the invention of water containers. In contrast to horses and camels, humans cannot consume large amounts of water at one time. Human thermoregulation requires considerable water for evaporative cooling, and this would have made it essential to carry water in containers [107]. However, while this may be speculative, it is not unreasonable to suggest given the access to Traditional Knowledge and the ingenuity of the Khoi and San groups who still engage (and historically engaged) in the ‘persistence hunt’ tactic that other ingredients to water may have been added, at the very least to make it more palatable and safer to drink, but also possibly additional ingredients, plants, herbs etc. as supplement(s) to assist with demands of the arduous tracking of slow-moving animals such as aardvark and porcupines, which were easily run down when encountered in open country [108]; but also lager and more swift animals such as eland, kudu, gemsbok, hartebeest, duiker, steenbok, cheetah, caracal, and African wild cat, all of which were run down in the hotter part of the day and killed when exhausted [109].

It is the foregoing appreciation of traditional knowledge systems and hunting strategies that intersect with the present TDR study into Rooibos and the need to better understand how its bioactive properties may provide the basis for an effective sport drink.

The present TDR project which concerns two aligned studies (upper body: [93] (Lower body: Kamati et al. to be published) that investigated the effectiveness of Rooibos as sport drink have shown that in the upper body exercise study that individuals who ingested the standardised Rooibos for a four-week period prior to a repetitive fatiguing exercise protocol generated consistently higher muscular force output in terms of peak torque (Nm) during elbow flexion in all five bouts of maximal exercise. In the lower body exercise test on a Wattbike cycle ergometer, during the submaximal phase of the test that participants after consuming Rooibos beverage on average increased cycle distance by 15.8% and also generated an increase of 19.3 % in power when compared to the placebo trial. One of the interesting results from the study that may provide an explanation for the improved performance in distance achieved in the submaximal phase of exercise testing was possibly related to the higher levels of triglyceride measured immediately after, and one-hour after the Rooibos exercise trials. As Powers and Howley [94] point out "the entire triglyceride molecule is a useful source of energy for the body". This infers that during the Rooibos arm of the study the indication of higher levels of triglyceride provided additional energy for working muscle during submaximal exercise, which in turn facilitated better endurance and the ability to cycle further.

It is therefore suggested that the improvement in the mean distance achieved by participants during the submaximal phase of the lower body Wattbike ergometer exercise test may be an indication that supplementation with a Rooibos beverage prior to exercise delays the switch to anaerobic metabolism and the onset of rapid fatigue.

The foregoing closing comments about a unique TDR approach provide a strong indication that not only would Rooibos make an effective sport beverage due to its bioactive compounds and antioxidant qualities, but also that Rooibos appears to have enhanced physical performance in selected exercise modalities, thus acting as a potential ergogenic aid. Furthermore, Rooibos appears to have facilitated the retention of higher levels of triglycerides during exercise, which is likely to assist with improved performance during aerobic – endurance type activities. These outcomes point towards the potential of Rooibos as a sport drink, which has beneficial implication for the Rooibos industry and the opportunity to realize the principles of the Nagoya Protocol that requires industries that trade in indigenous biological resources, such as Rooibos, to share benefits with traditional knowledge holders in a fair and equitable way

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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